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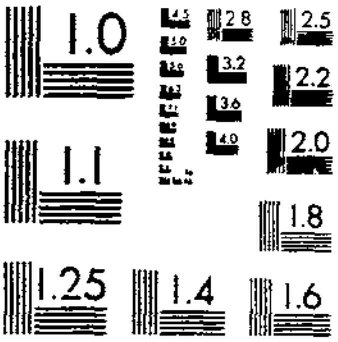

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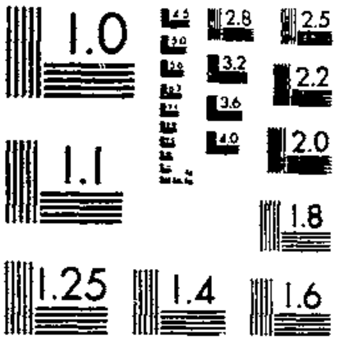

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REGIONAL ADJUSTMENTS IN GRAIN PRODUCTION

A Linear Programing Analysis

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PREFACE

This report is the first of a series based on exploratory studies, regional in nature, analyzing the farm surplus situation and the corollary adjustment problems of agriculture. Wheat and feed grains—the larger and more pressing facets of excess agricultural output—provide the theme of this first analysis. Economic efficiency, limited by certain specific assumptions, is the framework within which this analysis was made. Factors noneconomic in nature also are involved in the location of production. These factors are (1) for the most part nonquantifiable and (2) probably of less importance in influencing the location of production than those of costs and prices. Hence, this analysis is limited to economic factors.

The results presented here are necessarily tentative because of the complexity of the analysis problem and data deficiencies. Readers, therefore, should look on these results as first approximations and as a basis for further analysis. Extended analyses in progress are designed to erase many of the analytical limitations evident herein. Because of the nature of the analysis problem, a particular methodology and its implications are emphasized in this report.

Because of space limitations only brief explanations of methods used to collect and estimate the data required for this study and only aggregates of these data are presented here. However, additional explanation of the methodology and more detailed data are available in A Linear Programing Analysis, supplement to this bulletin, which may be had on request from, the Information Division, Agricultural Research Service, U.S. Department of Agriculture. Included in the supplement are: (1) Mathematical notes for economic models, the programing matrix, and weights used for grain yields and production costs; (2) notes and supplementary data for yields, acreages and production costs; and (3) a formal presentation of the method used to estimate demand restraints.

Specialists in the United States Department of Agriculture and at many State Agricultural Experiment Stations furnished much of the basic information used in the study. The authors gratefully acknowledge this assistance. Special appreciation is expressed to K. L. Bachman, G. T. Barton, C. W. Crickman, R. A. Loomis, and H. L. Stewart, Farm Economics Research Division, Agricultural Research Service, for valuable suggestions in regard to conceptual as well as data problems and to L. A. Ibnen of the Department of Economics, Iowa State University, who assembled and analyzed much of the basic data.

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Growth Through Agricultural Progress

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Regional Adjustments In Grain Production

A Linear Programing Analysis

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SUMMARY

The study reported here was a regional aggregative analysis of the wheat and feed-grain economy in the United States. The general objective was to ascertain the regional production location of wheat and feed grains if annual output were in balance with an assumed level of demand, and if production were located in those areas that produce the grain requirements most efficiently. Problems of surplus production of individual grains cannot be investigated independently. As experience in the last decade has shown, control of the acreage of one grain crop usually leads to an increase in the acreage of one or more of the others. Recent developments in mathematical programing provide methods for analyzing simultaneously possible production adjustments for various crops.

Although the programing study is partly methodological, empirical results can be used to specify the relatively high-cost grain-producing regions in the United States with the production restraints and costs specified. The restraints were the acreage of land considered to be available for production of grains in each region and the quantities of wheat and feed grains required for consumption in 1954. Given the chosen levels of production restraints, product prices, and production costs, the optimum regional location of production was determined by those areas that produce the specific grain requirements at either (1) minimum cost or (2) maximum profit, depending on the assumptions of the analysis.

One hundred and four unique major grain-producing regions in the United States were delineated for the analysis. These regions do not include the total land area of the Nation, but in 1954, they accounted for around 90 percent of all feed grains and wheat produced in this country. The small quantity of grain produced in the omitted areas was assumed to be independent of the system. The census year 1954 was used as a base year for determining production costs, grain prices, yields, and consumption requirements, and 1953—when no acreage-control programs were in effect—was the base year for estimating maximum grain acreages.

Five models, designated as A, B, C, D, and E, were formulated to determine the optimum production locations for wheat and feed grains. The maximum regional grain acreages were common to all five. Food wheat, feed wheat, and a feed-grain rotation were the regional production possibilities (activities) in models A, B, C, and E, but for model D, the regional production possibilities were food wheat,

feed wheat, corn, oats, barley, and grain sorghums. Other differences between the models were: (1) Models A, B, C, and D were minimum total production cost models, but model E was a maximum total profit model; (2) annual land rents were included in the activity production costs for model B, but not for models A, C, D, and E; and (3) wheat and feed-grain activities had separate regional production restraints for model C only.

The linear programing solutions of the models, though not alike, show a high degree of similarity; especially the solutions of models A, B, and E, which proved to be the most realistic solutions. These three models agreed in showing that 58 particular regions would be needed for production of grain. The solutions also agreed in showing that 33 specific regions would not be needed for production of grain. There was disagreement for only 16 regions. Two solutions agreed in showing that 7 of the 16 regions would be required, and that the remaining 9 regions would not be required. Production of feed grains was consistently specified by the solutions to these three models for the Corn Belt, Delaware, New Jersey, eastern Pennsylvania, and Maryland. Production of wheat was designated in each solution for the Pacific Northwest and northeastern Colorado. The three programing solutions differed most from model to model in the Lake States and the Northern Plains, particularly in North Dakota and South Dakota. Production specifications for North Dakota and South Dakota varied from all feed grain (meaning large quantities of barley) for model B to nearly all wheat for model E.

Production of feed grains and wheat was not specified in any model for Michigan, southeastern Colorado, eastern New Mexico, the Delta States, and the Southeast, except that model E specified production of a small quantity of wheat in southern Alabama and a small quantity of feed grain in western Kentucky and eastern Virginia.

On the basis of the study, areas for which little or no production of grain was specified were those in which most of the adjustments in the use of resources in grain production would be needed. The number of acres specified as not needed would be 31.9 million acres for model A, 34.7 million acres for model B, 22.9 million acres for model C, 62.4 million acres for model D, and 28.8 million acres for model E.

Competitive prices of wheat and feed grains were determined for models A, B, C, and D through the dual programing solution. Land rents were determined by the dual solution to each of the five models. In general, these rents can be described as residual or imputed values. In terms of the models, however, the derived rents can be described also as competitive prices of land used for production of grain.

In interpreting the results for all models, it should be remembered (1) that spatial production patterns were computed under the assumption of production techniques reflected in the technical coefficients equal to the average of the region, and (2) that the coefficients were constant for the delineated regions. Locational variations from the regional coefficients used would mean that some acreages in the "outgoing" regions would remain in grain production and some acreages in the "staying-in" regions would be withdrawn. Only grain crops were used as competitive alternatives in programing, although inclusion of land rent as a cost in model B gave some recognition to alternative crops.

Assumptions and data with such limitations were used for this exploratory stage in the analysis because of computational problems. The empirical task was a heavy one. Gathering data and making computations involved sizable efforts. About 4 man-years were spent in routine development of coefficients. Had manpower and computational funds been more adequate and had cruder coefficients been used, a somewhat more appropriate model could have been constructed. This model would have grain and nongrain crops and livestock activities and an objective function of return maximization.

Under ideal conditions for conducting a study to analyze regional resource problems, adequate funds, computational facilities, and time would be available. Adequate stores of information on coefficients would be available for indicating shifts at both extensive and intensive margins of production. Many homogeneous production areas would be delineated with supply and demand functions and commodity prices predicted for each. A general equilibrium model, considering the full range of farm and nonfarm opportunities in use of resources, would be used. The possibility of contracting intensity of production through use of less fertilizer per acre, for example, in regions having relatively lower costs would be considered also.

As time and funds become available, work should proceed that will account for alternative crops, regional demands, transportation costs, and new farming techniques. In a model that considers production patterns under potential techniques, some parts of the 21 regions programed in the Southeast, for example, probably would "remain" in grain production. Some grain production would be expected to remain in each of the other regions also, if such things as intraregional variations in production functions and complementary and supplementary relationships were reflected adequately in the model.

From a practical viewpoint, the solutions reported here provide a starting point for considering spatial adjustment of production of grain. But further refinements and improvements are essential for final design and implementation of adjustments based on regional comparative advantage in grain production.

INTRODUCTION

The General Problem

One of the major short-run problems of agriculture in the United States is the accumulation of surplus stocks of feed grains and wheat. These accumulated stocks are only a material indication of a more basic problem—the growing tendency of the industry to produce in excess of domestic requirements and foreign outlets. With the rapid accumulation of stocks of grains in the last several years, it becomes increasingly important that alternatives be found to bring production into line with annual requirements for such crops as feed grains, cotton, and wheat.

Stocks of all feed grains combined on October 1, 1959, were more than three times the normal carryover. Without including production from the 1959 crop, these stocks were large enough to produce a national pig crop of average size. Relatively, stocks of wheat were

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even greater. The carryover of wheat has exceeded annual production most of the time since 1954. Carryover stocks of wheat on July 1, 1959, were more than twice the normal annual domestic disappearance. Imposition of acreage controls for corn and wheat after 1953 also encouraged greater acreages of barley, oats, and grain sorghums, and a buildup in stocks of these grains. Sorghum carryover stocks, for example, increased from 75 million bushels in 1955 to 510 million bushels in 1959.[1]

Figure 1 illustrates the growing magnitude of stocks of wheat and corn relative to annual production. The carryover of wheat will nearly equal annual production in 1959, while the carryover of corn will be about 50 percent of the annual crop. The need for finding alternatives to these crops is apparent. Further annual increases in stocks can be eliminated only if steps are taken to bring production in line with annual domestic uses and foreign outlets for grain produced in the United States.

Grains are not the only surplus crops. The Commodity Credit Corporation holds sizable quantities of cotton, and relatively smaller stocks of dairy products, soybeans, rice, tobacco, and peanuts. But in terms of both value and acreage, wheat and feed grains represent the major part of farm commodity surpluses. Hence, the study from which this report resulted was concentrated on analysis of the grain problem.

[1] Hereafter, the term "sorghum" refers to grain varieties only.

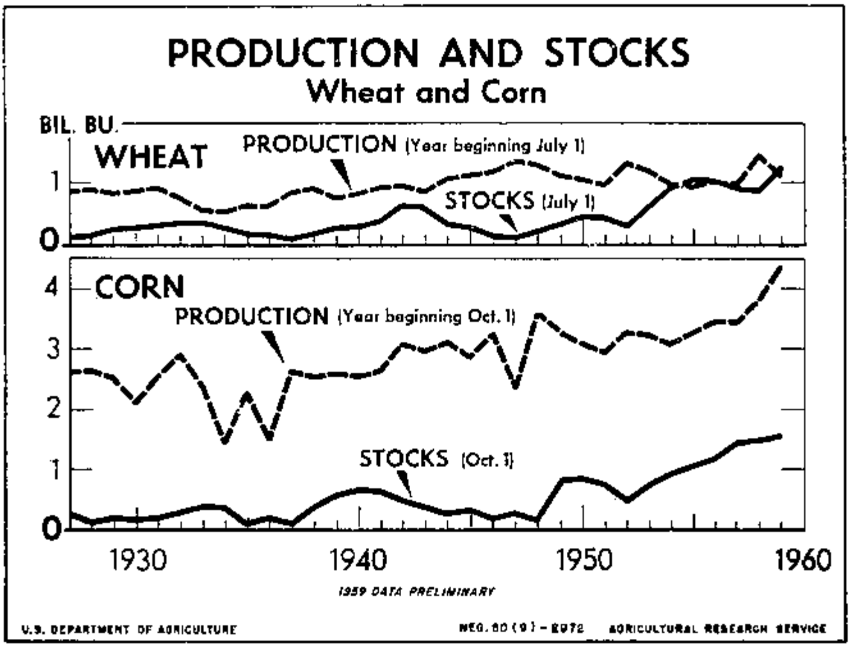

FIGURE 1

The Scope of the Problem

Grain surpluses are a major concern of farmers, because much of their income is derived from the wheat and feed grains they produce. The combined value of these five grains in 1955 was approximately 42 percent of the total value of the 79 principal farm crops (*30, 1956*).[2] Hence, if an attempt were made to dispose of grain surpluses on the open market in a normal year, farm income would be reduced drastically.

Grain surpluses also affect consumers. Through Federal price-support programs, consumers are paying the cost of storing these surpluses. In fiscal 1959, the estimated realized cost for all government programs that concern wheat and feed grains—primarily for stabilization of farm prices and income—was about $1.1 billion. In addition, consumers pay, for the commodities they generally consume, prices somewhat higher than "free market" prices would be otherwise.

That the grain economy is out of balance is an unequivocal statement. How to get it back into some semblance of equilibrium is a problem that has no simple solution. Although production of grain is concentrated in certain regions of the United States (the Corn Belt, Great Plains, and Pacific Northwest), significant quantities of wheat are grown in 40 States, and at least one of the feed grains is grown in 48 States (*30, 1956*). Furthermore, even though production of these grains is widely dispersed, large quantities are shipped long distances to meet demands of the various areas in continental United States (*31, pp. 17–27*).

The Specific Problem

The general objective of the study reported was the analyzing of regional production patterns for grain crops in the United States. The framework within which this analysis is made is one of economic efficiency in grain production. What would be the most efficient pattern of grain production if annual requirements were met at least cost relative to the comparative advantage of various regions in producing grain? Several exploratory models are used to determine which regions might shift from grain production if these objectives were attained.

The more specific major objectives of the study were:

(1) To formulate several programing models with special characteristics for analyzing particular facets of the grain surplus problem.

(2) To obtain empirical solutions to the analytical models that will indicate comparative regional efficiencies of resource use in production of wheat and feed grains.

(3) To use the empirical solutions to suggest optimum spatial production and land use patterns for wheat and feed grains.

(4) To estimate competitive rents for grainland, and prices of wheat and feed grains.

(5) To analyze weaknesses in the basic assumptions of the analyses and suggest ways of improving similar investigations.

(6) To describe the problems encountered in collecting and processing data for the study, and to suggest means of acquiring improved data.

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[2] Italic numbers in parentheses refer to Literature Cited, page 65.

(7) With the experience of this investigation as a basis, to suggest studies that would seem to be more adequate for analyzing regional resource-efficiency problems.

It is recognized that the grain economy is not independent of other types of farm production, but that the total farm complex, as well as the rest of the economy, has a definite bearing on what happens to grain production. More of the relevant variables in the economy would have been included in this analysis if time, funds, and the solution to certain technical problems had permitted.

For purposes of analysis, 104 major grain-producing regions in the United States were delineated to provide the analytical framework for the models used.

ECONOMIC MODELS

Several linear programing models are used in this analysis. By using the simplex linear programing routine, it is possible to derive a competitive equilibrium solution for two or more products in a spatial or regional economy. This equilibrium solution includes the specification of regional product levels, and factor and product prices. The necessary assumptions for linear programing analysis are: (1) At least one limited resource; (2) a finite number of production processes having constant input-output coefficients; (3) additive processes; and (4) divisibility of inputs and outputs for any positive level.

Basic Assumptions

In order to reduce the analysis of the wheat and feed grain economy to a manageable size, certain simplifying assumptions were necessary. Although these assumptions may not describe exactly the economic structures within regions, they permitted the use of programing models that were sufficiently comprehensive and detailed to be consistent with the general objectives of the study.

These formal basic assumptions for the structure of the grain economy were made:

(1) There are N unique, spatially separated but interdependent production regions, with many producers of wheat and feed grains.

(2) All producers in a specific production region have only the choice of producing the same (homogeneous) products or product mixes, and quality is uniform between regions.

(3) All producers in a specific production region have identical input-output coefficients and use the same production techniques.

(4) Input-output coefficients are constant within the relevant range, that is, constant returns to scale exist.

(5) An acre of feed grain (or wheat) land can be substituted for an acre of wheat (or feed grain) land at a constant rate within each region.

(6) Total production in each region is limited only by fixed quantities of land suitable for grain production.

(7) The economic objective of each producer is profit maximization.

(8) The system is static in that consumption must be met from current production; the production period is the crop year.

(9) Total grain-consumption requirements are exogenous, determined by annual per unit requirements of the human and livestock populations at a point in time.

The Specific Models

Five analytical models were formulated as steps in attaining the objectives outlined. The structural changes made from model to model were attempts to add greater realism to the analysis or to investigate some particular facet of the grain-production problem. Only the structure and objectives of the models are described here. The methods used in obtaining the data needed in each of these models are briefly outlined in the sections that follow.

Model A

For each of the (N=104) homogeneous grain-producing regions, three types of grain-producing activities were considered—food wheat, feed wheat, and a feed grain rotation.[3] The quantity of grain produced by these three activities—individually or in combination—is limited by the maximum acreage available within each region for production of grain. The production costs associated with each of these activities include labor, power, machinery, seed, chemicals, and certain miscellaneous items.

A central market was assumed for wheat and feed grain, and the cost of transporting these grains from the producing regions to the market was set at zero. There are two national demand restraints, one for food wheat and one for feed grain.

The objective of model A was to determine the spatial pattern of grain production that would provide the Nation's annual requirements of wheat and feed grains at minimum total cost, under the cost conditions cited. A corollary objective of model A was to estimate the annual value, or "shadow" prices, of land used for grain in the various regions.

Model B

Model A assumed that land has no alternative use or that its opportunity cost in the next best enterprise is not significant (for example, grass in the western plains). In some areas, however, alternative enterprises provide opportunity costs of some importance. Therefore, model B was formulated to determine how consideration of certain opportunity costs, represented by specified land rents, would affect the optimum grain-production pattern. Otherwise, the structure of model B is the same as that of model A. The sole difference is in the cost coefficients, which, in addition to the costs enumerated, include an estimated land rent.

Model C

The basic assumption, stated earlier, that an acre of land in each region could be used for production of either wheat or a feed-grain rotation was relaxed for model C. In model C, the acreage of grain in each region was divided into two components: A maximum wheat acreage and a maximum feed-grain acreage. Thus in model C, there are 208 land restraints or restrictions instead of 104 as in models A and B. All other variables (costs, demand requirements, and so on) in model C are the same as those for model A.

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[3] See the following section for an explanation of the method used in delineating these regions.

Model D

Agronomists have posed the possibility of establishing a meadow crop in a rotation without using a nurse crop such as oats. The feed value produced from an acre of oats is less than that produced from corn. Hence, if oats could be eliminated from the customary rotation, a large potential increase in the feed supply would result.

