A Programming Analysis of Interregional Competition and Surplus Capacity of American Agriculture

by Earl O. Heady and Norman K. Whittlesey

Department of Economics and Sociology
Center for Agricultural and Economic Development
and
Farm Production Economics Division
Economic Research Service
United States Department of Agriculture
cooperating

AGRICULTURAL AND HOME ECONOMICS EXPERIMENT STATION
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This study is the third in a series dealing with interregional adjustments of agricultural production and land use.[2] While prior studies dealt mainly with benchmark situations in 1954, the current study emphasizes interregional competition and surplus agricultural capacity estimated to exist in 1965. The emphasis is on interregional allocations of production for wheat, feed grains, cotton and soybeans and on the flow of products among consuming regions in a manner (a) to provide an optimal United States use of resources and (b) to mesh production exactly with consumption and export requirements. The analysis is made by several linear-programming models and solutions which include up to 962 equations and 2,682 real variables.

Studies dealing with the interregional adjustment of agricultural production are needed for several reasons. An important need is a better assessment of the nation's surplus producing capacity in order that long-run solutions might be provided for output, price and income problems. Long-run solutions generally would require adjustment of agriculture in line with the comparative advantage of the many individual producing regions. Some regions would remain in production of cotton, wheat, feed grains and soybeans (the crops included in this study); other regions would need to shift to less intensive uses, such as grazing and forestry. Research is needed to identify regions that might be expected to orient their resources in each of these directions. Educational, capital and income policies might then be directed accordingly.

The acreage-control programs in effect over the past 30 years have tended to restrain and modify the extent to which production can be shifted among regions in response to relative changes in technology and demand. Emphasis has been on the withdrawal of land over all producing regions, rather than to let land retirement concentrate in regions of least advantage. Consequently, it is likely that the current allocation of production among producing regions of the nation and the corresponding flow of products to consuming regions differs considerably from the pattern which, through market or other mechanisms, might be reflected in current tcehnology, population density and commodity demand in the various sections of the country. Existing quantitative tools permit the determination of optimal regional production patterns, obtained either through simulated market equilibrium or through government programs oriented toward market equilibrium. This study has been made to examine these different conditions.

Objectives of the Study

The major purpose of this study is to define efficient interregional allocations of food and fiber production over the United States and to designate the possible effect of alternative market equilibriums or farm policies in attaining or restraining these patterns. Interregional shifts in food production have been restrained over most of the past 3 decades by government policies tied to historic acreages and aimed at curtailing production. Important changes have taken place in population location, technology, factor prices and other variables which otherwise alter the comparative advantage of producing regions. Institutional factors, however, have impeded the shifts that would otherwise take place under these changes, and the pattern of land use under an efficient production pattern is not well known. Therefore, the specific objectives of this study are:

1. To indicate the amount and location of land that should be withdrawn from wheat, feed grains and cotton production if surplus production were eliminated in 1965.

2. To reflect an efficient allocation of production

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[1] Project 1406 of the Iowa Agricultural and Home Economics Experiment Station, in cooperation with the Center for Agricultural and Economic Development and the United States Department of Agriculture.

[2] Earl O. Heady and Alvin C. Egbert. Spatial programming models to specify surplus grain-producing areas. In: Studies in Process Analysis. Monograph 18. John Wiley and Sons, New York. 1963. pp. 161-214; Alvin C. Egbert, Earl O. Heady and Ray F. Brokken. Regional changes in grain production; an application of spatial linear programming. Iowa Agr. and Home Econ. Exp. Sta. Res. Bul. 521. 1964; Alvin C. Egbert and Earl O. Heady. Regional adjustments in grain production; a linear programming analysis. U.S. Dept. Agr. Tech. Bul. 1241 (with supplement). 1961.

EARL O. HEADY is professor of economics at Iowa State University, and NORMAN WHITTLESEY currently is with the Farm Production Economics Division, Economic Research Service of the United States Department of Agriculture as an agricultural economist but was with the Agricultural Adjustments Branch, Farm Production Economics Division, Economic Research Service, United States Department of Agriculture, at the time this study was made.

and land use under a minimum cost objective function for alternative adjustment or supply-control programs.

3. To specify the impact of programs aimed directly at wheat or feed grains upon the production allocation of nonprogram crops.

4. To analyze the effect of changes in final demand upon the allocation of production and land disposal.

5. To formulate optimal land-use patterns when marginal land within, as well as between, regions is removed from production.