Possibilities for establishing rotations without nurse crops are based on wide seeding of corn rows in the second year with a meadow crop seeded between corn rows, seeding meadow in the spring after corn, then controlling weeds by chemicals or clipping, or both.

Model D was designed to investigate the possible impact of this innovation on the optimum grain-production pattern. This model uses six grain activities: Food wheat, feed wheat, corn, oats, barley, and sorghum.[4] Production costs and production and consumption restraints are the same as those in model A. Again, the objective is that of minimizing total production cost.

Model E

Preceding models assumed that production regions, although spatially separated, are interdependent in a central market, but that transportation costs are zero. A step toward greater realism in a model is the consideration of both transportation costs and many markets. Thus, we have a multiple-point economy for both production and distribution. But a linear programing solution to a combination production and transportation problem with more than 30 production and market regions either would be impossible, or, with present digital computers, the cost would be prohibitive. In addition, it is difficult to obtain data on transportation costs between points. As the freight-rate components of transportation costs are available for wheat and feed grains that move by currently used routes, this problem may be handled by assuming that transportation costs other than freight, for example, costs of loading and unloading and commissions, are constant between regions.

The assumption of one market and a transportation cost of zero was withdrawn for model E and replaced by these assumptions: (1) Farm prices of wheat and feed grains at all points are equal to the prices at a central market minus transportation costs; and (2) the differences between historic prices for different locations are due solely to differences in transportation costs. If these assumptions are approximated, a net-profit solution for model E is equivalent to a minimum-cost solution of a combination production–transportation problem, provided the markets absorb the programed quantities at the assumed prices.

The objective of model E then is to maximize total net profit, given the production and consumption restraints. These restraints are the same as those in model A. The input–output coefficients, also, are the same for the two models.

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[4] Implicit in the models described so far is that wheatland will be either continuously cropped or grown in rotation with cultivated summer fallow or other crops, such as peas, flax, or grasses, if other crops are normally grown in rotation with wheat in specific areas. Other crops in rotation with wheat are possible, as other crop acreages are not part of the acreage restraints in each region. For the same reason, other crops can be a part of the feed-grain rotation acre.

LIMITATIONS OF THE MODELS

The models used in the study reported represent some refinement over similar calculations made in previous studies, but they involve limitations of which the writers are aware. A complete model of the general equilibrium type, which is appropriate for the type of problem under analysis, would imply knowledge of all relevant production, cost, demand, and supply functions for all products with which the commodities considered compete in production or consumption. Data for an analysis within this framework, however, were not available, and alternative approaches were used. Some of the major practical limitations of the general model used are outlined:

(1) When a resource used in the programing model is a small part of the total resource available, the price existing at a point in time probably reflects quite accurately the price that would need to be paid for this resource by each productive activity in the model. But when the resources used by the model activities are a substantial part (but not all) of the total resource supplies, observed prices may be an imperfect measure of the resource prices dictated by the model solution. This is the case when the quantity of a resource used in the programing solution is less than that which generated the observed price.

(2) To some extent, specification of production regions is arbitrary. Distinct boundaries between producing regions do not exist. Some differences in soil productivity and climate are evident in even the smallest regions specified.

(3) Producers do not have identical input-output coefficients. The quality of management varies. The quality of land used for grain production varies not only between, but within farms, even though farm operators may tend to use their better land for grain. Classification of land within regions by productive capacity for grain, and the use of several classes of land for regional land restraints would be more realistic. If several land classes were used, however, the size of the problem (matrix) would be greatly expanded.

(4) Not all farmers within a region use the same production technique. As will be seen in the pages that follow, however, this assumption was made only to facilitate the measurement of production costs. In terms of the models, it is only necessary that unit costs be similar for farms within a region.

(5) Not all grain produced in the United States is of the same quality. Some of the differences in quality are necessary to fulfill specialized demands (examples are durum wheat and malting barley). Also, the five grains are not perfect substitutes for each other over all ranges in livestock feeding. But with the fixed ratios assumed for production of feed grains in each region for models A, B, C, and E, it is probable that the national grain "mix" specified by the solutions would permit the level of livestock production assumed.

(6) Constant returns to scale may not exist either within or between farms within each region for the possible production range (from zero production to the output limit prescribed by the land restraint).

(7) Total production within each region is not limited by land alone. Production is limited also by the amount of capital farmers

control. Grain production can be increased by higher proportions of other inputs, such as fertilizer.

(8) The assumption that wheatland can be used for production of feed grains and vice versa without appreciable changes in yield may not be valid for some regions.

(9) Consumption of grain is not independent (exogenous) of prices. Consumers vary consumption with changes in relative prices. Because of the degree of demand aggregation and the 1-year time period assumed, constant per capita consumption rates may closely approximate demand restraints.

Although these limitations exist in varying degree for all regional analyses, the magnitude of computational burden, if all identifiable variables were considered, would exceed that manageable with existing computer and research resources. Investigations in the area of aggregative regional analysis cannot achieve complete realism. One objective of the study reported, however, was to provide a steppingstone for the more refined studies that might follow. At best, aggregative analyses can be expected only to provide broad guides for resource adjustments and policy formulation.

BASIC DATA AND COEFFICIENT DERIVATION

The methods used in obtaining basic data and transforming them into programing coefficients are described here. The descriptions of the models in the previous section indicated the size of the task and the difficulties encountered in assembling the required data. Hence, the methods used can be described only briefly here. Additional details are given in the supplement.

Because of the many data assembled in the 1954 Census of Agriculture and the publications that summarize and supplement the census, most of the basic data used in the analyses are for 1954. Maximum grain acreages in each region are the only exception; they are from 1953 data.

Grain-Programing Regions

Delineation of meaningful grain-producing regions (in terms of the objectives of the study) was in itself a sizable job. At least one of the five grains under study is produced in all States and in most of the counties within these States. In many locations, however, grain production is only a small part of the total agricultural production and an insignificant part of the total grain economy. In many of these areas of sparse production, grain is either a complementary enterprise or has a special locational advantage. Thus, grain would be produced in certain areas with a wide range of prices. Also, for these sparse grain areas, data are very scarce. For these reasons, only major grain-producing areas of the United States were used for analysis.

Areas in which wheat and feed grain were harvested from 25 percent or more of the total cropland in 1954 were defined as major grain-producing areas. To some extent, this demarcating percentage is arbitrary. But the major grain-producing areas thus defined represented 90 percent of the total wheat and feed-grain acreages in 1953. Furthermore, in 1954, the percentages of wheat, corn, oats, barley, and sorghum produced in these major grain areas were estimated to be 93.1, 93.4, 86.9, 72.7, and 91.0, respectively, of total production. Thus, the defined major grain-producing areas are the source of most of the wheat and feed grain produced in the United States and are also the areas that are most significant in the grain-surplus picture.

The geographical outlines of the 104 "homogeneous" grain regions so delineated, together with their assigned numbers, are shown in figure 2. Henceforth, they are referred to as programing regions, or simply regions. In the discussions that follow, the designated numbers are used to identify these regions.

The programing regions are based primarily on State economic areas.[5] To demarcate programing regions that were relatively homogeneous for grain production and to keep the computational work at a minimum, the following procedure was used: First, four classes of economic areas were defined:

(1) Areas with grain production uniformly distributed, that is, the concentration of grain acreage within each county was approximately the same for all counties in the economic area.

(a) Areas with total harvested acreage of wheat and feed grains combined equal to or greater than 25 percent of total cropland.

[5] State economic areas were used because: (1) Types of farming and land productivities are similar within these areas; and (2) many of the data required for the study are summarized in the census by State economic areas.

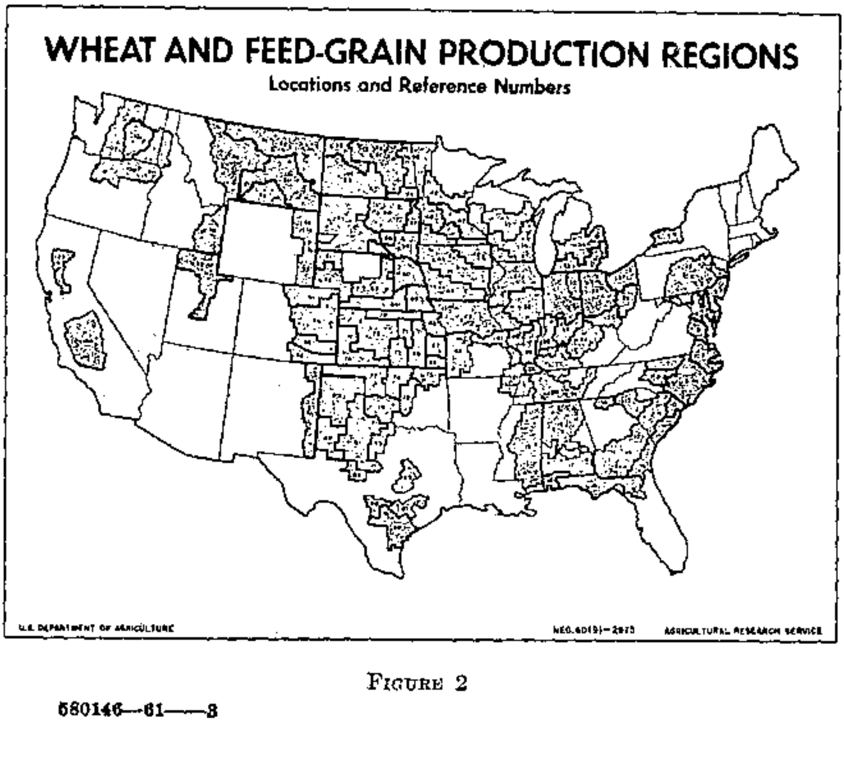

FIGURE 2

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(b) Areas with total harvested acreage of wheat and feed grains combined less than 25 percent of total cropland.

(2) Areas with grain production not uniformly distributed.

(a) Areas with total harvested acreage of wheat and feed grains combined equal to or greater than 25 percent of total cropland.

(b) Areas with total harvested acreage of wheat and feed grains combined less than 25 percent of total cropland.

By using dot maps showing the geographic distributions and concentrations of the harvested acreages of wheat and feed grains in 1954, State economic areas were placed in either group 1 or group 2. Group 1 was divided into classes 1a and 1b by computing the required percentages, (a) and (b) above, from State economic area acreages (*29, tables 1 and 6*). County acreages (*29, tables 1 and 9*) were used to divide group 2 into classes 2a and 2b. Thus classes 1a and 1b are State economic areas and classes 2a and 2b are counties.

Finally, classes 1a and 2a were aggregated to form the 104 programing regions. Criteria used to guide aggregation were as follows: State economic areas and counties within each region were required to be contiguous and to have similar grain yields, similar proportions of the five grains shown, and similar numbers of combines, cornpickers, and tractors per 1,000 acres of cropland. On the basis of these criteria, many times two or more State economic areas could not be aggregated. Hence, some programing regions consist of only one State economic area. In other instances, it was possible only to aggregate one economic area and a group of counties. A few regions are made up of counties only.

The 104 programing regions shown in figure 2 provided the basic units for making estimates of acreage, yield, and cost. But when the necessary data were not available for these regions for estimating input coefficients, State data were adjusted by other related data to compensate for within-State differences. In a few instances, State data were used without adjustment when a logical means of adjustment was not apparent.

The concept of "normal" is basic to the methods used in estimating the maximum regional grain acreages and regional yields. The word "normal" is used here to mean expected or average. The objective for yields was to obtain estimates that would reflect accurately the average quantity of inputs used per acre for production of wheat and feed grains in 1954. The general objective for all estimates was the obtaining of data that would reflect the relative competitive positions of the regions in production of wheat and feed grains.

Regional Acreages

Grain acreages of 1953 were used as estimates of the maximum regional acreages available for grain production. More grain was planted in 1953 than in any other year of the present decade. Acreage-control programs were not in effect in 1953, and the large grain acreages of that year perhaps represent the maximum area adapted to these crops under peacetime economic conditions. Thus, later figures on production adjustment suggest the quantity of land that might not be needed, relative to the 1953 base acreage, if production of feed grains and wheat were balanced with annual use.

Acreages planted to grain and summer fallowed are the components of the regional acreage restraints. Acreages planted to grain were not easily ascertained for many regions as either (1) estimates of planted acreages were not available, or (2) when estimates of planted acreages were available, they included plantings for hay, pasture, silage, cover crops, and so on. These difficulties existed mainly for small grains. The total number of acres harvested for the various uses of corn are estimated by Federal-State agencies, but numbers of acres harvested for grain only are not estimated for the small grains. A different method was used in estimating acreages of corn and small grains because of the kinds of data available.

The acreages of corn planted for grain were estimated by the following formula:

$$\left(\begin{array}{l}\text{Estimated acres of}\\ \text{corn planted for}\\ \text{grain in the i-th}\\ \text{region}\end{array}\right)=\left(\begin{array}{l}\text{Acres of corn}\\ \text{planted for all pur-}\\ \text{poses in the i-th}\\ \text{region}\end{array}\right)-\left(\begin{array}{l}\text{Estimated acres of}\\ \text{corn planted for}\\ \text{silage in the i-th}\\ \text{region}\end{array}\right)$$

$$(i=1, 2, 3, \ldots 104)$$

The acreages of wheat, oats, barley, and grain sorghums planted for grain were estimated by the following relationship:

$$\left(\begin{array}{l}\text{Estimated acres of the g-th}\\ \text{grain planted for grain in the}\\ \text{i-th region}\end{array}\right)=\frac{\left(\begin{array}{l}\text{Acres of the g-th grain har-}\\ \text{vested for grain in the i-th}\\ \text{region}\end{array}\right)}{\left(\begin{array}{l}\text{1—average abandonment rate}\\ \text{of the g-th grain in the i-th}\\ \text{region}\end{array}\right)}$$

$$(g=1, 3, 4, 5)$$

When available, 1953 planted or harvested acreages of wheat, corn, oats, barley, and sorghum were obtained from unpublished data of the Agricultural Estimates Division, Agricultural Marketing Service, and from State statistical bulletins (*2, 3, 4, 7, 20, 19, 25, 27, 12, 8, 9, 10, 11, 13, 16, 14, 15, 28, 5, 6, 32,* and *33*). When acreages were not available from these sources, regional acreages were estimated from State data (*23*) and 1954 economic area and county data (*29*).

The number of cultivated summer-fallow acres was included as a component of the regional acreage restraints because fallowed acreages are a necessary land input in semiarid wheat areas. Machinery and labor costs associated with fallowed land are a necessary part of the total per acre cost of production. Also, historic yields are based on production resulting from the use of cultivated summer fallow in rotation. Thus, the inclusion of cultivated summer fallow places estimates of acreage, yield, and cost in their proper relationship.

Estimates of cultivated summer-fallow acreages were obtained from the census (*29, table 1*) and from unpublished data of the Crop Estimates Division, Agricultural Marketing Service. It was assumed that fallowed acreages did not change significantly from 1953 to 1954.

Only recently have annual data on cultivated summer fallow become available, and these data are far from complete.

The estimated acreages of wheat and feed grains available for planting in each region are shown in table 1.

TABLE 1.—*Estimated acreages of land available for production of wheat and feed grains, by regions, 1953* [1]

Region	Wheat	Corn	Oats	Barley	Sorghum
	1,000 acres	*1,000 acres*	*1,000 acres*	*1,000 acres*	*1,000 acres*
1	316.4	110.4	161.8	14.0	
2	858.2	1,018.0	430.1	173.8	
3	89.2	320.3	11.9	23.3	
4	103.2	157.5	15.7	21.3	
5	59.2	118.8	18.1	12.3	
6	12.8	526.3	18.0	3.8	
7	77.4	196.7	44.9	6.4	
8	136.7	123.2	95.7	14.0	
9	91.8	1,223.0	98.8	7.1	
10	8.0	247.4	34.5	.2	
11	1.0	241.6	18.0	.1	
12	110.5	2,455.9	527.9	5.6	
13	90.2	192.2	140.4	10.8	
14	12.2	80.1	13.4	1.6	
15		517.3	24.3		
16	0.4	83.8	6.9		0.3
17	0.9	698.2	21.9		6.2
18	18.1	1,120.3	72.5		19.1
19	2.7	1,132.9	89.7		2.7
20	107.9	741.4	66.7	52.5	
21	161.7	647.9	38.7	3.9	.6
22	184.4	789.7	40.5	54.6	
23	25.5	227.0	6.2	2.0	
24	48.6	242.5	18.1	20.2	
25	189.6	359.5	20.5	4.4	
26	134.5	208.1	64.6	4.3	
27	382.2	415.1	262.5	7.4	
28	1,698.6	2,421.1	795.0	20.6	
29	205.8	467.8	71.0	12.8	
30	498.6	1,320.9	68.6	13.8	
31	939.1	2,909.6	905.8	5.6	
32	220.3	510.2	263.9	1.9	
33	537.7	682.9	418.5	9.7	
34	893.6	691.1	692.4	39.6	
35	14.9	201.6	766.0	11.3	
36	41.4	817.2	1,370.3	68.2	
37	185.6	4,900.9	2,654.6	13.3	
38	677.8	3,176.3	986.4	.8	
39	305.9	769.4	52.5	5.2	
40	461.1	450.6	92.9	8.3	

See footnote at end of table.

TABLE 1.—*Estimated acreages of land available for production of wheat and feed grains, by regions, 1953* [1]—Continued

Region	Wheat	Corn	Oats	Barley	Sorghum
	1,000 acres	*1,000 acres*	*1,000 acres*	*1,000 acres*	*1,000 acres*
41	252.3	333.7	99.2	7.7	----------
42	442.6	500.1	492.5	77.0	22.3
43	1,171.2	2,853.7	759.5	3.4	6.9
44	122.2	2,834.3	1,304.4	2.1	----------
45	21.0	6,800.8	4,002.5	54.9	----------
46	27.1	2,455.0	1,613.2	11.9	----------
47	62.2	1,120.2	1,483.0	45.7	----------
48	96.1	1,290.4	988.8	185.5	----------
49	103.2	339.4	767.4	93.7	----------
50	2,707.0	192.6	830.2	1,090.9	----------
51	6,035.1	119.6	721.6	1,022.1	----------
52	2,427.6	20.4	161.1	181.5	----------
53	4,033.3	293.3	453.5	236.2	----------
54	481.9	159.2	271.9	162.8	----------
55	1,558.7	237.8	237.0	67.7	----------
56	2,277.4	747.3	938.2	192.5	----------
57	216.5	449.9	628.9	108.9	----------
58	246.8	410.4	303.2	52.9	----------
59	143.6	1,835.1	1,593.0	52.6	----------
60	263.2	2,335.9	1,258.4	15.4	1.3
61	253.5	81.1	62.6	44.1	.1
62	3,647.4	233.8	109.9	266.1	24.9
63	491.1	1,157.2	271.0	52.5	18.2
64	1,358.2	939.4	80.7	13.9	117.0
65	1,596.1	2,426.8	647.0	9.8	38.1
66	398.1	584.6	208.4	1.9	26.9
67	292.9	208.4	175.4	10.3	101.2
68	484.9	96.0	127.4	7.4	42.9
69	6[illegible]5.5	173.1	178.7	8.2	143.5
70	1,076.3	532.2	79.3	4.6	100.0
71	1,063.1	97.4	112.8	1.8	96.2
72	2,347.6	36.4	161.7	7.5	182.8
73	6,565.5	99.7	106.7	78.0	814.3
74	4,473.6	8.0	14.1	20.1	592.4
75	155.0	76.2	154.1	4.0	31.5
76	2,568.2	12.2	94.8	17.4	46.4
77	2,485.9	6.7	27.1	8.4	383.8
78	277.9	78.4	102.3	5.8	39.1
79	1,763.5	23.7	109.2	11.9	116.8
80	1,820.1	5.0	9.4	28.7	1,017.3
81	1,342.4	12.4	182.7	18.6	398.7
82	75.4	4.4	1.7	3.7	1,090.5
83	277.5	14.9	65.9	5.4	5.7
84	48.4	2.8	11.5	.5	34.5
85	36.6	296.2	----------	----------	106.1

See footnote at end of table.