Other objectives of the study are:

6. To estimate the regional and national derived equilibrium product prices under each of the program alternatives.

7. To estimate the regional rental value of cropland and acreage quotas under optimal land-use patterns.

8. To determine the net interregional flows of final products under the production patterns of each program alternative.

PROGRAMMING MODELS

The objectives of this study are achieved by use of three linear-programming models. Several solutions, providing information about specific variations in restraints, demand and farm programs, were derived for each model. The models each include 144 spatially separated producing regions. About 96 percent of the national output of wheat, feed grains, cotton and soybeans is produced in the 144 regions. Regional boundaries are county lines. The individual regions are considered sufficiently homogeneous with respect to soil types, climate, historic yields and production costs to serve as a producing entity. Each region has a potential of four production possibilities: wheat, feed grains, soybeans and cotton.

The models also contain 31 spatially separated consuming regions, defined by state boundaries of 48 states, to reflect the projected demand requirements of wheat, feed grains and oilmeals (a single national demand was specified for cotton lint). The discrete demand quantities are composites of industrial (for both food and nonfood uses), livestock and export needs for each region. The 1,400 transportation activities provide for the movement of wheat, feed grains and oilmeals among the consuming regions. Transportation activities are defined only between groups of producing regions aggregated to the level of consuming regions, rather than from individual producing regions to consuming regions. A transfer activity in each consuming region allows wheat to be used for livestock feed at a "transformation" cost varying upward from zero. This activity and the "transformation" costs attached to it provide the possibility of considering single- or multiple-price plans for wheat.

Acreage restraints, provided individually for wheat, feed grains and cotton in each producing region, are based upon the historical acreage of each crop within the region. Acreage restraints for individual crops are varied, however, for models representing different assumptions regarding agricultural programs. The upper limit on soybean production is set at 40 percent of total cropland acreage in each producing region. Minimum production was not required of any crop in any region.

Basic Model

Since construction of the three models was similar, we include a mathematical summary of a "basic model" whose characteristics are common to all programming models used. The objective function, indicated in equation 1, relates to minimizing national costs of production and interregional transportation of the bill of goods represented by demand of the 31 consuming regions for wheat, feed grains, cotton and oilmeal,

$$\text{Min } f(X) = C'X \qquad (1)$$

In equation 1, C is an $(nk + t)$ row vector including production, transfer and transportation costs corresponding to k crops, n producing regions and t transfer and transportation activities; X is an $(nk + t)$ vector representing levels of crop production, transfer and transportation activities. Equation 1 is minimized subject to the conventional restraints $AX \geqq b$ and $X \geqq O$ where A is a coefficient matrix of $(pn + md)$ $(nk + t)$ order (conforming to the p land restraints for each producing region, m demand regions and d regional demand restraints) and b is a $(pn + md)$ column vector reflecting maximum acreage restraints in each producing region and minimum demand requirements in each consuming region. More specifically, the objective function is

$$f(c) = \sum_{j=1}^{144} \sum_{k=1}^{4} c_{jk} X_{jk} + \sum_{m=1}^{30} \sum_{r=1}^{30} \sum_{p=1}^{3} c_{mrp} T_{mrp} + \sum_{s=1}^{31} c_s R_s = \text{Minimum} \quad (r \neq m), \qquad (2)$$

where,

c_{jk} = the cost of producing one unit of the kth crop in the jth producing region,

c_{mrp} = the cost of transporting one unit of the pth commodity to (from) the rth demand region from (to) the mth demand region ($r = 30$ is the maximum number of such activities that may occur for any crop, since there are 31 demand regions),

c_s = the cost (artificial price differential) of using one unit of wheat as a feed grain in the sth demand region ($s = m$),

R_s = the level of the activity transferring wheat into a feed grain in the sth demand region ($m = s$),

T_{mrp} = the level of transportation of the pth commodity to (from) the mth consuming region from (to) the rth consuming region (p equals 1, 2, 3 for wheat, feed grains and oilmeal, respectively), and

X_{jk} = the level of the kth producing activity in the jth producing region (k equals 1, 2, 3 and 4 for wheat, feed grains, soybeans and cotton, respectively).

Total production in the ith region is restrained by the total cropland equation,

$$b_{io} \geqq \sum_{k=1}^{4} a_{ijk}X_{jk} \quad (i = j = 1,2, ..., 144), \quad (3)$$

and by the intraregional upper bounds on acreage for each crop as in,

$$b_{ik} \geqq a_{ijk}X_{jk} \qquad (i = j = 1,2, ...,144; \; k = 1,2,3,4). \quad (4)$$

Other variables of equations 3 and 4 are defined as:

a_{ijk} = the amount of land used by one unit of the kth producing activity of the i = jth producing region (k equals 1, 2, 3 and 4 for wheat, feed grains, soybeans and cotton, respectively),

b_{ik} = the amount of land available for use by the kth crop in the ith producing region, and

b_{io} = the total cropland available for production within the ith producing region.

Minimum requirements for wheat, feed grains and oilmeals in each consuming region are reflected in equations 5, 6 and 7, respectively. These demands must be satisfied by producing regions within the consuming region or by shipments from other consuming regions.

$$d_{m1} = \sum_{j=1}^{n} X_{j1}P_{j1} + \sum_{r=1}^{30} e_{mr1}T_{mr1} + e_{ms}R_s \quad (5)$$

$$(m = s = 1,2,...,31; r \neq m).$$

$$d_{m2} = \sum_{j=1}^{n} X_{j2}P_{j2} + \sum_{r=1}^{30} e_{mr2}T_{mr2} + e_{ms}R_s \quad (6)$$

$$(m = s = 1,2,...,31; r \neq m).$$

$$d_{m3} = \sum_{j=1}^{n} X_{j3}P_{j3} + \sum_{j=1}^{n} X_{j4}P'_{j4} - \sum_{r=1}^{30} e_{mr3}T_{mr3} \quad (7)$$

$$(m = 1,2,...,31; r \neq m).$$

The single national demand for cotton lint is,

$$d_c = \sum_{j=1}^{144} X_{j4}P_{j4} \; . \quad (8)$$

The variables of the demand equations are:

d_c = the national demand for cotton lint expressed in pounds,

d_{mp} = the demand for the pth commodity, expressed in feed units,[3] in the mth demand region where p is defined as above,

e_{mrp} = the amount of the pth commodity transported to (from) the rth consuming region from (to) the mth consuming region by the mrpth transportation activity (p equals 1, 2 and 3, respectively, for wheat, feed grains and oilmeals),

e_{ms} = the amount of wheat transferred from the mth wheat demand restraint to the mth feed-grain demand restraint by one unit of the sth transfer activity, (m = s),

P_{jk} = the per unit output of the kth activity in the jth producing region, expressed in feed units for all products except cotton lint, which is expressed in pounds (k is defined as above), and

P'_{j4} = the oilmeal output, in feed units, of the cotton activity in the jth producing region.

The "basic model" just summarized is the same as models I and II applied later. The basic models form a matrix of the order 674 x 1,814 without slack vectors; this is shown in tabular form in table 1. Model III differs slightly and will be explained later. It has 962 restraints and 2,682 real activities.

Specific Models

Potentially, four individual producing activities were available in each of the 144 producing regions. However, activities were included in an individual region only if it had a historical record in producing the crop. There were 144, 134, 99 and 58 regions having previously produced feed grains, wheat, soybeans and cotton, respectively. Although cotton contributes lint for the single national demand, oilmeal from cottonseed contributes to individual regional demands. The output of each crop activity is considered to contribute directly to demand at zero transport cost in the consuming region where it is produced (fig. 1).[4]

All models have regional acreage restraints for each of the major crop activities. Regional restraints also exist for acreage of total cropland. Individual regional crop-acreage restraints need not sum to total cropland acreage in each region, since the former reflects the maximum allowable production of each crop in the region, to simulate various supply-control programs.

Regional production requirements were estimated for wheat, feed grains and oilmeals and include quanti-

[3] All crop-activity outputs, except cotton lint, were converted to equivalent feed units for use in computations and for comparing the output of various activities with final demands. Since each consuming region had feed-grain demands for which all feed-grain activities and wheat activities competed, the output of the four feed grains and the wheat were most conveniently expressed in similar units. Soybeans and cottonseed were similarly expressed in equivalent feed units.

[4] Figures 3 and 4, showing the physical location of each producing and consuming region, may aid the reader in grasping this point.

Table 1. Tabular illustration of models I and II without the identity matrix.

Row names	Type of re-straint	Activities: Producing[a] Wheat	Feed grain	Soy-beans	Cotton	Wheat feed grain transfer[b]	Transportation Wheat	Feed grain	Oil-meals	Number of rows
Land										
Total	≤	1	1	1	1					144
Wheat	≤	1								134
Feed grain	≤		1							144
Soybean	≤			1						99
Cotton	≤				1					58
Demand[c]										
$Wheat_1$	≤	p^d				$-a^e$	$-a^e$			31
$Feed\ grain_1$	≥		p^d			a		$-a^e$		31
$Oilmeals_1$	≥			p^d	p^d				$-a^e$	31
$Wheat_2$	≥						a^e			
$Feed\ grain_2$	≥							a^e		
$Oilmeals_2$	≥								a^e	
Cotton lint	≥				p					1
Cost[f]	=	C	C	C	C	C	C	C	C	1
Number of activities		134	144	99	58	31	459	459	430	

[a] All producing activities shown are assumed to be contained in the first demand region.

[b] The amount of wheat transferred into feed grain in the region.