TABLE 1.—*Estimated acreages of land available for production of wheat and feed grains, by regions, 1953* [1]—Continued

Region	Wheat	Corn	Oats	Barley	Sorghum
	1,000 acres	*1,000 acres*	*1,000 acres*	*1,000 acres*	*1,000 acres*
86	22.7	43.3	26.4	2.2	13.8
87	1.2	289.2	----------	----------	35.6
88	5.2	291.9	----------	----------	312.3
89	6,095.1	103.6	147.5	146.8	----------
90	3,485.9	1.2	75.4	270.3	----------
91	505.2	22.9	44.8	38.9	----------
92	629.1	1.2	25.2	36.5	----------
93	685.8	30.2	71.8	42.2	----------
94	3,884.4	155.6	40.0	95.7	118.0
95	492.0	32.9	10.8	21.5	52.1
96	505.2	1.8	2.7	9.3	42.1
97	412.6	4.5	.4	1.7	124.9
98	1,538.3	.5	40.0	171.1	----------
99	489.1	1.2	4.7	23.8	----------
100	4,334.2	.8	89.1	260.7	----------
101	2,756.1	2.7	13.0	13.2	----------
102	506.0	9.5	16.4	12.1	----------
103	103.4	12.0	35.6	388.8	13.9
104	157.6	28.5	11.8	779.8	37.6
Total	94,716.0	67,084.5	34,163.6	7,272.0	6,378.7

[1] Acreages include cultivated summer fallow.

REGIONAL YIELDS

Normal regional yields, as defined previously, were estimated in two steps. First, the 1945–54 average yields were computed. These yields were then adjusted by a factor representing the average increase in yield between the midpoint of the period 1945–54 and the year 1954. Trends were computed from data for the period 1937–54.

When annual data were available, 1954 average yields were computed by this method. The sources of the data are those listed for acreages. When annual data were not available for the period 1945–54, harvested yields per acre were estimated from State data (*23*)and census economic area and county data (*29*). These yields per harvested acre were then adjusted by a factor representing the average percentage of the total acreage harvested, with total acreage equaling harvested acreage plus abandonment plus fallow.

The estimated yields for each grain by regions are shown in table 2. These are net yields—per acre seed requirements were subtracted.

TABLE 2.—*Estimated net yields per acre for wheat and feed grains, by regions, 1954* [1]

Region	Wheat	Corn	Oats	Barley	Sorghum
	Bushels	*Bushels*	*Bushels*	*Bushels*	*Bushels*
1	26.9	45.6	39.0	30.0	----------
2	21.3	50.0	36.4	37.3	----------
3	18.1	45.9	29.2	26.2	----------
4	18.4	40.8	32.2	27.2	----------
5	21.2	39.6	35.2	30.7	----------
6	16.2	36.6	27.4	21.9	----------
7	19.3	29.4	32.0	29.9	----------
8	18.3	31.2	32.2	30.6	----------
9	17.7	29.2	29.9	24.1	----------
10	17.8	21.3	28.2	21.6	----------
11	16.5	18.6	23.1	17.0	----------
12	16.6	16.2	27.2	23.6	----------
13	16.5	18.0	27.2	23.6	----------
14	16.1	18.6	24.0	21.0	----------
15	----------	15.0	21.2	----------	----------
16	22.8	20.9	21.7	----------	19.0
17	20.4	15.4	22.1	----------	14.8
18	19.6	21.5	29.5	----------	17.1
19	15.7	19.8	20.9	----------	15.0
20	14.9	27.6	25.3	14.9	----------
21	18.0	25.6	24.4	18.6	19.2
22	17.1	36.4	27.0	19.0	----------
23	16.6	32.6	27.7	19.6	----------
24	15.8	36.3	28.6	24.4	----------
25	17.4	50.8	27.7	24.5	----------
26	23.0	51.3	37.1	29.8	----------
27	26.0	50.4	40.9	32.8	----------
28	24.1	56.6	39.5	29.1	----------
29	19.0	44.4	30.0	24.6	----------
30	19.1	39.8	28.5	26.5	----------
31	24.3	55.6	38.0	25.5	----------
32	27.0	56.0	39.8	26.2	----------
33	26.6	43.4	37.1	28.7	----------
34	27.6	43.3	37.2	32.0	----------
35	20.6	44.6	37.9	33.0	----------
36	27.3	58.6	53.6	38.4	----------
37	25.2	59.9	41.2	30.6	----------
38	27.1	57.0	36.6	26.6	----------
39	18.8	36.1	23.7	25.0	----------
40	19.4	35.2	25.2	25.5	----------
41	21.3	36.0	23.9	25.9	17.0
42	19.7	28.2	24.5	23.3	16.1
43	22.7	42.8	27.1	27.8	22.3
44	15.5	46.1	28.1	22.4	----------
45	14.7	50.1	31.2	17.8	----------

See footnote at end of table.

TABLE 2.—*Estimated net yields per acre for wheat and feed grains, by regions, 1954* [1]—Continued

Region	Wheat	Corn	Oats	Barley	Sorghum
	Bushels	*Bushels*	*Bushels*	*Bushels*	*Bushels*
46	17.6	51.4	37.1	27.5	----------
47	17.0	47.6	38.2	26.9	----------
48	13.6	39.5	32.6	23.6	----------
49	14.6	40.3	33.2	27.8	----------
50	9.2	26.4	30.0	25.0	----------
51	8.0	20.2	24.6	18.7	----------
52	7.0	17.8	24.4	17.6	----------
53	7.5	17.8	25.5	18.5	----------
54	7.9	22.1	25.8	18.9	----------
55	8.1	19.0	22.4	16.7	----------
56	9.0	22.2	25.5	17.0	----------
57	8.6	29.7	30.0	20.1	----------
58	8.5	21.6	24.2	16.4	----------
59	9.6	36.5	29.5	18.8	----------
60	16.2	38.9	22.8	16.8	21.4
61	12.8	24.4	23.7	19.3	16.7
62	10.0	26.4	24.4	21.8	15.3
63	10.6	32.2	17.8	12.7	21.5
64	11.2	25.2	19.2	14.3	21.4
65	17.5	37.0	22.7	16.3	30.5
66	17.8	31.5	17.4	17.6	25.5
67	17.9	25.5	18.7	19.2	19.8
68	17.1	22.1	20.9	18.1	17.5
69	17.4	24.0	19.9	18.5	18.4
70	10.8	22.1	13.7	11.7	19.8
71	13.3	22.2	18.8	14.3	19.9
72	13.8	21.0	19.7	13.3	18.6
73	9.4	20.4	16.0	12.8	18.6
74	7.3	16.1	15.6	10.3	17.0
75	12.0	18.4	13.5	12.7	12.5
76	13.0	16.5	17.3	11.6	14.8
77	6.6	11.2	10.1	7.3	12.9
78	10.4	19.5	15.7	9.8	13.1
79	10.3	18.0	15.4	10.1	14.7
80	6.1	27.2	16.6	12.2	27.5
81	7.5	13.7	17.9	12.1	10.0
82	5.0	14.5	15.9	13.2	15.0
83	8.3	13.7	16.0	12.4	9.1
84	4.5	11.3	14.2	9.1	12.7
85	5.8	17.7	----------	----------	19.0
86	4.2	14.0	16.6	9.9	16.1
87	4.5	17.6	----------	----------	15.9
88	4.5	17.1	----------	----------	23.6
89	8.0	14.6	28.0	29.6	----------
90	8.0	16.4	29.4	27.0	----------

See footnote at end of table.

TABLE 2.—*Estimated net yields per acre for wheat and feed grains, by regions, 1954* [1]—Continued

Region	Wheat	Corn	Oats	Barley	Sorghum
	Bushels	*Bushels*	*Bushels*	*Bushels*	*Bushels*
91	6.5	13.0	23.9	16.4	----------
92	10.6	25.4	40.6	30.2	----------
93	8.7	24.2	22.8	22.5	----------
94	7.0	16.3	15.8	12.7	8.8
95	5.2	42.8	17.9	14.8	16.5
96	2.5	16.7	11.9	10.1	8.6
97	1.6	10.0	19.7	10.6	10.8
98	12.9	45.2	39.4	30.6	----------
99	9.9	38.1	49.4	47.2	----------
100	16.9	64.5	40.0	31.0	----------
101	12.6	52.5	37.6	30.7	----------
102	11.6	71.7	51.5	33.1	----------
103	12.5	36.1	18.2	23.2	33.5
104	9.8	25.4	17.0	27.1	36.4

[1] Estimated yield less seed.

PRODUCTION COSTS

The methods used in estimating per acre costs of grain production are described here. In the section that follows, the methods used in transforming these costs into the programing coefficients are described. It is hoped that this method of presentation will better illustrate the formulation of the programing coefficients.

The basic items that make up the per acre cost are land, labor, machinery and power, seed, chemicals, and miscellaneous inputs. However, a charge for annual land services was considered for model B only. Indirect or overhead costs, such as management, purchasing, selling, housing, and so on, were not estimated because a satisfactory method and data for estimation were lacking. Some detailed unit cost studies have used 10 percent of the direct cost as an estimate of the indirect cost, but use of this method would not change the relative values of the activity costs. Hence, the inclusion of a proportional indirect cost would not affect the programing solutions to the problems considered in this study.

Composite Acre

Because uniform and complete data on average production costs for wheat and feed grains in each programing region were lacking, these costs had to be synthesized by some consistent method. To get some realistic estimate of per acre cost, a composite acre was devised for each region. This composite acre was made up of 12 possible elements, each of which represents a unique production operation. These 12 acre-elements, or types of production situations, used for production-cost estimates are:

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(1) Mechanical, planted and harvested, not irrigated;
(2) Mechanical, planted and harvested, irrigated;
(3) Mechanical, planted but not harvested (abandoned);
(4) Mechanical, cultivated summer fallow;
(5) Semimechanical, planted and harvested, not irrigated;
(6) Semimechanical, planted but not harvested, irrigated;
(7) Semimechanical, planted but not harvested (abandoned);
(8) Semimechanical, cultivated summer fallow;
(9) Nonmechanical, planted and harvested, not irrigated;
(10) Nonmechanical, planted and harvested, irrigated;
(11) Nonmechanical, planted but not harvested (abandoned);
(12) Nonmechanical, cultivated summer fallow.

Except for the mechanical items, these acre-elements are self-explanatory. They are defined as follows: Mechanical—tractor power is used for all tillage operations and harvesting is done by combine or cornpicker; semimechanical—tractor power is used for all tillage operations and harvesting is done by hand (for corn) or with binder and thresher (for small grain); and nonmechanical—a production technique in which animal power is used for all tillage operations and harvesting is done by hand (as for corn) or with binder and thresher (as for small grain). Also, acre-elements 2, 6, and 10 imply that no abandonment is assumed on irrigated acres.

The list of 12 acre-elements is not exhaustive. On the basis of regional data, however, they seemed to be complete enough to provide reasonable estimates of average production costs, and at the same time to facilitate computations for planned further investigations.

An example will help to explain the method used in deriving costs for each crop and each region. Data for corn in region 1 indicated: (1) All production by mechanical techniques, (2) no irrigation, (3) no harvesting from land in cultivated summer fallow the preceding year, and (4) an average of 1-percent abandonment of the planted acres. Attached to each corn acre in region 1, therefore, were two types of acre-element costs—mechanical, planted and harvested but not irrigated; and mechanical, planted but not harvested. The weights, which are computed elsewhere on an acreage basis, are 0.99 for mechanical, planted and harvested but not irrigated; and 0.01 for mechanical, planted but not harvested. Furthermore, given per acre costs of $42.20 for the mechanical, planted and harvested acre and $34.50 for the mechanical, planted but not harvested acre, the estimated average per acre production cost for corn in region 1 is $42.12 ($42.20\times0.99+34.50\times0.01$).

Estimates of costs of labor, machinery, and power provided the greatest conceptual and empirical difficulties. Aggregate estimates of machinery and labor inputs exist for United States farms, but they are not broken down between individual farm enterprises. Hence, these costs were derived by estimating the average physical inputs per acre by type of operation (plowing, disking, harrowing, and so on) and then weighting physical inputs by the estimated per unit cost of the inputs involved. Because many of the published data on labor and machinery costs were either incomplete or out of date, supplementary data on these inputs were obtained from 25 agricultural experiment stations.

Methods used in estimating the basic cost items are now described.

Land

The annual value of land for grain production was used only in model B. The per acre value of land on cash-grain farms (*29, economic area table 4*) was assumed to be the best available basis for estimating the annual value of land services for grain production.[6] The sum of the interest rate and tax rate (*56*) was multiplied by the per acre value to obtain the annual input value of land (*24*). In region 1, for example, the interest and tax rates were 0.048 and 0.0184, respectively, per dollar of value, and the land value was $111 per acre. Hence, the estimated annual value of land was $6.37. The estimated annual per acre cost for land by regions is shown in table 3. No attempt was made to differentiate between values when land was used for the different grains.

Labor

Inputs of physical labor were estimated for each production operation. The method is illustrated in the tabulation below for wheat

TABLE 3.—*Estimated annual regional land costs (rents) per acre for grain production, by regions, 1954*

Region	Cost	Region	Cost	Region	Cost	Region	Cost
1	$7.37	27	$9.14	53	$1.59	79	$4.43
2	8.81	28	12.50	54	2.12	80	4.98
3	5.59	29	4.60	55	1.28	81	3.68
4	7.03	30	7.14	56	2.23	82	4.07
5	5.91	31	11.99	57	3.68	83	3.32
6	4.58	32	10.62	58	2.14	84	5.00
7	6.08	33	9.97	59	4.08	85	8.22
8	4.84	34	8.46	60	7.65	86	5.00
9	5.73	35	3.33	61	2.66	87	5.36
10	8.29	36	10.30	62	3.71	88	5.40
11	4.46	37	14.70	63	4.20	89	1.60
12	4.73	38	18.70	64	3.95	90	2.76
13	6.12	39	4.97	65	7.41	91	.82
14	2.77	40	5.31	66	5.62	92	1.51
15	3.83	41	7.03	67	3.84	93	1.96
16	6.48	42	3.77	68	3.66	94	2.88
17	3.40	43	6.66	69	5.07	95	2.40
18	3.92	44	8.03	70	3.55	96	2.40
19	3.88	45	13.01	71	5.22	97	2.98
20	3.71	46	9.55	72	7.07	98	4.08
21	5.41	47	6.69	73	4.21	99	3.77
22	3.27	48	6.46	74	3.81	100	6.14
23	4.60	49	2.92	75	3.53	101	4.26
24	6.58	50	4.06	76	5.16	102	2.73
25	7.12	51	2.13	77	3.75	103	11.61
26	5.38	52	1.69	78	4.65	104	7.60

[6] This value also includes an estimate of the value of farm buildings on a per acre basis. Thus, an upward bias is introduced into the estimated values; however, the resulting bias is probably negligible for cash-grain farms.

production in region 1, which is based on the mechanical, planted and harvested, not irrigated acre-element.

Operation:	*Hours required per acre*
Plowing	1. 46
Disking	1. 15
Harrowing	. 69
Drilling	. 82
Harvesting	1. 54
Hauling	1. 03
Total	6. 69

The data on labor hours required for harvesting and hauling omit the portion of an "average" acre not harvested.

Data on the number of man-hours of labor required for each production operation were obtained from several publications (*17, 18, 26*) and from the survey data noted previously. When possible, modal coefficients were used. When a modal production operation was not evident in the data, simple averages or single estimates were used. The per acre labor cost for each acre-element was obtained by multiplying the estimated number of man-hours required per acre by an estimate of the hourly wage rates on cash-grain farms. The per acre labor costs for each grain and each region were computed by weighting each acre-element labor cost by the proper coefficient.

Power and Machinery

The method used in estimating the power and machinery cost was similar to that used in estimating labor. The estimating problem was more complex, however, because of the multitude of items that compose machinery costs. Instead of one coefficient—hours per acre—and one price—wages—coefficients and prices for each implement required to produce each grain in each region were estimated. The tabulation that follows illustrates the procedure used in estimating this cost for an acre of corn in region 28 in Ohio. The example is for the mechanical, planted and harvested but not irrigated acre-element.

Implement	Size	Hours of use required per acre ×	Cost per hour =	Cost for implement per acre
Tractor	19 HP	10. 45	$0. 81	$8. 46
Plow	2–14″	1. 30	. 71	. 92
Disk	7′ T	1. 00	. 67	. 67
Harrow	10′	. 50	. 22	. 11
Drag	9′	. 35	. 26	. 09
Cultipactor	10′	. 40	. 60	. 24
Planter	2–R	. 60	. 65	. 39
Cultivator	2–R	1. 50	. 80	1. 20
Picker	1–R	1. 80	1. 71	3. 08
Wagon	Std	1. 00	. 08	. 08
Total				15. 24

The machinery sizes and number of hours required per acre used in estimating machinery cost were modal values when these values could be determined. When a modal value was not apparent, simple averages or single observations were used. Machinery sizes and hours of use required per acre were obtained from F.M. 92 (*26*) and from survey data. Extensive searching and many computations were necessary in order to estimate the per hour cost of each implement. Information was obtained or estimated for this purpose as to size, price; annual use; total life; interest, tax, and insurance rates; grease and repair rates; and fuel and oil consumption rates. With these basic data, the items that make up the per hour cost of each implement—depreciation, insurance, interest, taxes, fuel, oil, grease, and repairs—could be computed.

Seed

The cost of seed was not included as a part of the total per acre production cost. Instead, the estimated quantity of seed required per acre was subtracted from the estimated yield. This method was used because total demand for seed is a function of the acreage grown in each region. But these acreages are variables to be determined within the system (that is, the model). Hence, the simplest way of allowing seed cost and demand for seed to be variables determined by the system is to deduct the seeding rate from the yield. To use this method, it is necessary that grain seed be planted in the region in which it is produced; and that planted acreages within each region be constants between years. Only State seeding rates were available (*30, 1954*). Therefore, adjustments were made in State rates to compensate for variations within the States.