[c] Demand restraints for two regions (indicated by subscripts 1 and 2) are shown to demonstrate the effect of the transportation activities.

[d] The output of each activity. It is expressed in feed units for all activities except cotton lint which is expressed in pounds.

[e] The amount of each commodity transferred within a region or between regions by one unit of the transportation activities.

[f] The per-acre cost of each activity.

ties for human food, livestock feed and foreign export. A single national demand was specified for cotton lint. Except for two solutions of Model I, demand constraints were similar for all solutions in the sense that they require the same total production and the same final product distribution. The two exceptions are solutions of Model I to examine the effects of different levels of demand and price on interregional production patterns.

Transportation activities (459, 459 and 430 activities for wheat, feed grains and oilmeals, respectively) were included for all rational possibilities of commodity movements among consuming regions. Movement was assumed to originate and terminate at the geographic center of consumption regions. A transfer activity in each consuming region allowed the use of wheat for feed in cases where the farm crop serves as an efficient source of livestock feed.

Model I

Model I is basically the one previously outlined in mathematical form. Its solutions serve as the basis for comparison with those from other models.

Model I has cost coefficients of the wheat—feed-grain transfer activities equal to zero, implying a multiple-price plan for wheat. Wheat can be used for livestock, at a price equal to its equilibrium feed value, as long as wheat requirements used for food and export purposes are first attained (at a price level corresponding to these uses).

Model II

Model II is the same as Model I except that wheat—feed-grain transfer activities have nonzero costs. The cost is assumed equivalent to the differential between a supported price of wheat at $1.95 per bushel and the price of corn at $1.10 per bushel. The cost differential varies, however, depending upon the actual historical ratio of wheat and corn prices in each consuming region. Hence, this solution examines the regional production distribution when all wheat is priced at a higher support level, but with the possibility that it can be used as feed grain if this "excess price" is considered for its usage as feed grain. This cost is assumed representative of the difference between the equilibrium value and the supported price of wheat. In this model, wheat and feed-grain production patterns are analyzed under the assumption of a single-price level (supported at its historic "food" level) for wheat.

Model III

Model III differs from Model I with respect to the structure of cropland restraints. Cropland in each producing region is divided into three production or soil categories on the basis of the estimated differences in crop yield and permissible cropping intensity. This change has the effect of multiplying total cropland constraints and producing activities by three, resulting in a coefficient matrix with 962 constraints and 2,682 real activities. This condition adds realism in the sense that it is no longer necessary to have complete retirement of a region from production of a particular crop activity.

Product prices

Equilibrium prices for the final products, in the programming sense analyzed here and not in a market equilibrium context, are valuable by-products of least-cost, linear-programming models. These prices, including equilibrium land rental values, reflect (a) the relative scarcity of factors of production and (b) the per-unit costs in the least efficient producing region used to satisfy the final product demand in a given consuming region. If inshipments of products are not involved, the construction of shadow or equilibrium prices for crops, P, is

$$P = \frac{C_p + L + Q}{Y} \qquad (9)$$

where C_p is the per-acre cost of production, L is land rent per acre, Q is the value of production quotas (if any) per acre and Y is yield per acre. In this case, the cost and yield are those of the highest cost producing region employed within the particular consuming region. Both the land rent and the quota value of this producing region may be greater than zero, since more than one crop competes for the cropland. If inshipments are necessary or desirable to satisfy the demand in question, the price construction becomes more complicated. The transportation cost, C_t, must be included in equation 9. The equation then becomes

$$P = \frac{C_p + L + Q + C_t}{Y}, \qquad (10)$$

where C_p, L, Q and Y now refer to the highest cost producing region supplying the demand in question. This producing region will seldom be within the consuming region whose product price is being determined, and the prices for different products and regions will be determined simultaneously in the model.

PRODUCTION DATA

This study is a continuation of a series initiated in 1955 by Iowa State University and the United States Department of Agriculture.[5] Data for the earlier studies served as the initial base from which certain coefficients for the current study were projected. The early models were representative of the year 1954, except that acreages serving as maximum production constraints were for 1953. The year 1953 was the last one in which

[5] For reports of earlier work, see: Earl O. Heady and A. C. Egbert; ibid; Alvin C. Egbert and Earl O. Heady. Regional adjustments in grain production: a linear programming analysis. U.S. Dept. Agr. Tech. Bul. 1241. 1961; and Alvin C. Egbert, Earl O. Heady and Ray F. Brokken. Regional adjustments in grain production; an application of spatial linear programming. Iowa Agr. and Home Econ. Exp. Sta. Res. Bul. 521. 1964.

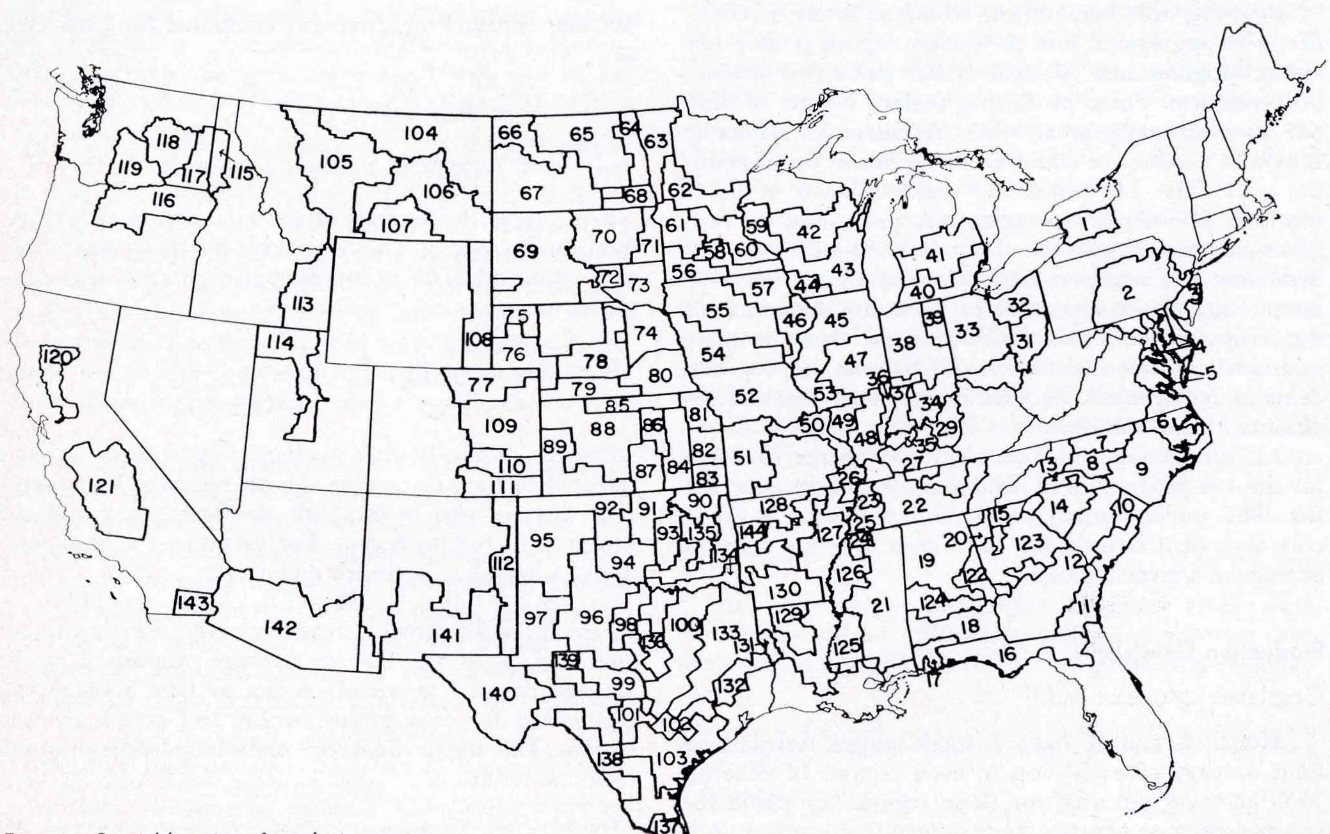

Fig. 1. Spatial location of producing regions.

major farm programs did not restrict acreages of wheat, feed grains or cotton. In general, the methods of the earlier studies were used with yields and costs by regions projected to 1965, the year to which this study refers. However, modifications were made, where possible or necessary, to improve coefficients and provide data unique to particular models.

Producing Regions

The producing regions from the earlier studies formed the basis for those used in this analysis. The programming regions, circumscribed by political boundaries, are based primarily on state economic areas or groups of counties. These areas are assumed internally homogeneous with respect to type of farming and resource productivity. However, they are used mainly because most production information is reported only on the basis of counties or economic areas. In cases where four classes of economic areas or groups of counties were defined, the programming regions for crop production were demarcated by the following procedure:

1. Those with grain production uniformly distributed (i.e., the concentration of grain acreage within each county was approximately the same for all counties in the economic area). a. Total harvested acreage of crops used in the study was 25 percent or more of total cropland. b. Total harvested acreage of study crops was less than 25 percent of total cropland.