Chemicals

Regional fertilizer costs for each of the five grains were calculated mainly from the U.S. Census of Agriculture (*29, county table 6 and economic area tables 4 and 5*). Specific data for only the "more important" crops are recorded in the census. When fertilizer applications were not tabulated for a grain crop in the census, this cost was estimated with the aid of unpublished data of the Farm Economics Research Division, ARS.

The per acre cost of lime for each grain was estimated by dividing the total cost of lime applied in a region in 1954 by the total cropland (*29, economic area tables 1 and 2 and county tables 1 and 6*).

Data were not available to show expenditures for insecticides, fungicides, and herbicides for wheat and feed grains by regions. Hence, these costs were first estimated for each State. The State estimates were then used to estimate chemical costs for regions within States. The basic data used for insect, pest, and chemical weed-control expenditures were those compiled by Brodell and others (*1, tables 9–12*).

Miscellaneous

Miscellaneous costs include those involved in the spreading of manure, fertilizer, and lime, and those of water for acreages produced by irrigation. No attempt was made to estimate the value of manure applied to wheat and feed grains. The spreading cost alone was charged to crop enterprises. Costs of spreading manure were estimated only for the programing regions in the Northeast, Appalachian, Corn Belt, and Lake States regions and the corn-producing areas of the Northern Plains. For some of the fertilizer applied to grains, the cost of application was accounted for in the method used to compute machinery and labor cost. This accounting method was used for fertilizer applied by attachments on planters, drills, and cultivators. For fertilizer spread by other methods (*21*), an additional application cost, which included charges for labor, power and machinery, was computed. Costs of lime spreading by custom operators were assumed to have been included in the lime expenditures reported by farmers (*29, county table 6 and economic area table 2*). An additional spreading cost was computed for lime spread by farmers (*21*). In areas in which less than 0.5 percent of the grains were produced by irrigation methods (*29, county table 1a*), irrigation costs were not estimated.

Estimates of the production costs (except land) outlined above are summarized in table 4. These costs are based on the composite acre described earlier.

TABLE 4.—*Estimated production costs per acre, excluding land, for specified crops, by regions* [1]

Region	Wheat	Corn	Oats	Barley	Sorghum
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*
1	29.23	34.76	28.34	28.64	----------
2	28.08	33.08	26.40	25.14	----------
3	29.86	29.29	28.28	30.61	----------
4	28.14	32.36	27.58	27.81	----------
5	24.36	30.59	24.31	24.31	----------
6	25.25	32.12	26.87	24.92	----------
7	32.35	39.01	32.31	32.38	----------
8	30.17	32.57	29.04	30.16	----------
9	28.35	35.48	28.22	28.56	----------
10	22.79	30.85	23.62	24.08	----------
11	27.24	31.93	24.53	25.43	----------
12	23.37	25.49	23.39	23.49	----------
13	22.79	27.56	21.90	22.30	----------
14	26.46	30.08	24.57	25.91	----------
15	----------	26.53	25.49	----------	----------
16	23.36	35.09	28.85	----------	27.42
17	23.73	29.61	28.66	----------	29.13
18	23.42	29.17	28.21	----------	28.10
19	22.87	28.65	22.92	----------	26.29
20	25.84	28.61	24.55	24.40	----------
21	22.60	24.12	19.89	19.53	----------
22	24.25	30.64	23.62	23.53	----------
23	26.68	28.35	25.84	26.29	----------
24	28.04	30.33	27.07	27.57	----------
25	25.93	33.07	27.16	21.65	----------

See footnote at end of table.

TABLE 4.—*Estimated production costs per acre, excluding land, for specified crops, by regions* [1]—Continued

Region	Wheat	Corn	Oats	Barley	Sorghum
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*
26	29.64	34.72	24.03	24.16	----------
27	30.28	34.78	26.02	26.49	----------
28	25.72	32.85	21.15	21.75	----------
29	26.25	30.96	22.81	20.95	----------
30	20.68	20.82	18.82	17.81	----------
31	23.70	26.99	20.75	19.12	----------
32	20.45	26.45	18.67	17.24	----------
33	28.11	29.57	23.45	26.40	----------
34	30.45	30.40	29.62	28.68	----------
35	21.85	30.93	24.03	22.33	----------
36	21.57	30.34	21.28	22.06	
37	20.37	23.82	18.85	19.78	----------
38	18.52	18.52	14.17	15.77	----------
39	20.65	20.14	15.09	16.10	----------
40	18.74	22.70	14.40	15.57	----------
41	20.06	23.34	17.12	19.85	22.21
42	20.79	23.34	16.91	18.32	21.60
43	19.86	21.78	16.76	23.29	26.01
44	16.59	21.58	14.08	17.20	----------
45	14.74	19.43	11.40	11.94	----------
46	16.90	21.67	12.63	12.45	----------
47	17.67	25.08	18.69	18.39	----------
48	14.71	19.51	9.65	13.93	----------
49	13.40	23.22	14.66	13.59	----------
50	8.52	18.70	12.57	11.77	----------
51	6.57	17.83	8.53	8.70	----------
52	5.84	19.41	8.50	8.75	----------
53	7.23	16.26	9.16	9.31	----------
54	8.25	16.39	9.92	10.15	----------
55	6.16	11.53	7.75	7.64	----------
56	7.23	11.62	8.00	8.05	----------
57	10.23	17.50	12.88	12.83	----------
58	7.01	11.53	8.71	9.62	----------
59	10.12	16.45	9.44	12.20	----------
60	11.74	14.40	10.24	11.14	13.31
61	7.20	14.50	11.72	10.70	16.04
62	7.05	20.12	13.50	14.16	15.53
63	10.28	18.68	16.07	14.80	20.75
64	6.44	17.06	12.20	10.82	16.17
65	12.68	17.57	11.80	10.57	14.19
66	17.56	18.01	14.20	12.23	15.71
67	18.91	21.83	14.88	12.84	19.26
68	20.20	22.47	15.97	16.70	17.68
69	16.65	19.77	12.82	14.25	18.83
70	9.21	16.23	12.54	10.54	16.41

See footnote at end of table.

TABLE 4.—*Estimated production costs per acre, excluding land, for specified crops, by regions*[1]—Continued

Region	Wheat	Corn	Oats	Barley	Sorghum
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*
71	11. 21	18. 53	12. 28	10. 42	16. 82
72	9. 49	19. 28	10. 62	9. 19	15. 57
73	5. 80	11. 22	8. 85	7. 52	10. 05
74	3. 88	17. 20	6. 45	6. 03	8. 54
75	15. 40	19. 97	16. 70	15. 29	17. 85
76	9. 41	21. 89	9. 67	8. 79	17. 16
77	6. 08	13. 30	7. 75	6. 65	9. 06
78	10. 93	19. 36	12. 03	11. 20	17. 23
79	7. 55	16. 89	8. 43	7. 41	10. 65
80	4. 90	22. 62	5. 58	5. 39	13. 78
81	5. 54	11. 35	7. 49	6. 69	8. 04
82	5. 13	21. 25	6. 56	6. 06	9. 10
83	7. 06	12. 79	8. 54	7. 92	8. 68
84	5. 19	9. 52	7. 77	7. 09	8. 55
85	7. 15	14. 07	----------	----------	13. 47
86	4. 77	14. 47	9. 24	8. 06	13. 48
87	7. 73	16. 30	----------	----------	13. 66
88	6. 30	13. 11	----------	----------	10. 54
89	5. 07	32. 38	9. 42	9. 11	----------
90	6. 83	35. 84	18. 46	14. 10	----------
91	6. 76	34. 48	13. 71	12. 56	----------
92	8. 88	44. 92	24. 44	20. 90	----------
93	8. 61	23. 57	15. 53	16. 59	----------
94	5. 50	12. 35	9. 60	9. 07	10. 92
95	7. 63	22. 71	15. 21	15. 94	19. 98
96	3. 61	14. 33	10. 40	9. 21	12. 90
97	4. 04	16. 46	15. 59	15. 21	16. 28
98	10. 56	3. 40	26. 60	20. 56	----------
99	10. 36	50. 30	31. 19	31. 31	----------
100	10. 95	51. 48	17. 28	16. 66	----------
101	6. 76	57. 58	13. 18	14. 90	----------
102	8. 65	73. 17	27. 77	23. 09	----------
103	10. 11	40. 25	13. 28	14. 25	32. 90
104	9. 21	31. 36	9. 33	14. 17	16. 11

[1] These estimates are based on a composite acre; see previous section in text.

DEMAND RESTRAINTS

Separate demand restraints (restrictions) were considered for food wheat and feed grain in aggregate for 1954. Hence, the calculations provided later show regional production patterns designed to meet aggregate demand at the 1954 level. Techniques of production also represent 1954 as a point in time. The year 1954 was used because data for it were available. These demand restraints, which are assumed to be fixed or constant, were based on the normal per unit requirements of the human or livestock populations, or both, and the actual net exports in the base year 1954.

Because it was believed that grain stocks "put an abnormal pressure" on grain disappearance in 1954, an attempt was made to estimate a normal domestic disappearance for each grain. No attempt was made, however, to estimate normal net exports, because of the many unmeasurable factors in the world market.

The total (domestic and foreign) estimated demand levels were approximately 757 million bushels of wheat and 3,887 million corn-equivalent bushels of feed grain. Although these estimates were derived by simple techniques, they seem quite reasonable and do not differ greatly from actual disappearances of wheat and feed grains in 1954 (*22*). Seed requirements and grain for forage were not included in the estimates, as seed requirements were subtracted from yields and the study reported is concerned with grain production alone.

As shown in figure 2, not all the land area in the United States was included in the programing regions. Hence, it was necessary to estimate the normal production of wheat and feed grains in these nonprogramed areas in order to determine how much of the estimated total demand or requirements would need to be produced in the programing regions. Production from the nonprogramed areas was subtracted from the total demand requirements mentioned above. This remainder formed the demand restraints that had to be met from production in the programed regions.

The normal production in the nonprogramed areas was estimated by a residual method.[7] First, for each State and each grain, the total planted acreage in the programing regions within a State was subtracted from the 1953 acreage planted for grain in the State. When these residual acreages were multiplied by the estimated 1954 normal yields for the State, the total production in the nonprogramed areas was obtained.[8] With corn, oats, barley, and grain sorghums converted to corn-equivalents, these quantities were 80 and 338 million bushels of wheat and feed grain, respectively. Subtracting these quantities from total requirements gave 677 million and 3,549 million bushels of wheat and feed grain, respectively, as the demand or requirement quantities to be provided from the programed regions.

The estimated acreages and total attainable production in both the programed and the nonprogramed regions are summarized in table 5. That the attainable production in the programing regions accounts for most of the grain produced in the United States is evident. In fact, if the feed grains are converted to corn-equivalent bushels, the percentage of feed grains in the programed areas accounts for about 91 percent of the total U.S. production. The similar percentage for wheat production in the programed regions is 93.1.

Grain Prices

As model E is based on the criterion of maximum profit, it was necessary for this model to estimate the regional grain prices received by farmers. Estimating grain prices that were consistent with the

[7] A residual method was used because 1953 county data were not available for many States.

[8] The yields were estimated by the same method used in estimating normal yields for programing regions.

TABLE 5.—*Estimated available acreages and attainable total net production of wheat and feed grains in the United States, programed and nonprogramed areas, 1954* [1]

Crop	Programed areas		Nonprogramed areas [2]		United States
	Amount	Percentage	Amount	Percentage	
	1,000 acres	*Percent*	*1,000 acres*	*Percent*	*1,000 acres*
Available acreage:					
Wheat	94, 716	94. 9	5, 080	5. 1	99, 796
Corn	67, 084	89. 1	8, 173	10. 9	75, 257
Oats	34, 164	85. 6	5, 755	14. 4	39, 919
Barley	7, 272	77. 8	2, 056	22. 2	9, 328
Sorghum	6, 379	93. 7	431	6. 3	6, 810
	1,000 bushels		*1,000 bushels*		*1,000 bushels*
Net production:					
Wheat	1, 079, 354	93. 1	80, 356	6. 9	1, 159, 710
Corn	2, 752, 492	93. 4	195, 280	6. 6	2, 947, 772
Oats	1, 092, 497	86. 9	164, 340	13. 1	1, 256, 837
Barley	169, 063	72. 7	63, 521	27. 3	232, 584
Sorghum	115, 937	91. 0	11, 472	9. 0	127, 409

[1] Seed requirements were subtracted from per acre yields.
[2] A residual, see text.

fundamental concepts underlying model E was not simple. First, the differences in regional prices should be a measure of the relevant transportation cost between regions. Second, the regional prices should represent the relative values of each grain in a competitive market.

Briefly, regional grain prices were estimated as follows: The average wheat-corn price relative for the period 1932–41 provided the basis for estimating the price of wheat.[9] First, the 1945–54 United States average price of corn was multiplied by the 1932–41 United States wheat-corn price relative. This product was then subtracted from the actual United States average price of wheat for the period 1945–54. Next, this difference was subtracted from each average State wheat price for the period 1945–54 (*30, 1956*). Finally, regional wheat prices were estimated by adjusting the calculated State average prices by the price gradients indicated on a wheat iso-price map. It was assumed that prices within each State were a linear function of distance. Regional corn prices were estimated with the aid of a corn iso-price map, by adjusting 1945–54 average State corn prices in a way similar to that used in adjusting State wheat prices. Individual prices for oats, barley, and sorghum were not estimated—these grains are converted to corn-equivalents for programing. Thus, in essence,

[9] Data indicate that for more recent periods the market wheat price has been maintained above the competitive level; for example, the price of wheat relative to corn has increased from 122 for the period 1931–42 (*30, 1944*) to 131 for the period 1945–54 (*30, 1956*).

the prices used for these three grains were the corn prices weighted by their respective feed values in terms of corn.

The estimated regional wheat and corn prices used for programing are presented in table 6.

The Programing Coefficients

The previous sections described the methods and problems involved in estimating for each region maximum acreages, normal yields, production costs, demand restraints, and corn and wheat prices. The

TABLE 6.—*Estimated normal prices per bushel for wheat and corn, by regions, 1954*

Region	Wheat	Corn	Region	Wheat	Corn	Region	Wheat	Corn
	Dollars	*Dollars*		*Dollars*	*Dollars*		*Dollars*	*Dollars*
1	1.88	1.66	36	1.85	1.51	71	1.88	1.50
2	1.86	1.68	37	1.85	1.51	72	1.85	1.51
3	1.91	1.66	38	1.87	1.50	73	1.85	1.52
4	1.90	1.65	39	1.87	1.51	74	1.84	1.54
5	1.92	1.68	40	1.87	1.51	75	1.85	1.50
6	1.92	1.60	41	1.86	1.52	76	1.85	1.51
7	1.96	1.68	42	1.85	1.56	77	1.84	1.55
8	1.96	1.68	43	1.83	1.54	78	1.85	1.50
9	1.94	1.62	44	1.88	1.52	79	1.84	1.53
10	1.93	1.62	45	1.88	1.50	80	1.84	1.54
11	1.94	1.62	46	1.90	1.46	81	1.85	1.48
12	1.93	1.62	47	1.92	1.40	82	1.85	1.48
13	1.93	1.67	48	1.91	1.38	83	1.85	1.48
14	1.92	1.69	49	1.95	1.40	84	1.85	1.50
15	------	1.66	50	1.95	1.38	85	1.86	1.49
16	1.90	1.66	51	1.94	1.36	86	1.86	1.49
17	1.91	1.66	52	1.94	1.48	87	1.87	1.50
18	1.92	1.68	53	1.94	1.46	88	1.87	1.50
19	1.83	1.63	54	1.92	1.36	89	1.79	1.60
20	1.92	1.66	55	1.89	1.45	90	1.74	1.65
21	1.87	1.60	56	1.92	1.40	91	1.79	1.60
22	1.87	1.60	57	1.93	1.37	92	1.74	1.64
23	1.90	1.62	58	1.89	1.45	93	1.76	1.58
24	1.89	1.61	59	1.92	1.46	94	1.82	1.56
25	1.88	1.55	60	1.87	1.50	95	1.83	1.57
26	1.88	1.60	61	1.76	1.58	96	1.83	1.58
27	1.88	1.58	62	1.79	1.57	97	1.81	1.54
28	1.86	1.51	63	1.86	1.47	98	1.72	1.80
29	1.86	1.55	64	1.86	1.49	99	1.73	1.88
30	1.86	1.54	65	1.87	1.50	100	1.85	1.79
31	1.83	1.49	66	1.88	1.51	101	1.86	1.83
32	1.85	1.51	67	1.87	1.51	102	1.88	1.85
33	1.87	1.52	68	1.86	1.51	103	1.95	1.89
34	1.88	1.54	69	1.86	1.51	104	1.95	1.89
35	1.86	1.52	70	1.86	1.49			

methods used in converting these data into coefficients used in the five analytical models are described here. The order of presentation used follows: First, the conversion of basic data into the matrix coefficients required for model A is described in some detail. The necessary modification in the coefficients or parameters to meet the conditions of the other four models is then set forth.

Model A

The acreage restraints—the maximum number of acres of land that can be used for all grain production in each region—are the sums of the individual grain acreages given in table 1. The demand restraints for the programed areas, that is, the quantities of food wheat and feed grain that must be produced within the system, are 677.5 million bushels of food wheat and 3,548.9 million bushels of feed grain. These acreage and production restraints are presented in table 7.

TABLE 7.—*Acreage restraints, by regions, and total production restraints (simplex A_0)*

Region	Acreage	Region	Acreage	Region	Acreage	Region	Acreage
	1,000 acres		*1,000 acres*		*1,000 acres*		*1,000 acres*
1	603	27	1,067	53	5,016	79	2,025
2	2,480	28	4,935	54	1,076	80	2,881
3	445	29	757	55	2,101	81	1,955
4	298	30	1,902	56	4,155	82	1,176
5	208	31	4,760	57	1,404	83	369
6	561	32	996	58	1,013	84	98
7	325	33	1,649	59	3,624	85	439
8	370	34	2,317	60	3,874	86	108
9	1,421	35	994	61	441	87	326
10	290	36	2,297	62	4,282	88	610
11	261	37	7,754	63	1,990	89	6,493
12	3,100	38	4,841	64	2,509	90	3,833
13	434	39	1,133	65	4,718	91	611
14	107	40	1,013	66	1,220	92	692
15	542	41	693	67	788	93	830
16	91	42	1,535	68	758	94	4,293
17	727	43	4,795	69	1,119	95	609
18	1,230	44	4,263	70	1,792	96	561
19	1,228	45	10,879	71	1,371	97	544
20	969	46	4,107	72	2,736	98	1,750
21	853	47	2,711	73	7,664	99	519
22	1,069	48	2,561	74	5,114	100	4,685
23	261	49	1,304	75	421	101	2,785
24	329	50	4,827	76	2,739	102	544
25	574	51	7,898	77	2,912	103	554
26	412	52	2,790	78	504	104	1,015

	1,000 bushels
Wheat	677,509
Feed grain	3,548,911

As stated previously, three grain-producing activities—food wheat, feed wheat, and a feed-grain rotation—were considered for each region in model A. The outputs or yields for food wheat are the yields shown in table 2. The outputs of feed wheat and feed grain are obtained by converting the yields to corn-equivalent bushels. The output of each feed-wheat activity was the corn-equivalent yield. But the output of each feed-grain activity, which consisted of corn, oats, barley, and sorghum, is obtained by summing the weighted corn-equivalent yields; the weights are ratios of the acreages of each grain shown in table 1 to the total acreage of the four feed grains in the region. The example below uses the data of region 1. No sorghum is produced in this region.