2. Those with grain production not uniformly distributed. a. Same as 1a. b. Same as 1b.

By using this breakdown, economic areas or counties were aggregated into producing regions if they (a) were contiguous and (b) had similar yields and production practices. Some producing regions consist of only one state economic area; others represent an economic area and a group of counties, or are made up of counties only. The 144 producing regions shown in fig. 1 resulted. The numbered regions are those used for programming purposes in the study. Regions without numbers were not incorporated into the analysis; they represent only about 4 percent of national production of the crops in question. Production in these nonprogrammed regions is subtracted from the appropriate demand requirements in defining regional demand restraints for the models.

All production cost and yield coefficients used are for the 144 programming regions and are those expected for 1965 under normal production practices. A single cost and yield is used for each crop over all relevant acreage in a given region.

Production Constraints

Cropland: Models I and II

Models I and II have a single upper restraint to limit acreage of each crop in each region. In general, 1953 acreages are used for these regional cropland restraints, because acreage controls were not used to limit the production of crops in that year.[6] Both intraregional and interregional adjustments in crop production are thus allowed within the boundaries of the regional production capacity reflected by 1953 acreages. In addition, a total cropland restraint, b_{io}, in each producing region is defined as

$$b_{io} = \sum_{k=1}^{7} A_{ik} \qquad (i = 1,2,\dots,144; \quad k = 1,2,\dots,7) \quad , \qquad (11)$$

where A_{ik} is the harvested acreage of the kth crop (wheat, corn, oats, barley, grain sorghums, soybeans or cotton) in the ith region in 1953. Where 1953 data were not available, 1954 census data were used to establish this restraint. Also, in any case where 1954 acreage was greater than 1953 acreage, the larger of the two totals was used. In equation 11, the A_{ik} for wheat includes summer fallow acreage for regions where this practice is used.

Acreage quotas

The individual restraints indicated in equation 4 were used to simulate production-control programs in models testing various policies. They are referred to as acreage quotas at later points in this bulletin. As a basis for these individual crop restraints, it was necessary to establish a regional base acreage for each crop activity. These base acreages, consistent with procedures used in administering production-control programs, represent historical production patterns for each producing region computed as 1951-60 average acreages. The 10-year average acreage, $\overline{b}_{ik}$, first was computed for each crop as

$$\overline{b}_{ik} = \frac{\sum_{t=1}^{10} b_{ikt}}{10} \qquad (i=1,2,\dots,144; \quad k=1,2,\dots,7), \qquad (12)$$

where b_{ikt} is the acreage of the kth crop in the ith region during year t. The base acres for the several crops were summed. The proportion of each then was computed as

$$P_{ik} = b_{ik} \left[\sum_{k=1}^{7} \overline{b}_{ik} \right]^{-1} \qquad (i=1,2,\dots,144; \quad k=1,2,\dots,7) \quad , \qquad (13)$$

where P_{ik} is the 10-year average proportion of acreage devoted to the kth crop in the ith region. This proportion then is used to establish the base acreage of the kth crop in the ith region. For example, the base acreage of wheat, b_{i1}, in the ith region is

$$b_{i1} = P_{i1} b_{io} \quad , \quad (i = 1,2,\dots,144) \quad , \qquad (14)$$

where b_{io} is the total acreage restraint for the ith region and p_{i1} is the 10-year average proportion of the acreage devoted to wheat. A similar base acreage was established for feed grains, wheat and cotton in each region. The upper limit on soybean acreage in each region is set at

[6] Nationally, the total acreage of wheat, feed grains, cotton and soybeans was greater in 1953 than in any previous or subsequent year.

$$b_{i6} = b_{io}\ (0.4) \qquad (i = 1,2,...,144). \qquad (15)$$

Hence, for many regions, we assume that soybeans cannot be grown on more than 40 percent of the existing cropland without a significant effect on yield or soil erosion. However, in regions where the historic percentage of soybeans, p_{i6}, was greater than 40, the larger actual percentage is used. In instances where $p_{ik} = 0$, the kth crop was assumed not adaptable in the ith region.

The base acreages of each crop were used in five solutions of the programming models. The remaining solutions were derived while using variations of the wheat, feed-grain and cotton base acreages to simulate various government-control programs. Hence, if we set $b_{i1} = b_{io}$, while feed grains and cotton are held at their base acreage, a policy of no acreage restriction on wheat production is simulated. Likewise, if regional acreage restrictions of wheat are set at $b_{i1} = 0.9 b_{io}$, the wheat program of 1961 is simulated, since it allowed wheat acreage to be only 90 percent of the base acreage.

Cropland: Model III

Model III allows three qualities of land in each region. Basic assumptions used in this model were (a) that land of one quality can be farmed independently of land of a different quality, (b) that the over-all costs of producing a crop are equal for the three land qualities, and (c) that land of different qualities differs in the yield per acre and in possible cropping intensity. For example, the best quality of land may be used for continuous corn, while erosion problems allow corn in only 3 out of 5 years on land of another quality. Henceforth, the three qualities or groups of land will be referred to as: Class 1 (the best land), Class 2 and Class 3 (the poorest land).

Model III requires a uniform method of classifying soils among regions. Shrader and Landgren[7] indicate that the Conservation Needs Inventory (CNI) of the U.S. Department of Agriculture[8] is the only consistent set of soil groupings throughout the United States. Although this classification scheme was designed to indicate erosion susceptibility and to guide intensiveness of land use, it is the best available method for classifying soil according to productivity and is used in the current study.

The CNI study defined eight (I-VIII) classes of land, and subdivided these into subclasses (a-h) according to particular problems regarding erosion and cropping intensity. The risks of soil damage or limitations in use become increasingly greater from Class I to Class VIII. Soils in the first four classes are capable, under good management, of producing adapted cultivated field crops. Classes V-VII are capable of producing some crops under highly intensive management practices but are better left in their natural vegetation. Class VIII soils do not return on-site benefits for inputs of management of crops, grasses or trees. However, areas classified as cropland in nearly every county of the United States include land of one or more of the soil classes V-VIII.

For the current study, a sample of counties was drawn from records of the CNI study for each of the 144 producing regions.[9] Three soil classes were determined accordingly. For purposes of the current study, identification of soil groups by regions is this:

(1) Class 1 of this study equals the CNI classes I and II,

(2) Class 2 of this study equals CNI class III, and

(3) Class 3 of this study equals CNI classes IV-VIII.

A cropland restraint was established for each of the regional soil classes of this study. Since all crops of this study are fairly intensive, it was deemed necessary to adjust the sample distributions of cropland in the various classes for the potential erosion hazard involved. This adjustment made the sample distribution of soil classes consistent with the total cropland restraints used in each region. To clarify this requirement: Assume that a region has only two classes of cropland, Class I and Class IVe, in equal proportions of 100 acres each, and that corn is the only grain crop grown in the region.[10] Class I land could be in continuous corn and Class IVe land could be in corn only 3 out of 5 years. This structure would need to be reflected in the regional historical acreage of corn in the region. The base acreage of corn for this region would be $100 + 100\ (0.6) = 160$ acres, and this figure would be used as the cropland restraint in the context of this study. Notice, however, that only 37.5 percent of this acreage would be on Class IVe land, as compared with 50 percent of Class IVe land in all cropland of the region.

To make the adjustment just described, it was necessary to use state totals for the complete breakdown of cropland by class and subclass. The estimated acres of cropland, available after considering the intensity with which land could be used, in each of the three productivity classes by region were substituted for the total cropland used for models I and II. Crop yields also had to be estimated for each of these three soil classes. The process used in making these yield estimates is explained for equations 16 and 17.

Crop Yields

All input-output coefficients, including crop yields, were estimated for 1965. Crop yields and per-acre costs were estimated for each of the 144 producing regions.

[7] William D. Shrader and Norman E. Landgren, Land use implications of agricultural production potentials. Department of Economics and Sociology. Ames, Iowa. Unpublished paper. 1962.

[8] United States Department of Agriculture. Basic statistics of the national inventory of soil and water conservation needs. Needs Inventory Committee. U.S. Dept. Agr. Bul. 317. 1962.

[9] The county data from the Conservation Needs Inventory was acquired from records at Iowa State University and various state Soil Conservation Service offices.

[10] The subclassification "e" denotes a potential erosion hazard in the CNI classification. United States Department of Agriculture. Basic statistics of the national inventory of soil and water conservation needs. Needs Inventory Committee. U.S. Dept. Agr. Stat. Bul. 317. 1962.

Yield data: Models I and II

Crop yields first were projected to 1965 for each state. Average state yields per harvested acre for the years 1944-62 formed the basis for the projections. The state yield for each crop was estimated by the linear regression

$$\hat{Y}_{kg} = a + bt, \quad (16)$$

where $\hat{Y}_{kg}$ refers to the 1965 estimated yield of the kth crop in the gth state and t refers to the year. (Where b was negative, the mean for the series was used as $\hat{Y}_{kg}$.) These projected figures were used for the 1965 state yields, except for certain "boundary conditions" used to insure against unreasonable or unattainable yields. In no case was a state yield projected beyond the highest level attained during the base period.

To complete the estimation process, it was necessary to compute relative mean yields for each state, $\overline{Y}_{kg}$, and regions within states, $\bar{y}_{kgi}$. These estimates were made from data for the period 1950-60. Some cases were encountered in which regional data for the 11-year period were not available. In these instances, census data for the years 1949, 1954 and 1959 were used to compute the mean estimates.