Grain	Yield per acre ×	Corn conversion factor ×	Rotation weight =	Weighted yield
Corn	45.6	1.000	0.386	17.6
Oats	39.0	.495	.565	10.9
Barley	30.0	.791	.049	1.2

Per acre output, feed-grain activity, region 1 29.7

The activity cost coefficients used for food wheat and feed wheat were the per acre wheat costs shown in table 4. However, the feed-grain activity cost was a weighted cost derived from the data in tables 1 and 4. Again, region 1 data were used to show the required steps.

Grain	Total per acre cost ×	Rotation weight =	Weighted cost
Corn	34.76	0.386	13.42
Oats	28.34	.565	16.01
Barley	28.64	.049	1.40

Feed-grain activity cost, per acre, region 1 30.83

The activity costs and outputs derived for model A are shown in table 8.

Model B

The structure of model B is the same as that for model A, except for the modification of cost coefficients to include land rent. The estimated regional land rents shown in table 2 were added to each respective activity cost presented in table 8.

Model C

For model C, the land restraints were modified, but the input–output coefficients were the same as in model A. In model C, each region

TABLE 8.—*Activity costs and yields (outputs) per acre, by regions, model A*

Region	Cost		Yield		
	Wheat	Feed grain	Food wheat	Feed wheat	Feed grain
	Dollars	*Dollars*	*Bushels*	*Bushels*	*Bushels*
1	29.23	30.83	26.9	30.1	29.7
2	28.08	30.45	21.3	23.9	39.3
3	29.86	29.34	18.1	20.3	43.2
4	28.14	31.47	18.4	20.6	43.9
5	24.36	29.31	21.2	23.8	35.7
6	25.25	31.90	16.2	18.2	35.7
7	32.35	37.67	19.3	21.6	26.8
8	30.17	30.97	18.3	20.5	24.5
9	28.35	34.90	17.7	19.9	28.1
10	22.79	29.96	17.8	19.9	20.4
11	27.24	31.42	16.5	18.5	18.1
12	23.37	25.12	16.6	18.6	15.7
13	22.70	25.01	16.5	18.5	16.7
14	26.46	29.23	16.1	18.1	17.6
15	------	26.49	------	------	14.8
16	23.36	34.59	22.8	25.6	20.2
17	23.73	29.57	20.4	22.9	15.2
18	25.42	29.09	19.6	21.9	21.0
19	22.87	28.22	15.7	17.6	19.0
20	25.84	28.04	14.9	16.7	25.4
21	22.60	23.84	18.0	20.2	24.8
22	24.25	29.88	17.1	19.2	34.0
23	26.68	28.27	16.6	18.6	32.0
24	28.04	29.93	15.8	17.7	33.7
25	25.93	32.62	17.4	19.5	48.5
26	29.64	32.07	23.0	25.8	43.2
27	30.28	31.32	26.0	29.1	38.6
28	25.72	29.90	24.1	27.1	47.3
29	26.25	29.66	19.0	21.3	40.0
30	20.68	20.69	19.1	21.5	38.3
31	23.70	25.51	24.3	27.3	46.8
32	20.45	23.79	27.0	30.2	43.6
33	28.11	27.24	26.6	29.9	33.8
34	30.45	29.97	27.6	30.9	30.7
35	21.85	25.43	20.6	23.1	24.2
36	21.57	24.58	27.3	30.6	38.3
37	20.37	22.08	25.2	28.2	46.0
38	18.52	17.49	27.1	30.3	47.8
39	20.65	19.80	18.8	21.0	34.4
40	18.74	21.20	19.4	21.7	31.1
41	20.06	21.88	21.3	23.9	30.2
42	20.79	20.05	19.7	22.0	20.0
43	19.86	20.73	22.7	25.4	36.6
44	16.59	19.21	15.5	17.4	36.0
45	14.74	16.43	14.7	16.5	37.1

TABLE 8.—*Activity costs and yields (outputs) per acre, by regions, model A*—Continued

Region	Cost		Yield		
	Wheat	Feed grain	Food wheat	Feed wheat	Feed grain
	Dollars	*Dollars*	*Bushels*	*Bushels*	*Bushels*
46	16.90	18.07	17.6	19.7	38.2
47	17.67	21.39	17.0	19.0	31.1
48	14.71	15.14	13.5	15.2	28.5
49	13.40	17.00	14.5	16.3	23.6
50	8.52	12.71	9.2	10.3	18.4
51	6.57	9.22	8.0	9.0	14.1
52	5.84	9.24	7.0	7.9	13.3
53	7.23	11.31	7.5	8.4	14.6
54	8.25	11.71	7.9	8.9	15.9
55	6.16	9.40	8.1	9.1	14.8
56	7.23	9.44	9.0	10.1	16.5
57	10.23	14.63	8.6	9.7	20.6
58	7.01	10.28	8.5	9.5	17.2
59	10.12	13.18	9.6	10.7	26.1
60	11.74	12.93	16.2	18.1	29.2
61	7.20	12.67	12.8	14.4	18.1
62	7.05	16.35	10.0	11.2	19.6
63	10.28	18.10	10.6	11.9	27.1
64	6.44	16.55	11.2	12.6	23.5
65	12.68	16.31	17.5	19.7	31.5
66	17.56	16.96	17.8	20.0	25.5
67	18.91	18.66	17.9	20.0	18.3
68	20.20	18.52	17.0	19.1	15.6
69	16.65	16.05	17.4	19.5	17.2
70	9.21	15.81	10.8	12.1	20.0
71	11.21	15.66	13.3	14.9	16.6
72	9.49	13.73	13.8	15.4	14.9
73	5.80	9.86	9.4	10.5	16.9
74	3.88	8.50	7.3	8.2	16.2
75	15.40	17.75	12.0	13.5	10.8
76	9.41	12.49	13.0	14.5	10.8
77	6.08	9.00	6.6	7.4	12.1
78	10.93	15.45	10.4	11.6	12.7
79	7.55	10.13	10.3	11.6	11.6
80	4.90	13.53	6.1	6.8	26.5
81	5.54	7.90	7.4	8.4	9.7
82	5.13	9.13	5.0	5.6	14.0
83	7.06	9.20	8.3	9.3	9.5
84	5.19	8.41	4.5	5.0	11.1
85	7.15	13.92	5.8	6.5	17.9
86	4.77	12.54	4.2	4.7	12.8
87	7.73	16.00	4.4	5.0	17.4
88	6.30	11.78	4.4	5.0	20.3
89	5.07	15.27	8.0	9.0	17.6
90	6.83	15.14	8.9	10.0	19.9

TABLE 8.—*Activity costs and yields (outputs) per acre, by regions, model A*—Continued

Region	Cost		Yield		
	Wheat	Feed grain	Food wheat	Feed wheat	Feed grain
	Dollars	*Dollars*	*Bushels*	*Bushels*	*Bushels*
91	6. 76	17. 75	6. 5	7. 3	12. 5
92	8. 88	22. 77	10. 2	11. 5	22. 4
93	8. 61	17. 52	8. 7	9. 7	15. 9
94	5. 50	10. 90	7. 0	7. 8	11. 8
95	7. 63	19. 57	5. 2	5. 8	22. 2
96	3. 61	12. 22	2. 5	2. 8	8. 6
97	4. 04	16. 28	1. 6	1. 8	10. 5
98	10. 56	21. 67	12. 9	14. 5	23. 4
99	10. 36	32. 03	9. 9	11. 1	35. 3
100	10. 95	16. 88	16. 9	18. 9	23. 4
101	6. 76	18. 14	12. 6	14. 2	24. 4
102	8. 65	37. 68	11. 6	13. 0	37. 3
103	10. 11	15. 43	12. 4	14. 0	18. 6
104	9. 21	19. 83	9. 8	11. 0	30. 2

has two acreage restraints, a wheat and a feed–grain restraint. Thus, for programing, the size of the matrix was nearly double that of model A, but the demand restraints were those of model A. The wheat restraint of model C is that shown under wheat in table 1, while the feed–grain restraint is the sum of the four feed–grain acreages shown in the table.

Model D

For model C, the number of activities per region was left unchanged, and the number of acreage restraints was doubled. For model D, the number of activities was doubled and the acreage restraints remained the same as those in model A. Each feed grain was considered as a separate activity in model D, and thus the possible activities in each region were food wheat, feed wheat, corn, oats, barley, and sorghum.

Table 2 provided the basic yield data for deriving the outputs for the six regional activities of model D. Outputs for feed wheat, oats, barley, and sorghum were obtained by weighting the yields presented in table 2 by their respective corn–equivalent conversion factors, that is, wheat=1.121, oats=0.495, barley=0.791, and sorghum=0.985. Activity outputs for food wheat and corn were the same as the yields given in table 2. Activity costs for model D are those presented in table 4. The same cost was used for the food wheat and feed wheat activities of each region.

Model E

The only difference between models E and A is in the objective function. The objective of model E is maximum total net returns while that of model A is minimum total cost. Hence, the structure and input–output coefficients are the same for the two models.

To obtain the net returns needed for model E, two steps were necessary: Activity gross returns were calculated by multiplying activity yields of table 8 by the relevant wheat and corn prices listed in table 6. The food wheat activities were multiplied by the corresponding regional wheat prices and the other two feed activities by the corresponding regional corn prices. Net returns were then obtained by subtracting the corresponding costs in table 8 from the computed gross returns.

Although the price levels for this profit-maximizing model are at 1954 levels, the resulting optimum program would be the same for other absolute price levels, so long as the relative differentials between regions remain the same as those used here.

Limitations of the Data

The objective in basic calculations was to derive normal inputs and outputs to reflect the relative competitive positions of the programing regions. Whether or not this objective was achieved is the chief limitation of the data. Necessarily, arbitrary methods were used in making some estimates. But many methods of estimation were examined before a specific method was decided upon. Also, when possible, the results of estimating methods were checked against available data. This check was made when particular data were available for some regions but not for others. The magnitude of the study necessitated that frequent compromise be made between using a particular estimator or spending excessive time searching for a "better" one. As no specific sampling method was used, it was not possible to choose between estimators by any known statistical criteria. It was necessary, therefore, to rely on judgment conditioned by time and budget.

Wide variation in input-output coefficients between farms within the programing regions are known to exist. The results of the study reported are conditioned accordingly. Certainly, some farmers in each region would produce under competitive market prices, even though the empirical results indicate that production of grains would be eliminated from a particular region. But emphasis in the study was on defining "broad" areas for resource adjustments in grain production, given certain demand requirements. Followup studies will examine the problem of within-region resource adjustments.

EMPIRICAL RESULTS

The solutions for the five economic models outlined earlier are presented in this section. The results are then compared on the basis of production patterns, acreages, and costs.

Model A

The producing regions, the acreages required for grain production, and the number of bushels of wheat and feed grain produced in each region specified by the model A solution are shown in table 9. Figure 3 shows the geographic locations of these regions.

TABLE 9.—*Producing regions, acreages utilized and production, model A solution*

Region	Acreage	Wheat	Feed grain [1]
	1,000 acres	*1,000 bushels*	*1,000 bushels*
2	[2] 92		3,600
3	445		19,189
4	298		13,075
25	574		27,833
26	412		17,770
28	4,935		233,287
29	757		30,303
30	1,902		72,903
31	4,760		222,916
32	996		43,444
36	2,297	30,121	45,623
37	7,754		356,616
38	4,841		231,170
39	1,133		39,025
40	1,013		31,522
41	693		20,970
43	4,795		175,338
44	4,263		153,258
45	10,879		403,933
46	4,107		157,062
47	2,711		84,314
48	2,561		73,085
49	1,304		30,795
50	4,827		89,054
51	7,898		111,446
52	2,790		37,225
53	5,016	37,722	
54	1,076		17,072
55	2,101		31,183
56	4,155		68,643
57	1,404		28,884
58	1,013		17,430
59	3,624		94,739
60	3,874		113,009
61	441	5,667	
62	4,282	42,692	
63	1,990		53,852
64	2,509	28,104	
65	4,718		148,795
66	1,220		31,068
69	1,119	19,469	
70	1,792	19,394	
71	1,371	18,213	
72	2,736	37,617	
73	7,664	72,121	

See footnotes at end of table.

TABLE 9.—*Producing regions, acreages utilized and production, model A solution*—Continued

Region	Acreage	Wheat	Feed grain [1]
	1,000 acres	*1,000 bushels*	*1,000 bushels*
74	5, 114	----------	82, 640
76	2, 739	35, 469	----------
77	2, 912	19, 301	----------
79	2, 025	20, 898	----------
80	2, 881	----------	76, 304
81	1, 955	14, 562	----------
82	1, 176	----------	16, 450
83	369	3, 063	----------
84	98	----------	1, 088
88	610	----------	12, 359
89	6, 493	52, 009	----------
90	3, 833	34, 035	----------
92	692	7, 086	----------
94	4, 293	29, 964	----------
98	1, 750	22, 569	----------
100	4, 685	79, 077	----------
101	2, 785	35, 147	----------
102	544	6, 316	----------
103	554	6, 895	----------
104	1, 015	----------	30, 643
Total	177, 664	677, 511	3, 548, 915

[1] Expressed in corn-equivalent bushels.
[2] Part of maximum acreage; see table 7.

Production of corn is specified primarily in the Corn Belt, and production of wheat is designated mainly in the Great Plains and the Pacific Northwest.[10] The regions in North Dakota, South Dakota, Kansas, and Texas, which are shown in the solution as producing feed grains, currently produce large quantities of wheat. But the production of feed grains specified by the model solution consists mainly of barley and oats in North Dakota and sorghum in Kansas and Texas. (See table 2, regions 50, 51, 52, 54, 74, and 80.) If wheat prices were to fall below their current levels, feed grains might replace wheat in these regions.

Subtracting the 65 producing regions shown in table 9 from the original total of 104 indicates that 39 regions are not required to fulfill the demand requirements specified for wheat and feed grains (757 million bushels of wheat and 3,877 million corn-equivalent bushels of feed grain) under model A. Figure 3 shows that a majority of these regions are in the South. The remaining regions not required for production are in northwestern New York, northeastern Ohio, southern Michigan, central Wisconsin, central Texas, south-central Montana, eastern Wyoming, southeastern Colorado, eastern New Mexico, north-central Utah, western Missouri, and eastern Kansas.

[10] In the discussions that follow, the term "wheat" is used to refer to food wheat. When production of feed wheat is discussed, it is so noted.

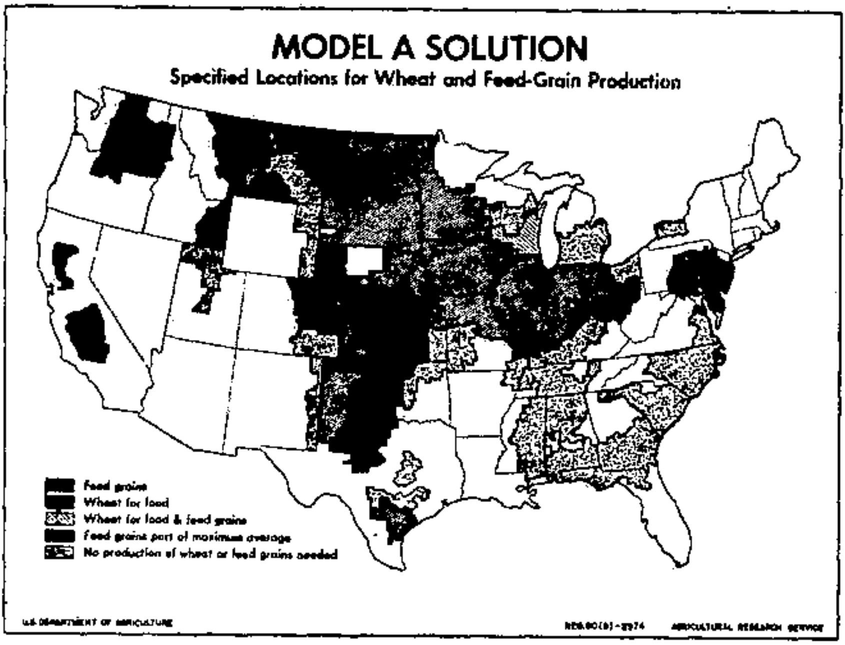

FIGURE 3

The number of acres involved in grain production within the 39 regions plus the unused acreages in region 2 (fig. 3) would be 31,471,000. Of greater interest than these acreages, perhaps, is their production potential. Given the production patterns of 1953 and the normal yields of 1954 (tables 1 and 2), these regions represent a production potential as follows:

	Million bushels
Wheat	142
Corn	453
Oats	165
Barley	18
Sorghum	10

These figures indicate the size of resource adjustments in grain production needed to balance production and consumption in terms of model A.

High production costs resulting from small farm units and relatively high per acre machinery inventories are the apparent reasons why grain production in northwestern New York, northeastern Ohio, and southern Michigan is not prescribed by the model A solution. In these areas, the high costs more than offset the high wheat yields as compared with the Great Plains. High costs also prevent the areas of the South from having a place in the solution. Even though in many instances, yields in the South are not as high as those in the Northeast, they are higher than yields in the Great Plains. While large per acre investment in farm machinery is a partial explanation for high production costs in the Northeast, the converse seems to be true for the Southeast, where considerable nonmechanical production methods are still used. In such southwestern areas as southern Colorado and eastern New Mexico, high yield variability and low average yields resulting from frequent crop failures apparently account for the absence of these areas in the solution to model A.

The grain price obtained by the dual solution to the production (minimum-cost) problem is the cost of producing a bushel of grain in the highest cost region in the solution set. If the highest cost region is marginal, the cost is "real." If the highest cost region is not marginal, the cost is an "opportunity cost." Specifically for model A, the price of feed grain, \$0.77, is due to region 2. Region 2 is a marginal region, in which \$0.77 is the cost of producing feed grain. But the price of wheat, \$0.97, is an opportunity cost and is due to wheat production in region 36. To explain: Given the \$0.77 price of feed grain and with the price of wheat at \$0.97, production of wheat and production of grain give the same net return (rent) per acre in region 36. These net returns can be calculated by multiplying the difference between price and cost per bushel by the yield; for example, 27.6 (\$0.97−\$0.79)=\$4.97 for wheat and 38.3 (\$0.77−\$0.64) =\$4.98 for corn.[11]

A similar computation shows that for marginal region 2 the imputed rent[12] is zero for feed grains and negative for wheat.

The imputed rents for each activity can be obtained by performing similar computations. The results of these computations show that only the regions in the final program have positive rents within the framework of the model, which includes no crops other than feed grains and wheat. Only imputed rents for the activities in the optimum set of model A are presented in table 10. The rents of the unused activities, which are due to either a wheat or a feed-grain activity in each region except region 36, are not shown. Table 9 indicates the specific activities that produce the rents listed in table 10. Estimated regional rents for grainland, as shown by table 3, are shown also in table 10 to permit comparisons. A region-by-region comparison of these rents shows that approximately three-fourths of the imputed rents are below the estimated rents.

Several reasons may account for these differences: (1) Some indirect costs, such as those of management, buildings, and general farm operation, were not included in the activity costs. If these costs had been included, the equilibrium grain prices would have been higher, which would cause the imputed rents to be higher. (2) Transportation costs were not included in the activity costs. The inclusion of transportation costs would reduce the imputed rents for regions shipping to distant markets. (3) Equilibrium grain prices are below the recent average prices of wheat and corn (*30*). Hence, in general, the estimated land rents are expected to be higher than the imputed rents. (4) Other factors, such as residential demand, productive activities other than grain crops, and institutions, are also a part of the total complex that influences land values.

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[11] These small differences are due to rounding.

[12] Hereafter, rents obtained by the dual solution are referred to as imputed rents to avoid confusion with the computed land rents given in table 3.

TABLE 10.—*Estimated and imputed rents per acre of grainland, by regions, model A solution*

Region	Estimated rent [1]	Imputed rent [2]	Region	Estimated rent [1]	Imputed rent [2]
	Dollars	*Dollars*		*Dollars*	*Dollars*
2	8.81	0	60	7.65	9.62
3	5.59	3.88	61	2.66	5.30
4	7.03	2.19			
25	7.12	4.85	62	3.71	2.62
26	5.38	1.29	63	4.20	2.70
			64	3.95	4.40
28	12.50	6.61	65	7.41	7.88
29	4.60	1.20	66	5.62	2.54
30	7.14	8.81			
31	11.99	10.77	69	5.07	.22
32	10.62	9.59	70	3.55	1.32
			71	5.22	1.76
36	10.30	4.98	72	7.07	3.88
37	14.70	13.33	73	4.21	3.32
38	18.70	19.10			
39	4.97	6.89	74	3.81	3.88
40	5.31	2.80	76	5.16	3.14
			77	3.75	.35
41	7.03	1.51	79	4.43	2.50
43	6.66	7.31	80	4.98	6.89
44	8.03	8.63			
45	13.01	12.25	81	3.68	1.73
46	9.55	11.47	82	4.07	1.68
			83	3.32	1.02
47	6.69	2.49	84	5.00	.11
48	6.46	6.85	88	5.40	3.85
49	2.92	1.18			
50	4.06	1.47	89	1.60	2.74
51	2.13	1.69	90	2.76	1.80
			92	1.51	1.05
52	1.69	1.07	94	2.88	1.27
53	1.59	0	98	4.08	1.97
54	2.12	.47			
55	1.28	2.08	100	6.14	5.44
56	2.23	3.30	101	4.26	5.46
			102	2.73	2.58
57	3.68	1.23	103	11.61	2.02
58	2.14	2.92	104	7.60	3.32
59	4.08	7.06			

[1] Estimates based on land values and interest and tax rates.
[2] Given by the dual solution to the minimum-cost problem.

The r^2 (the simple coefficient of determination) for the estimated rents and the imputed rents is 0.57. This fact indicates that, to a significant degree, land values in the programing regions are related to land productivity (yield) and the cost of producing grain.

MODEL B

The land charges added to other activity costs for model B are those shown in table 3. The level of land prices in the Great Plains and possibly in the Corn Belt is due largely to the demand for grain.

Hence, it is reasonable to consider the price of land as an endogenous variable in these areas. But in regions of the East, the South, and the west coast, such enterprises as cotton, dairy, fruits, and tobacco "compete" for the use of land. Given these two possibilities, however, the results of models A and B together might give a better indication of the grain-resource-adjustment problem than the results of either alone.

The producing regions, the acreages utilized, and the regional grain production specified by the model B solution are presented in table 11. The geographic locations of these regions are shown in figure 4. A comparison of figures 3 and 4 shows that inclusion of a land cost in the activity cost coefficients resulted in the following: Production of feed grains in regions 2, 36, 82, and 84 under model A is displaced by production of feed grains in regions 53 and 73 under model B. Wheat production in regions 53 and 73, together with wheat production in regions 77 and 103, under model A, is replaced by wheat production in regions 35, 36, 42, 91, and 93 under model B. No simple explanation can be given for these changes except that the changes provide for a minimum total production cost in terms of model B and the estimated land cost per bushel is relatively higher in the excluded regions 2, 41, 77, 82, 84, and 103.

When figures 3 and 4 are compared, it becomes obvious that the optimum regional pattern of grain production for model B differs only slightly from that for model A. The regions that go out of production—2, 41, 77, 82, 84, and 103—lie, respectively, in eastern Pennsylvania, northern New Jersey, southeastern Missouri, the panhandle of Oklahoma, western Texas, west-central Texas, and north-

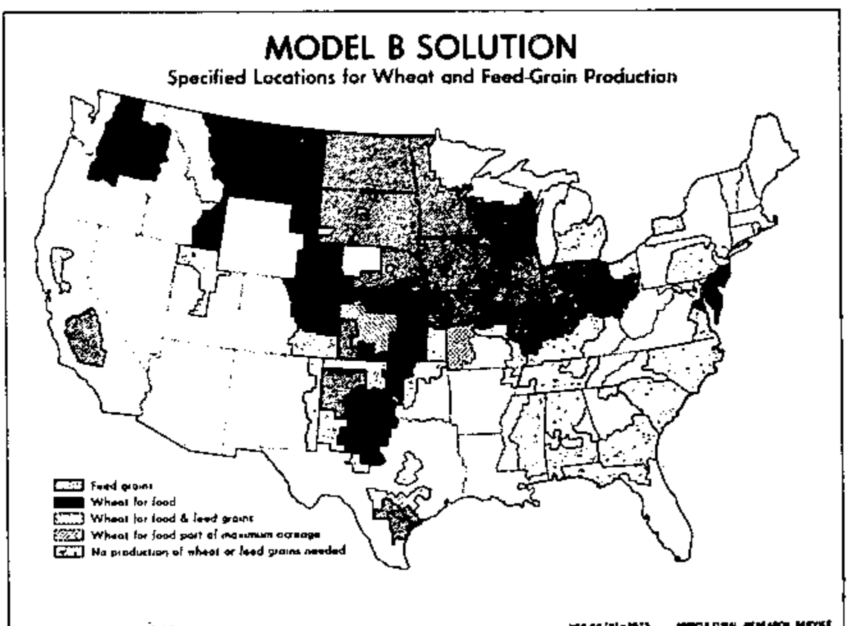

FIGURE 4

TABLE 11.—*Producing regions, acreages utilized and production, model B solution*

Region	Acreage	Wheat	Feed grain [1]
	1,000 acres	*1,000 bushels*	*1,000 bushels*
3	445		19,189
4	298		13,075
25	574		27,833
26	412		17,770
28	4,935		233,287
29	757		30,303
30	1,902		72,903
31	4,760		222,916
32	996		43,444
35	994	20,494	
36	2,297	62,619	
37	7,754		356,616
38	4,841		231,170
39	1,133		39,025
40	1,013		31,522
42	[2] 390	7,673	
43	4,795		175,339
44	4,263		153,258
45	10,879		403,933
46	4,107		157,062
47	2,711		84,314
48	2,561		73,085
49	1,304		30,795
50	4,827		89,054
51	7,898		111,446
52	2,790		37,225
53	5,016		73,438
54	1,076		17,072
55	2,101		31,183
56	4,155		68,643
57	1,404		28,884
58	1,013		17,430
59	3,624		94,739
60	3,874		113,009
61	441	5,667	
62	4,282	42,692	
63	1,990		53,852
64	2,509	28,104	
65	4,718		148,799
66	1,220		31,070
69	1,119	19,470	
70	1,792	19,394	
71	1,371	18,212	
72	2,736	37,617	
73	7,664	64,187	14,277

See footnotes at end of table.

TABLE 11.—*Producing regions, acreages utilized and production, model B solution*—Continued

Region	Acreage	Wheat	Feed grain [1]
	1,000 acres	*1,000 bushels*	*1,000 bushels*
74	5, 114		82, 645
76	2, 739	35, 469	
79	2, 025	20, 898	
80	2, 881		76, 305
81	1, 955	14, 561	
83	369	3, 063	
88	610		12, 359
89	6, 493	52, 008	
90	3, 833	34, 035	
91	611	3, 979	
92	692	7, 086	
93	830	7, 204	
94	4, 293	29, 969	
98	1, 750	22, 569	
100	4, 685	79, 077	
101	2, 785	35, 147	
102	544	6, 316	
104	1, 015		30, 643
Total	174, 965	677, 510	3, 548, 912

[1] Expressed in corn-equivalent bushels.
[2] Part of maximum grain acreage; see table 7.

central California. The regions that come into production—36, 42, 91, and 93—lie, respectively, in central Wisconsin, southwestern Missouri, southeastern Montana, and eastern Wyoming.

The total grainland in 41 entire regions and part of the grainland in region 42 are not needed to fulfill the requirements for food wheat and feed grains in the model B solution. In terms of 1954 yields and 1953 production patterns (tables 1 and 2), these regions represent a production potential as follows:

	Million bushels
Wheat	148
Corn	446
Oats	128
Barley	24
Sorghum	3

In these 42 regions, 34,651,000 acres would be unneeded. Thus, the grain production required would be concentrated on fewer acres than for model A. The use in the solution of regions of relatively higher wheat yields, especially regions 35, 36, and 42, explains this fact.

The model B dual (price) solution shows that the equilibrium prices for wheat and feed grain are $1.25 and $0.93, respectively. Compared with model A, the inclusion of land rent in the activity costs, therefore, has increased the prices of wheat and feed grain by $0.28 and $0.16 a bushel, respectively.

Imputed rents obtained by the dual solution are presented in table 12. No exact interpretation of these values can be given as estimated land rents were included in the activity costs. But the values might be interpreted as residuals or royalties accruing to the limited factor, land. The variance of the imputed rents, however, was reduced with the inclusion of a land charge. The respective variances of the imputed rents are 14.0 and 6.2 for models A and B. The reduction in variance would be expected, as in regions with yields high relative to cost, the higher net returns tend to be capitalized into higher land values. Hence, adding land costs to other production costs tends to make per bushel costs more nearly equal between regions.

Model C

For model C, the total acreage of grain in each region was divided into two parts or restraints. Separate restraints were used for wheat and feed grains. Because of the structure of the model, the acreage of land used to produce food wheat cannot exceed the 1953 wheat acreage in a region. However, land used to produce feed grains can equal the total grainland in a region, if feed wheat is designated for the wheatland and feed grain is specified for the feed-grain acreage.

The producing regions, the acreages utilized, and the production of food wheat, feed wheat, and feed grain specified by the model C solution are presented in table 13. The geographic locations of the producing regions are shown in figure 5. A comparison of tables 9 and 13 shows that more regions are specified for grain production for

TABLE 12.—*Imputed rents per acre of grainland, by regions, model B solution*

Region	Rent [1]	Region	Rent [1]	Region	Rent [1]
	Dollars		*Dollars*		*Dollars*
3	5.41	48	5.01	71	0.13
4	2.44	49	2.25	72	.69
25	5.60	50	.47	73	1.78
26	2.83	51	1.77	74	2.84
28	1.68	52	1.54	76	1.56
29	3.02	53	.81	79	.93
30	7.88	54	1.04	80	6.24
31	6.34	55	3.20	81	.08
32	6.34	56	3.72	83	0
35	.97	57	.94	88	1.73
36	2.18	58	3.71	89	3.37
37	6.23	59	7.20	90	1.51
38	8.38	60	6.58	91	.52
39	7.42	61	6.16	92	2.36
40	2.66	62	1.70	93	.26
42	0	63	3.12	94	.35
43	6.78	64	3.59	98	1.55
44	6.30	65	5.85	100	4.05
45	5.40	66	1.16	101	4.80
46	8.24	69	0	102	3.14
47	1.10	70	.75	104	.76

[1] Given by the dual solution to the minimum-cost problem.

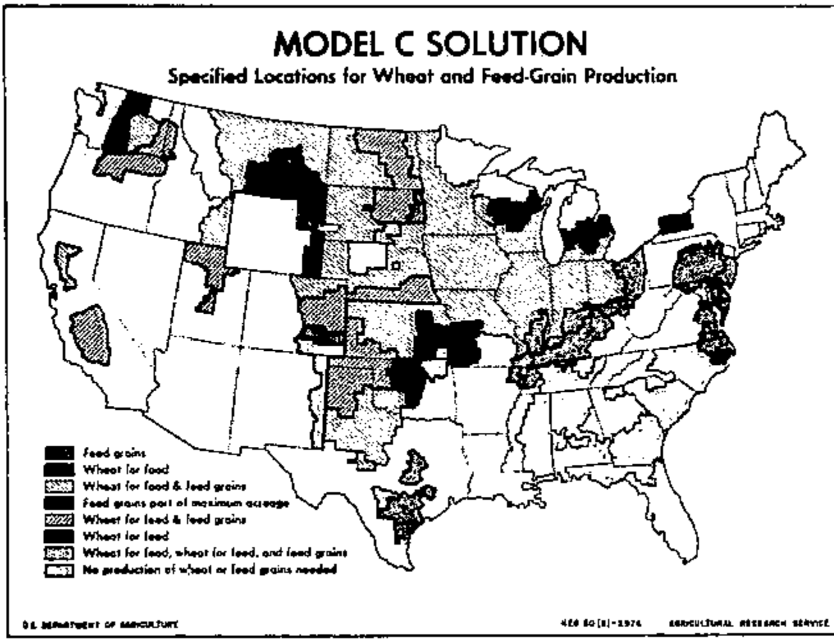

FIGURE 5

model C than for model A. These additional regions are 1, 5, 6, 16, 21, 22, 23, 24, 33, 34, 35, 42, 78, 85, 87, 91, and 97. But utilizing the additional regions does not mean that the total acreage needed to meet demand requirements is increased by the acreages available in these regions. The increase in acreage is less than this total because: (1) Only acreage of wheat or acreage of feed grain is used in 16 of the 17 regions listed above. (2) In 16 of the regions that were specified also by model A, either the wheat acreage or the feed-grain acreage is left idle; whereas for model A, total acreage was used in all except one region. Model C requires 9 million more acres than model A.

That additional acres are necessary to produce the wheat and feed grains needed is an expected result. In most regions, the wheat activity produces fewer bushels than the feed-grain activity. Fewer bushels of all grains can be produced in any one region when part of the grainland is restricted to wheat and part to feed grains. Consequently, a larger acreage is needed to meet the total demand or requirements restraints.

Under model C, 22,967,000 acres are not needed for grain production. In terms of 1953 production patterns and 1954 normal yields, this acreage represents a production potential of:

	Million bushels
Wheat	109
Corn	244
Oats	117
Barley	9
Sorghum	10

TABLE 13.—*Producing regions, acreages utilized, and regional wheat and feed grain production, model C solution*

Region	Acreage	Food wheat	Feed wheat [1]	Feed grain [1]
	1,000 acres	*1,000 bushels*	*1,000 bushels*	*1,000 bushels*
1	316	8,505		
2	1,622			63,807
3	355			15,340
4	194			8,543
5	149			5,322
6	548			19,572
16	(2)	8		
21	691			17,109
22	885			30,121
23	235			7,526
24	281			9,455
25	384			18,640
26	277			11,962
27	685			26,405
28	4,935	41,004		153,000
29	552			22,070
30	1,002	9,543		53,792
31	4,760	22,839		178,938
32	996	5,937		33,837
33	1,649	14,324		37,542
34	[3] 504			15,469
35	15	307		
36	2,297	1,128		86,326
37	7,754	4,677		348,088
38	4,841	18,341		198,805
39	827			28,480
40	1,013	8,936		17,174
41	693	5,369		13,341
42	443	8,705		
43	4,795	26,562		132,509
44	4,263	1,897		148,863
45	10,879	309		403,164
46	4,107	477		156,025
47	2,711	1,055		82,381
48	2,561	1,301		70,343
49	1,304	1,501		28,357
50	4,827	24,770		39,109
51	7,898		54,075	26,291
52	2,790	17,041		4,841
53	5,016	30,330		14,391
54	1,076		4,275	9,425
55	2,101	12,625		8,052
56	4,155		23,070	31,024
57	1,188			24,431
58	1,013	1,610	544	13,185

See footnotes at end of table.

TABLE 13.—*Producing regions, acreages utilized, and regional wheat and feed grain production, model C solution*—Continued

Region	Acreage	Food wheat	Feed wheat [1]	Feed grain [1]
	1,000 acres	*1,000 bushels*	*1,000 bushels*	*1,000 bushels*
59	3, 624	1, 375	----	90, 987
60	3, 874	4, 259	----	105, 335
61	441	3, 255	----	3, 392
62	4, 282	36, 364	----	12, 472
63	1, 990	5, 106	----	40, 563
64	2, 509	----	17, 059	27, 038
65	4, 718	----	31, 378	98, 460
66	1, 220	7, 086	----	20, 930
67	293	5, 241	----	----
69	616	10, 710	----	----
70	1, 792	11, 645	----	14, 316
71	1, 371	14, 118	----	5, 112
72	2, 736	32, 279	----	5, 771
73	7, 664	61, 781	----	18, 602
74	5, 114	----	36, 728	10, 351
76	2, 568	33, 259	----	----
77	2, 911	----	18, 495	5, 134
78	278	2, 879	----	----
79	2, 025	18, 200	----	3, 036
80	2, 881	----	12, 413	28, 091
81	1, 955	10, 001	----	5, 929
82	1, 176	376	----	15, 394
83	369	2, 300	----	877
84	49	----	----	549
85	402	----	----	7, 215
87	325	----	----	5, 653
88	605	----	----	12, 254
89	6, 493	48, 822	----	6, 990
90	3, 833	30, 955	----	6, 890
91	505	----	3, 688	----
92	620	6, 442	----	----
93	686	5, 952	----	----
94	4, 293	----	30, 415	4, 836
95	117	----	----	2, 596
98	1, 750	19, 843	----	4, 937
99	519	----	5, 420	1, 044
100	4, 685	----	82, 046	8, 216
101	2, 785	34, 782	----	705
102	506	----	6, 580	----
103	554	1, 287	----	8, 357
104	1, 015	----	1, 732	25, 888
Total	186, 645	677, 508	327, 927	3, 220, 984

[1] Expressed in corn-equivalent bushels.
[2] Less than 500 acres.
[3] Part of maximum feed grain acreage; see table 1.

These figures may well understate the grain potential that exists in United States agriculture.

The model C dual solution shows that the "equilibrium" prices of wheat and feed grains are $1.10 and $0.98, respectively. Compared with model A, the equilibrium price of wheat was increased by $0.13 and that of feed grains by $0.21, when wheat and feed grains were restricted to their respective 1953 base acreage. The imputed rents for land are presented in table 14. But instead of one rent for each region as was the case for model A, two rents for some regions are derived by the model C dual solution, one for land used to produce wheat and one for feed-grain land. Two rents for one region means that all acreages of wheat and feed grain are utilized. Underutilized land restraints have no rent under the empirical method used.

The data in table 14 show that in many regions the imputed rent from production of feed grains is higher than the estimated rent. But the imputed rents for wheat production are usually less than the estimated rents in the Corn Belt and other regions east of the Mississippi River. Usually, imputed rents are higher than estimated rents even when the former are weighted by their respective acreages. The average imputed rent, when weighted, is $6.42; the average estimated rent is $5.57. The r^2 for weighted imputed rents and estimated rents is 0.49, a smaller value than that for model A.

More specific analysis of land-use patterns and soil-productivity classes is needed in deciding whether model A or model C provides more meaningful results. But an inventory of regional land resources would probably reveal that the land-use pattern specified by model A is at least feasible in terms of individual farms. Furthermore, if the price of wheat were lowered relative to the price of feed grains, wheat production east of the Mississippi might decline greatly and barley might replace wheat in some parts of the Northern Plains.

Model D

The producing regions, the acreages utilized, and the regional grain production obtained as a model D solution are presented in table 15. Figure 6 shows the geographic locations of these regions and the grains produced in each. This model supposes a technical development that may prove possible but which is not yet in widespread use. As all grains are "independent" in this problem, it is not surprising that, in general, the solution indicates that corn should be concentrated in the western part of the Corn Belt and wheat in the Great Plains and the Pacific Northwest. Also, production of sorghum is specified in the panhandle of Texas, southeastern Texas, and south-central California. But it is surprising that no grain production is designated for the Red River Valley or for southern and southwestern North Dakota. No grain production in the panhandle of Oklahoma was specified in the model B solution also. Apparent high yield variability and relatively low average yields resulting from frequent crop failures explain the latter phenomenon. Production of corn in Ohio, the eastern part of Pennsylvania, and the programing areas of New Jersey, Delaware, and Maryland is not specified in this model because of the relatively high cost of production in these areas.

TABLE 14.—*Estimated and imputed rents per acre of wheat and feed-grain land, by regions, model C solution*

Region	Estimated rent [1]	Imputed rent for— [2]	
		Wheatland	Feed-grain land
	Dollars	*Dollars*	*Dollars*
1	7.37	0.26	----------
2	8.81	----------	8.26
3	5.59	----------	12.95
4	7.03	----------	11.42
5	5.91	----------	5.71
6	4.58	----------	3.21
16	6.48	1.81	----------
21	5.41	----------	.50
22	3.27	----------	3.40
23	4.60	----------	3.20
24	6.58	----------	3.03
25	7.12	----------	15.03
26	5.38	----------	10.36
27	9.14	----------	6.55
28	12.50	.70	16.54
29	4.60	----------	9.60
30	7.14	.37	16.87
31	11.99	3.14	20.61
32	10.62	9.14	18.75
33	9.97	1.04	5.74
34	8.46	----------	0
35	3.33	.81	----------
36	10.30	8.43	13.01
37	14.70	7.29	23.00
38	18.70	11.34	29.13
39	4.97	----------	14.12
40	5.31	2.51	9.34
41	7.03	3.39	7.86
42	3.77	.77	----------
43	6.66	4.97	14.99
44	8.03	.45	16.18
45	13.01	1.46	20.05
46	9.55	2.45	19.50
47	6.69	1.00	9.02
48	6.46	.12	12.84
49	2.92	2.60	6.14
50	4.06	1.55	5.35
51	2.13	2.24	4.66
52	1.69	1.89	3.87
53	1.59	1.05	3.07
54	2.12	.44	3.81
55	1.28	2.75	5.19
56	2.23	2.74	6.77
57	3.68	----------	5.55
58	2.14	2.29	6.54

See footnotes at end of table.

TABLE 14.—*Estimated and imputed rents per acre of wheat and feed-grain land, by regions, model C solution*—Continued

Region	Estimated rent [1]	Imputed rent for— [2]	
		Wheatland	Feed-grain land
	Dollars	*Dollars*	*Dollars*
59	4.08	0.43	12.55
60	7.65	5.97	15.75
61	2.66	6.92	5.06
62	3.71	3.88	2.95
63	4.20	1.37	8.39
64	3.95	5.90	6.58
65	7.41	6.68	14.51
66	5.62	1.94	7.90
67	3.84	.70	----------
69	5.07	2.42	----------
70	3.55	2.70	3.80
71	5.22	3.44	.66
72	7.07	5.63	.89
73	4.21	4.53	6.77
74	3.81	4.19	7.27
76	5.16	4.78	----------
77	3.75	1.19	2.77
78	4.65	.41	----------
79	4.43	3.82	1.28
80	4.98	1.77	12.45
81	3.68	2.68	1.55
82	4.07	.34	4.62
83	3.32	2.07	.10
84	5.00	----------	2.45
85	8.22	----------	3.59
87	5.36	----------	1.05
88	5.40	----------	8.11
89	1.60	3.76	1.93
90	2.76	2.92	4.37
91	.82	.37	----------
92	1.51	2.35	----------
93	1.96	.95	----------
94	2.88	2.19	.71
95	2.40	----------	2.22
98	4.08	3.60	1.17
99	3.77	.44	2.47
100	6.14	7.57	6.09
101	4.26	7.06	5.86
102	2.73	4.17	----------
103	11.61	5.60	2.78
104	7.60	1.54	9.66

[1] Estimates based on land values and interest and tax rates.
[2] Given by the dual solution to the minimum-cost problem.

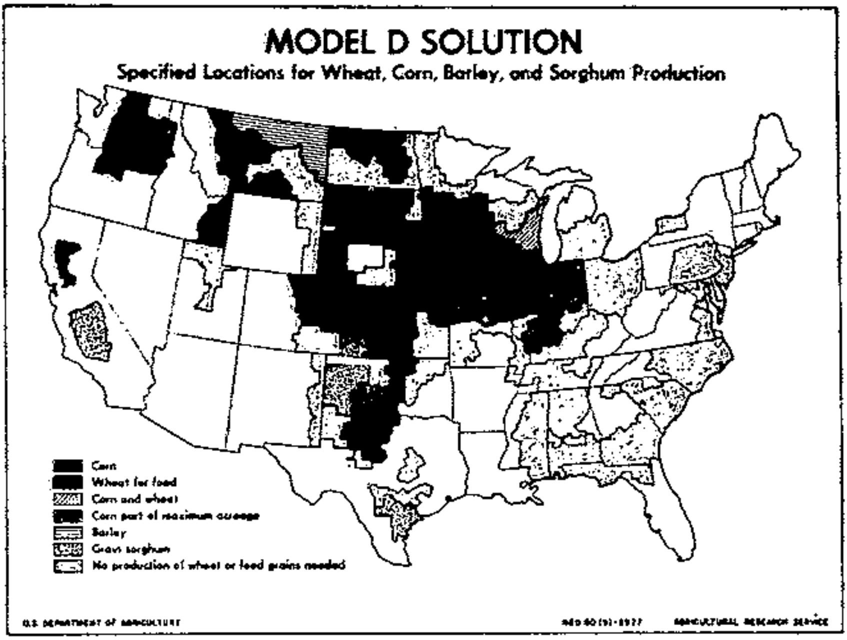

FIGURE 6

TABLE 15.—*Producing regions, acreages utilized and production, model D solution*

Region	Acreage	Wheat	Corn	Barley [1]	Sorghum [1]
	1,000 acres	*1,000 bushels*	*1,000 bushels*	*1,000 bushels*	*1,000 bushels*
30	1, 902	—	75, 600	—	—
31	4, 760	—	264, 562	—	—
32	996	—	55, 826	—	—
36	2, 297	21, 472	88, 528	—	—
37	7, 754	—	464, 324	—	—
38	4, 841	—	275, 705	—	—
39	1, 133	—	40, 905	—	—
43	4, 795	—	205, 113	—	—
44	4, 263	—	196, 652	—	—
45	10, 879	—	545, 036	—	—
46	4, 107	—	210, 991	—	—
47	2, 711	—	129, 180	—	—
48	2, 561	—	101, 049	—	—
51	7, 898	63, 108	—	—	—
52	2, 790	19, 589	—	—	—
55	2, 101	17, 020	—	—	—
56	4, 155	—	92, 416	—	—
58	1, 013	—	21, 897	—	—
59	3, 624	—	132, 320	—	—
60	3, 874	—	150, 826	—	—

See footnotes at end of table.

TABLE 15.—*Producing regions, acreages utilized and production, model D solution*—Continued

Region	Acreage	Wheat	Corn	Barley [1]	Sorghum [1]
	1,000 acres	*1,000 bushels*	*1,000 bushels*	*1,000 bushels*	*1,000 bushels*
61	441	5,667			
62	4,282	42,692			
64	2,509	28,104			
65	4,718		174,700		
66	[2] 923		29,115		
70	1,792	19,394			
71	1,371	18,212			
72	2,735	37,617			
73	7,664	72,120			
74	5,114	37,436			
76	2,739	35,469			
79	2,025	20,898			
80	2,881				78,148
81	1,955	14,561			
83	369	3,063			
88	610				14,176
89	6,493			151,806	
90	3,833	34,035			
92	692	7,086			
94	4,293	29,964			
98	1,750	22,569			
100	4,685	79,077			
101	2,785	35,147			
102	544	6,316			
103	554	6,896			
104	1,015				49,954
Total	147,226	677,512	3,254,745	151,806	142,278

[1] Expressed in corn-equivalent bushels.
[2] Part of maximum grain acreage; see table 7.

Fifty-eight entire regions and part of region 66 are not needed for grain production under model D. These 59 regions would "release" 62,392,000 acres of grainland. Furthermore, these 59 regions represent a possible grain production as follows:

	Million bushels
Wheat	308
Corn	780
Oats	306
Barley	62
Sorghum	35

These figures are based on acreages and yields given in tables 1 and 2.

The significance of model D is that the quantity of resources used for production of wheat and feed grains could be reduced considerably if techniques could be devised to reduce the need for including low-yielding small grains in corn rotations.

The price solution for model D shows that the equilibrium prices for feed grain and wheat are $0.53 and $0.90, respectively. The regional imputed rents are shown in table 16. The estimated land rents shown in table 3 are presented also in table 16 to permit comparisons. For only five regions—59, 60, 61, 89, and 101—are the imputed rents higher than the estimated rents. The fundamental cause of the low imputed rents is the small difference in the production costs of activities in the model D solution. The r^2 for these estimated rents and the imputed rents is 0.59.

Model E

Only the results that show the relative competitive positions of the programing regions in terms of production cost, given various technical assumptions, have been presented so far. Nothing was incorporated in the other four models to show how the production location relative to the market affects the competitive positions of the regions. Therefore, model E, for which estimated regional prices for grains and the objective of maximum profit were used, was formulated to determine how regional price differentials affect production location when demands are fixed. If prices of wheat and those of feed grains differ only in transportation costs, it can be shown that the model E solution will be identical with a total production and transportation cost model.

Table 16.—*Estimated and imputed rents per acre of grainland by regions, model D solution*

Region	Estimated rent [1]	Imputed rent [2]	Region	Estimated rent [1]	Imputed rent [2]
	Dollars	*Dollars*		*Dollars*	*Dollars*
30	7.14	1.99	65	7.41	3.70
31	11.99	4.45	66	5.62	0
32	10.62	5.60	70	3.55	.55
36	10.30	3.02	71	5.22	.81
37	14.70	10.18	72	7.07	2.90
38	18.70	13.67	73	4.21	2.64
39	4.97	.36	74	3.81	2.72
43	6.66	2.57	76	5.16	2.22
44	8.03	4.61	79	4.43	1.77
45	13.01	9.02	80	4.98	1.63
46	9.55	7.71	81	3.68	1.20
47	6.69	1.91	83	3.32	.42
48	6.46	3.16	88	5.40	2.79
51	2.13	.65	89	1.60	4.21
52	1.69	.50	90	2.76	1.16
55	1.28	1.14	92	1.51	.32
56	2.23	1.11	94	2.88	.78
58	2.14	.86	98	2.40	1.04
59	4.08	4.38	100	6.14	4.24
60	7.65	7.79	101	4.26	4.56
61	2.66	4.38	102	2.73	1.75
62	3.71	1.90	103	11.61	1.13
64	3.95	3.60	104	7.60	6.40

[1] Estimates based on land values and interest and tax rates.
[2] Given by the dual solution to the minimum-cost problem.

The producing regions, the acreages used, and the regional production of wheat and feed grains specified by the model E solution are shown in table 17. The geographic locations of these producing regions are shown in figure 7.

Comparison of tables 9 and 17, or figures 3 and 7, reveals that the maximum-profit solution differs significantly from the minimum-cost solution in terms of regional production patterns.[13] The major differences are: (1) Feed grains are specified in regions 5, 23, and 99 in the model E solution. No feed grains are specified in these regions by the model A solution. (2) Wheat replaces feed grains in regions 36, 47, 49, 50, 51, 52, 54, 55, and 56. (3) Wheat is replaced by feed grains in regions 77 and 90. (4) Wheat produced is earmarked for feed rather than for food in regions 61, 62, 89, 92, 98, 100, 101, 102, and 103. (5) Feed wheat is specified for parts of Nebraska, Montana, Idaho, Washington, Oregon, and California.

High wheat prices relative to corn prices in regions 36, 47, 49, 50, 51, 52, 54, and 55 account for the shifts to wheat in these regions. Apparently, the high wheat prices in these regions, which are in Wisconsin, Minnesota, North Dakota, and South Dakota, are due to the nearness of the regions to the points of effective demand—the milling centers and the Great Lakes. Also, these prices reflect the

[13] The sole difference between models A and E is in the objective criteria of the models. The objective for model A is minimum total cost, while the objective for model E is maximum total profit, given regional prices. This is the reason for making the comparisons that follow.

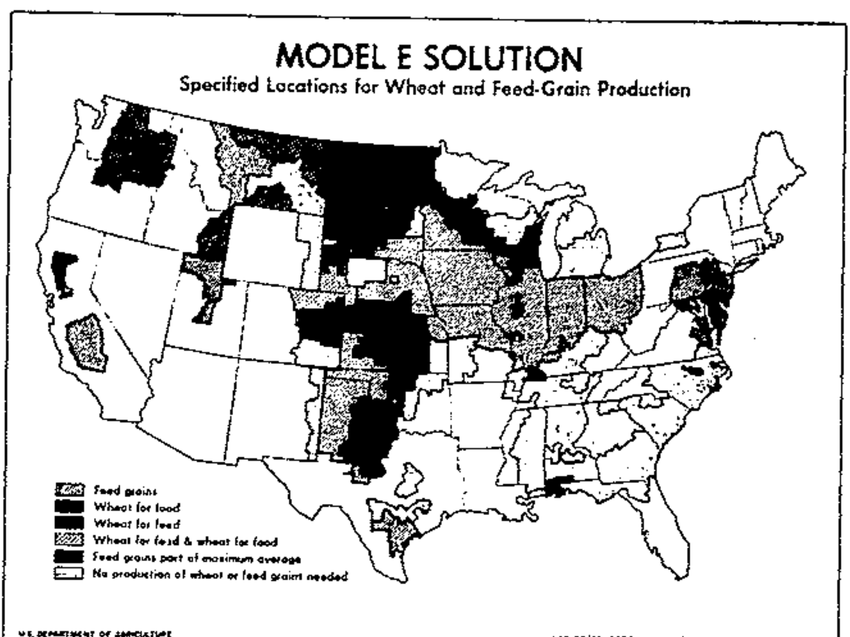

FIGURE 7

TABLE 17.—*Producing regions, acreages utilized and production, model E solution*

Region	Acreage	Food wheat	Feed wheat [1]	Feed grains [1]
	1,000 acres	*1,000 bushels*	*1,000 bushels*	*1,000 bushels*
2	2, 480			97, 567
3	445			19, 189
4	298			13, 075
5	208			7, 434
16	91	2, 087		
23	[2] 231			7, 402
25	574			27, 833
26	411			17, 770
27	1, 067			41, 137
28	4, 935			233, 287
29	757			30, 303
30	1, 902			72, 903
31	4, 760			222, 916
32	996			43, 444
36	2, 297	62, 620		
37	7, 754			356, 616
38	4, 841			231, 170
39	1, 133			39, 026
40	1, 013			31, 522
41	693			20, 970
43	4, 795			175, 339
44	4, 263			153, 258
45	10, 879			403, 933
46	4, 107			157, 062
47	2, 711	46, 006		
48	2, 561			73, 085
49	1, 304	18, 955		
50	4, 827	44, 165		
51	7, 898	63, 108		
52	2, 790	19, 589		
53	5, 016	37, 722		
54	1, 076	8, 509		
55	2, 101	17, 018		
56	4, 155	37, 519		
58	1, 013			17, 430
59	3, 624			94, 739
60	3, 874			113, 009
61	441		6, 351	
62	4, 282	21, 340	23, 922	
63	1, 990			53, 854
64	2, 509	28, 104		
65	4, 718			148, 802
66	1, 220			31, 069
69	1, 119	19, 470		
70	1, 792	19, 394		

See footnotes at end of table.

TABLE 17.—*Producing regions, acreages utilized and production, model E solution*—Continued

Region	Acreage	Food wheat	Feed wheat [1]	Feed grains [1]
	1,000 acres	*1,000 bushels*	*1,000 bushels*	*1,000 bushels*
71	1, 371	18, 212		
72	2, 736	37, 617		
73	7, 664	72, 121		
74	5, 114			82, 649
76	2, 739	35, 470		
77	2, 912			35, 114
79	2, 025	20, 898		
80	2, 881			76, 302
81	1, 955	14, 561		
82	1, 176			16, 449
83	369	3, 063		
84	98			1, 088
88	610			12, 359
89	6, 493		58, 307	
90	3, 833			76, 116
92	692		7, 944	
94	4, 293	29, 967		
98	1, 750		25, 300	
99	519			18, 315
100	4, 685		88, 681	
101	2, 785		39, 405	
102	544		7, 083	
103	554		7, 732	
104	1, 015			30, 643
Total	180, 764	677, 515	264, 725	3, 284, 179

[1] Expressed in corn-equivalent bushels.
[2] Part of maximum grain acreage; see table 7.

premiums paid for hard red spring and durum wheats, which are produced in several of these States. The specified wheat for feed in the western regions—61, 62, 89, 92, 98, 100, 101, 102, and 103—can be explained by the relatively high corn prices in these regions. The estimated normal price of corn is highest in Idaho, where it is higher than the price of wheat.

Although the locational pattern of wheat and feed grain production specified by the model E solution differs from that of model A, comparison of figures 2 and 7 shows that most of the same regions are specified in both solutions. Only five regions specified by the model E solution are not designated under model A. Conversely, only one region in the model E solution is not in the model A solution. Hence, four more regions are required to fulfill the requirements for wheat and feed grains. Aside from the degree of similarity of the models A and E solutions, the number of regions specified by the solutions is incidental to the study. The important thing is the location of the regions in relation to the adjustment problem.

Because of the similarity between the model A and the model E solutions, only the "new" producing regions are pointed out. The five "additional" regions required for production by the model E solution are in eastern Virginia, northeastern Ohio, western Kentucky, southern Alabama, and north-central Utah. The one region in the model A solution that is not specified by the model E solution is in northeastern South Dakota.

Thirty-five entire regions and part of region 23 are not required to fulfill the wheat and feed-grain requirements in terms of model E. Figure 7 shows the geographic locations of these regions, which represent about 29 million grain acres. Moreover, in terms of 1953 acreages and 1954 normal yields (see tables 1 and 2), these acres represent grain potentials as follows:

	Million bushels
Wheat	109
Corn	384
Oats	157
Barley	13
Sorghum	10

The equilibrium or shadow prices also were obtained by the dual solution to the maximum-profit problem; however, the interpretation of these prices differs from that for the minimum-cost problem. Specifically, the model E dual solution shows that the prices for wheat and feed grain are $0.86 and $0.74 per bushel, respectively. If from the estimated regional prices, $0.86 is subtracted from those for wheat and $0.74 from those for corn (table 6), the per acre net returns computed for each activity in the model E solution (in which net return equals the price minus the cost per bushel multiplied by the yield) are equal to the imputed rents derived by the dual solution.

Within the structure of model E, these shadow prices for wheat and feed grains can be interpreted as per bushel royalties. Specifically, if the price levels for wheat and feed grain were reduced by $0.86 and $0.74, respectively, we would expect the specified outputs to be produced in a competitive situation. Why is this so? It is because the marginal cost would not exceed the price in any producing region.

The feed-grain price of $0.74 is equal to the per bushel net return for feed grain in region 23. Thus, if $0.74 is subtracted from $1.62 (the price of corn in region 23), the difference is equal to the production cost per bushel, which in this region is $0.88. Hence, in region 23, the imputed rent is zero. This zero rent is analogous to the zero imputed rent for region 2 in the model A solution. But the price of $0.86 for wheat is an opportunity-cost price. This price results because both food wheat and feed wheat are specified for region 62. If $0.86 is subtracted from the estimated wheat price, $1.79, for region 62, and $0.74 is subtracted from the estimated corn price, $1.57, for this region, and if these net prices are used to compute net returns, these net returns—imputed rents—per acre for the activities are equal. This equal rent for two activities in region 62 is analogous to the situation for region 36 in the model A solution.

A regional comparison of the two types of rents given in table 18 shows that the imputed rents are higher than the estimated rents for more than a fourth of the regions. The coefficient of determination

TABLE 18.—*Estimated and imputed rents per acre of grainland, by regions, model E solution*

Region	Estimated rent [1]	Imputed rent [2]	Region	Estimated rent [1]	Imputed rent [2]
	Dollars	*Dollars*		*Dollars*	*Dollars*
2	8.81	6.69	59	4.08	5.75
3	5.50	10.36	60	7.65	9.33
4	7.03	8.35	61	2.66	4.89
5	5.91	4.28	62	3.71	2.23
16	6.48	.55	63	4.20	.36
23	4.60	0	64	3.95	4.75
25	7.12	6.79	65	7.41	7.57
26	5.38	5.18	66	5.62	2.54
27	9.14	1.16	69	5.07	.77
28	12.50	6.62	70	3.55	1.67
29	4.60	2.80	71	5.22	2.45
30	7.14	9.07	72	7.07	4.18
31	11.99	9.83	73	4.21	3.52
32	10.62	9.59	74	3.81	4.36
36	10.30	5.57	76	5.16	3.42
37	14.70	13.34	77	3.75	.43
38	18.70	18.62	79	4.43	2.62
39	4.97	6.89	80	4.98	7.68
40	5.31	2.80	81	3.68	1.89
41	7.03	1.81	82	4.07	1.26
43	6.66	8.41	83	3.32	1.20
44	8.03	8.99	84	5.00	.10
45	13.01	11.88	88	5.40	3.65
46	9.55	9.56	89	1.60	2.69
47	6.60	.41	90	2.76	2.98
48	6.46	3.14	92	1.51	1.49
49	2.92	2.53	94	2.88	1.22
50	4.06	1.50	98	4.08	4.77
51	2.13	2.11	99	3.77	8.12
52	1.69	1.78	100	6.14	8.90
53	1.59	.93	101	4.26	8.63
54	2.12	.19	102	2.73	5.86
55	1.28	2.22	103	11.61	6.00
56	2.23	2.39	104	7.60	14.79
58	2.14	1.73			

[1] Estimates based on land values and interest and tax rates.
[2] Given by the dual solution to the minimum-cost problem.

(r^2) between these rents is 0.49. Aside from errors of measurement and transportation costs, the possible reasons why the relationship is closer to one (1.0) outlined in the discussion of model A apply here also.

As noted above, model E represents an attempt to specify the minimum-cost location of wheat and feed-grain production when transportation costs are added to the activity production costs. It was assumed that regional price differentials were adequate to cover the transportation costs existing in the market, and that the programed quantities would be absorbed in the regional markets at the estimated prices. Further analysis is needed to determine whether these assumptions are realistic.

Some Comparisons of Model Results

That there is a high degree of similarity between the results of the five models is evident when figures 3 through 7 are compared. Moreover, the evident differences are less when comparisons are made for the regions than when comparisons are made to denote differences in particular grains specified for each region. This former comparison indicates that the similarity is even greater for models A, B, and E than for all five models. These three models can be taken as the more realistic of the five. It is reasonable, therefore, to look more closely at their results.

Production Regions

There is unanimous agreement in the solutions of the three models that grain production of 58 specified regions would be needed. The solutions also agree that grain production of 33 specified regions would not be needed. There is disagreement for only 16 regions. Two solutions agree in showing that grain production of 7 of the 16 is needed, and two that production of the remaining 9 regions is not needed. The geographic locations of the regions for which there is agreement or disagreement, together with the nature of the agreement, are shown in figure 8.

Given the assumptions of this study, it can be said with some certainty that the 33 regions as shown in figure 8 are at a comparative disadvantage in grain production. It might be possible, however, to improve the competitive position of a number of these regions if farms were reorganized and new techniques followed. Further study is needed to ascertain the potentialities of farm reorganization and improved techniques in these higher cost regions.

Acreage and Cost Comparisons

Estimates of total cost, average cost per bushel, total unused acreage, and total acreage needed to produce the specified wheat and feed grain demand requirements for the five model solutions are presented in table 19. The similarity of the solutions for models A, B, and E noted above, in specification of production location, is also evident in the acreage and cost data presented in table 19.

Specification of the number of acres required for production of grain crops was incidental to the study. The main quantitative objective was to determine the relative efficiency of selected regions in producing grain. Hence, only a brief attempt is made to explain the differences in acreage (table 19) for the model solutions. The simplest explanation for these differences is this. Average grain yields for the set of activities used in a model solution are either higher or lower because of the definition of crop activities than the set used in another model. To be more specific, the model B solu-

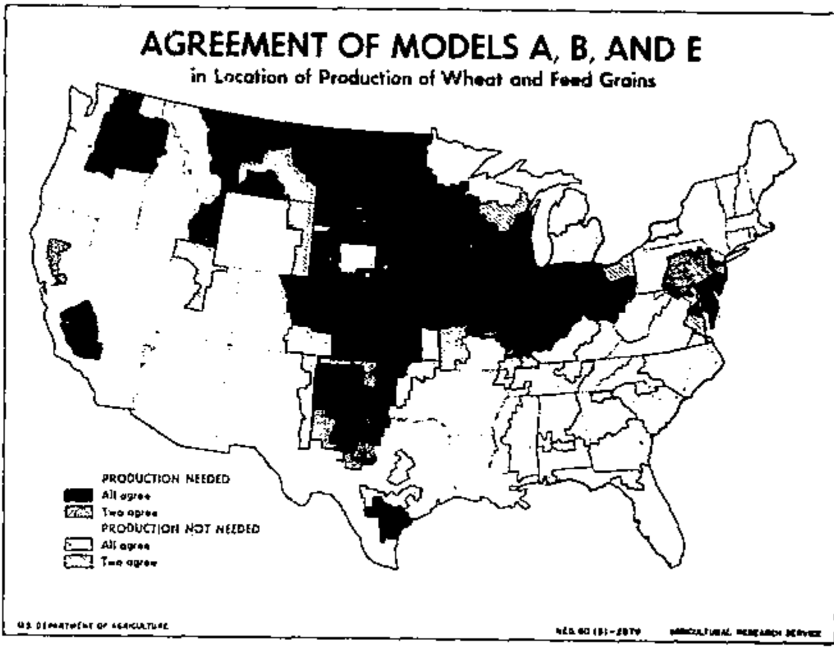

FIGURE 8

tion requires fewer wheat acres, 58,357 million, than A, 63,661 million, to produce 677.5 million bushels of food wheat because regions (those with wheat activities) with higher average yields were "selected" by model B.

In total, these higher average yields are due mainly to regions 35 and 36 in Wisconsin, which replace low-yielding acres in region 79, the panhandle of Oklahoma, and region 53, North Dakota. The general reason for the substitution of these producing regions is: Given the addition of estimated annual land rents to the activity costs for model B, the activities and their cost levels selected for production of wheat and feed grain are the minimum total cost set for production of both wheat and feed grains, not for wheat or feed grains individually.

Of all possible activities, a set of activities with their maximum levels that would produce the required quantities of wheat only at lower total cost than the set specified in the solution for either model A or model B could be determined without programing. This could be done, first by arraying the per bushel production costs for the wheat activities from lowest to highest, then "filling" the wheat requirements from the lowest cost set. But if this procedure were used, the grainland in certain regions specified for production of feed grains in a particular programing solution would be used to produce wheat instead. Consequently, feed grains would need to be produced in regions other than those allocated to wheat. If this shift were made, however, the total cost of producing the required quantities of wheat and feed grain would be higher than the total cost obtained by programing. For model E, for instance, the objective of maximum profit

TABLE 19.—*Summary of specified data for model solutions*

Model	Wheat and feed grain acreage			Direct costs			
				Total [2]		Average per bushel	
	Food wheat	Feed grain	Unused [1]	Food wheat	Feed grain	Food wheat [3]	Feed grain [4]
	1,000 acres	*1,000 acres*	*1,000 acres*	*1,000 dollars*	*1,000 dollars*	*Dollars*	*Dollars*
A	63, 661	114, 003	31, 951	491, 239	1, 921, 483	0. 73	0. 54
B	58, 357	116, 607	34, 651	510, 991	1, 906, 906	. 75	. 54
C	57, 562	[5] 129, 089	22, 964	547, 839	2, 037, 064	. 81	. 57
D	65, 712	81, 511	62, 392	479, 764	1, 601, 875	. 71	. 45
E	67, 121	[5] 113, 639	28, 855	544, 775	1, 935, 672	. 80	. 55

[1] The estimated total grain acreage of all regions is 209,615,000 acres (table 2).
[2] These costs include labor, power and machinery, chemicals, and miscellaneous items; see text for definitions.
[3] Total wheat production is 677.5 million bushels.
[4] Total feed-grain production is 3,548.9 million corn-equivalent bushels.
[5] Feed wheat acreage is included in this number.

would be substituted for that of minimum cost. This procedure could be followed also by starting with feed grain, but again the total cost would be higher because wheat would need to be produced in higher cost regions.

To summarize the implication of the foregoing paragraph, wheat and feed grains are interdependent in the models. Hence, each category of crops is selected by the models to minimize costs, or maximize profits, for all crops considered together, not for a single category.

As expected when the model was formulated, the total direct cost (table 19) of producing the requirements for food wheat and feed grain is lowest for model D.[14] For this model, the total direct cost of producing 677.5 million bushels of food wheat is $480 million. The average per bushel cost, therefore, is $0.71. Also, the total direct cost for producing 3,548.9 million bushels of feed grain is $1,602 million for model D, and the average cost per bushel is $0.45. These lower costs are due to the structure of the model. To explain: Each feed grain is an independent activity, that is, it is not part of a rotation. With this independence, corn makes up the greater part of the feed grain specified in the model solution, as it is produced at lower cost per unit than either oats, barley, or grain sorghums in most regions. Also, as corn is a higher yield feed-grain crop in most regions, fewer acres are needed to fulfill the feed-grain requirement. As table 19 shows, more acres of food wheat are required under model D than under models A, B, or C. But the wheat acres denoted by model D have lower per unit costs.

The next lowest total direct cost of producing 677.5 million bushels of wheat is indicated for model A. The total cost is $491 million, and the average per bushel cost is $0.73. But the next lowest direct cost for producing 3,548.9 million bushels of feed grains is that for model B. The total direct cost of producing requirements for both wheat and feed grains is higher for model B than for model A—$2,418 million compared with $2,413 million. The higher total direct cost for model B results because the land rent included in the activity costs for this model changed the "relative cost relationships" between activities as compared with model A. The model A solution represents an "acreage mix" with lower average direct costs but higher average indirect costs (land rent) as compared with the model B solution. Hence, if land costs were added to the total direct costs given in table 19 on the basis of the acreages represented by the solutions, the resulting total cost would be greater for model A than for model B.

Although the total acreage required to produce the wheat and feed grain needed is greater for model C than for any of the other four models, the acreage needed for food wheat is the smallest. Hence, the acreage of feed grains is greatest for model C. Also, the average per bushel costs—$0.81 for wheat and $0.57 for feed grain—are highest for model C.

Model E, using the criterion of maximum profit, produces a solution with costs nearly as high as those for model C. The total direct cost

[14] As used here, the term "direct cost" includes labor, power and machinery, chemicals, and miscellaneous items. (See text for definitions.) The discussions that follow are for this direct cost. It does not include such items as seed, taxes, or interest on land and real estate investment.

for model E was made up of $1,936 million for producing 3,548.9 million bushels of feed grain and $545 million for producing 677.5 million bushels of food wheat (table 19).[15] The per bushel cost of production was $0.80 for wheat and $0.55 for feed grain.

These higher costs can be explained as follows: Given the activity prices assumed for model E, some relatively high-cost activities are profitable in regions in which the price of wheat or feed grain is relatively high. For example, certain regional wheat activities in North Dakota, South Dakota, and Minnesota have relatively high production costs, but the price of wheat in these States is also relatively high. Hence, under model E, these activities are relatively profitable. Similarly, production of feed grain is specified for the West because prices are high relative to costs.

FURTHER RESEARCH PROBLEMS

The study reported was made from data that were assembled with the equivalent of about 4 man-years of professional time. Considerable detail went into the construction of basic data. After the data were assembled, the programing computations required only a few weeks. Even with this input of research resources, the study is considered as a first step in improving empirical models used, data employed, and range of problems analyzed. Some additional quantitative steps to be considered in future phases of the research are discussed below. Attainment of some of these steps may require improved data, greater research resources, or greater aggregation than was used in the study reported.

A step now underway is the use of regional demand restraints and associated transportation costs in establishing the objective functions and restraints of the programing models. Freight tariffs are available for many origins and destinations, but other transportation costs, such as handling and commissions, cannot be ascertained easily. Also, total transportation costs apply to a product that takes many forms—wheat, flour, bread, corn, middlings, cornmeal, breakfast cereal, and so on—between producer and consumer. But the difficulties encountered in ascertaining transportation costs should not be more formidable than those of establishing production coefficients.

Further studies are needed in which known differences in input-output coefficients within grain regions can be considered. Additional activities and restraints for lands of different productivities might be used in future analyses. But these refinements are not feasible with current digital computers and research budgets.

Future linear programing needs to be based on models with variable-demand restraints. Using such a method, optimum solutions could be derived for an infinite number of demand levels.[16] The variable-demand method has two advantages. It provides a

[15] The feed-grain aggregate includes feed wheat, as well as corn, oats, barley, and sorghum.

[16] High-speed computer routines have been written to handle problems of this type at the Statistical Laboratory, Iowa State University.

"tailored" solution to fit most demand projections—as demand projections are changed from time to time, a production solution is available for each.[17] Also, it reserves the problem of estimation of demand for consumption economists or others who are better qualified to make these estimates.

Analyses planned will consider technical improvements in agriculture and growth in population. These projections are to be used in estimating needed spatial patterns of crop production for future points in time. Technological change is more difficult to estimate than is increased demand resulting from growth in population and income. Technological advancement is contingent upon many variables, some of which are not quantifiable.

Eventually, it may be possible to develop a model that will take into account all possible or important crop and livestock activities in each region. This step is to be considered after cotton, soybeans, and other crops are incorporated into the current model.

Quality is a variable that should be considered in later research. Soft wheat cannot be substituted for the hard varieties in the manufacture of wheat products of a given quality. It was assumed in the study reported that the regions in the model solutions would provide a variety mix of wheat that would meet the special demands for each variety. Apparently, this assumption was not contradicted by the results.

Many other aggregative problems might be considered in linear-programing analyses of the grain economy. These include the determination of optimum-producing regions when crop failures are assumed in certain areas, the determination of the optimum level and location of grain stocks over time (dynamic programing), and a combination of the two. A model developed for the two latter steps could easily exceed computational facilities if a large number of production regions and years were considered.

Models that use continuous supply and demand functions might be used to describe the competitive position of various agricultural regions in the wheat and feed grain economy. Spatial equilibrium models using continuous supply and demand functions would seem, however, to be too complex for a detailed analysis of as many as 100 regions. Without the detail of many regions, analysis is general and is of little use in specifying needed adjustments.

Analyses of the agricultural industry of the type and detail used in the study reported are desirable from the viewpoint of realism and complete analysis. Experience with the study, however, revealed the true magnitude of such an analysis. But if the regional interdependence of the agricultural industry is to be known or approximated, a programing type of analysis seems to be the most feasible of the several empirical methods presently available. Inclusion of the steps mentioned is necessary before realism and completeness can be achieved. For such analyses, however, sizable research funds and much time would be required.

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[17] This statement applies to a relatively short period in which production techniques are unchanged.

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