These mean yields were assumed comparable to one another and were used in predicting regional crop yields for 1965. The following relationship was assumed in estimating the 1965 yields by producing regions:

$$\hat{y}_{kgi} = \frac{\bar{y}_{kgi}\ \hat{Y}_{kg}}{\overline{Y}_{kg}}\ . \quad (17)$$

In equation 17, $\hat{y}_{kgi}$ refers to the 1965 projected yield of the kth crop in the ith region and gth state.

Model III crop yields

As described, the cropland restraints of each region were divided into three production categories in Model III. It was necessary to estimate crop yields for each of the three land classes in each programming region. (Total variable costs of production were assumed generally the same for all classes of land within a region, an assumption substantiated by budget studies for the various CNI land classes in Texas and Oklahoma.)[11] The only differences assumed in crop production on the three land classes within a region were reflected by crop yields.

The procedure for estimating crop yields by land class incorporated the concepts discussed in the previous paragraph. Yield data based upon the CNI soil class were scarce, but some observations were available and useful for establishing estimational methods.[12] These crop-yield estimates by soil class were assumed representative of the relative within-region yield responses for all regions. It was recognized that class 2 land in Iowa is not the same as class 2 land in New Mexico. However, the land classes were established by soil scientists such that class 2 land relative to class 1 land in Iowa is about the same as class 2 land relative to class 1 land in New Mexico. It was possible, by using the above-mentioned data, to construct yield response equations, relative to the regional mean yield, that gave consistent estimates by land class for all regions. The estimated yields were weighted by the CNI soil-class acreages to provide yield estimates for the soil classes used in this study.

Production Costs

Cost coefficients, estimated for each crop in each region, were brought up to date from the 1954 data[13] by use of indexes of costs and technological trends. The cost figures estimated for 1965 include expenditures for labor, machinery and power, chemicals and miscellaneous inputs. Charges for land and overhead costs, including management, housing, purchasing and selling were not included. These costs usually represent 10 percent or more of total production costs but, for lack of data, were not included in estimates.

Individual feed-grain crops were not included as distinct activities in the programming models. Instead, the corn, oats, barley and grain-sorghum crops were aggregated into a single producing activity for each region. The output of this activity, and therefore the costs, consisted of a weighted average of each of the regional feed-grain crops. The weights used were the same as those employed in computing regional acreage restraints for individual crops. In other words, the weight of each crop included in the feed-grain activity was based upon the historical acreage of that crop.

Demand Data and Restraints

The consuming regions, with separate discrete demand restraints for food wheat, feed grains and oilmeals, are shown in fig. 2. Usually, each consuming region is a single state. Coastal states were used as single consuming regions so that as few ports of export or import as possible would be included in each. In the less populated areas of the West and in the smaller states of the East, regions sometimes include more than one state.

Demand restraints for wheat, feed grains and oilmeals were computed for each of the 31 consuming

[11] Larry J. Connor, William F. Lagrone and James S. Plaxico. Resource requirements, costs and expected returns; alternative crop and livestock enterprises; loam soils of the rolling plains of southwestern Oklahoma. Okla. Agr. Exp. Sta. Processed Series P-368. 1961.
J. W. Goodwin, J. S. Plaxico and William F. Lagrone. Resource requirements, costs and expected returns; alternative crop and livestock enterprises; clay soils of the rolling plains of southwestern Oklahoma. Okla. Agr. Exp. Sta. Processed Series P-357. 1960.
William F. Lagrone, P. L. Strickland and J. S. Plaxico. Resource requirements, costs and expected returns; alternative cropland and livestock enterprises, sandy soils of the rolling plains of southwestern Oklahoma. Okla. Agr. Exp. Sta. Processed Series P-369. 1961.
D. S. Moore, K. R. Tefertiller, W. F. Hughes and R. H. Rogers. Production costs and expected returns; alternative crop and livestock enterprises; clay soils in the northern portion of the rolling plains of Texas. Tex. Agr. Exp. Sta. Misc. Publ. MP-445. 1960.

[12] T. E. Corely, C. M. Stokes and F. A. Kummer. Mechanized cotton production in Alabama. Ala. Agr. Exp. Sta. Circular 127. 1959; Goodwin, Plaxico and Lagrone, op. cit.; Lagrone, Strickland and Plaxico, op. cit.; D. S. Moore, K. R. Tefertiller, W. F. Hughes and R. H. Rogers. Production requirements, costs and expected returns for crop enterprises, Harland soils—high plains of Texas. Tex. Agr. Exp. Sta. Misc. Publ. MP-601. 1962; Moore, Tefertiller, Hughes and Rogers, op. cit.

[13] Heady and Egbert, op. cit.

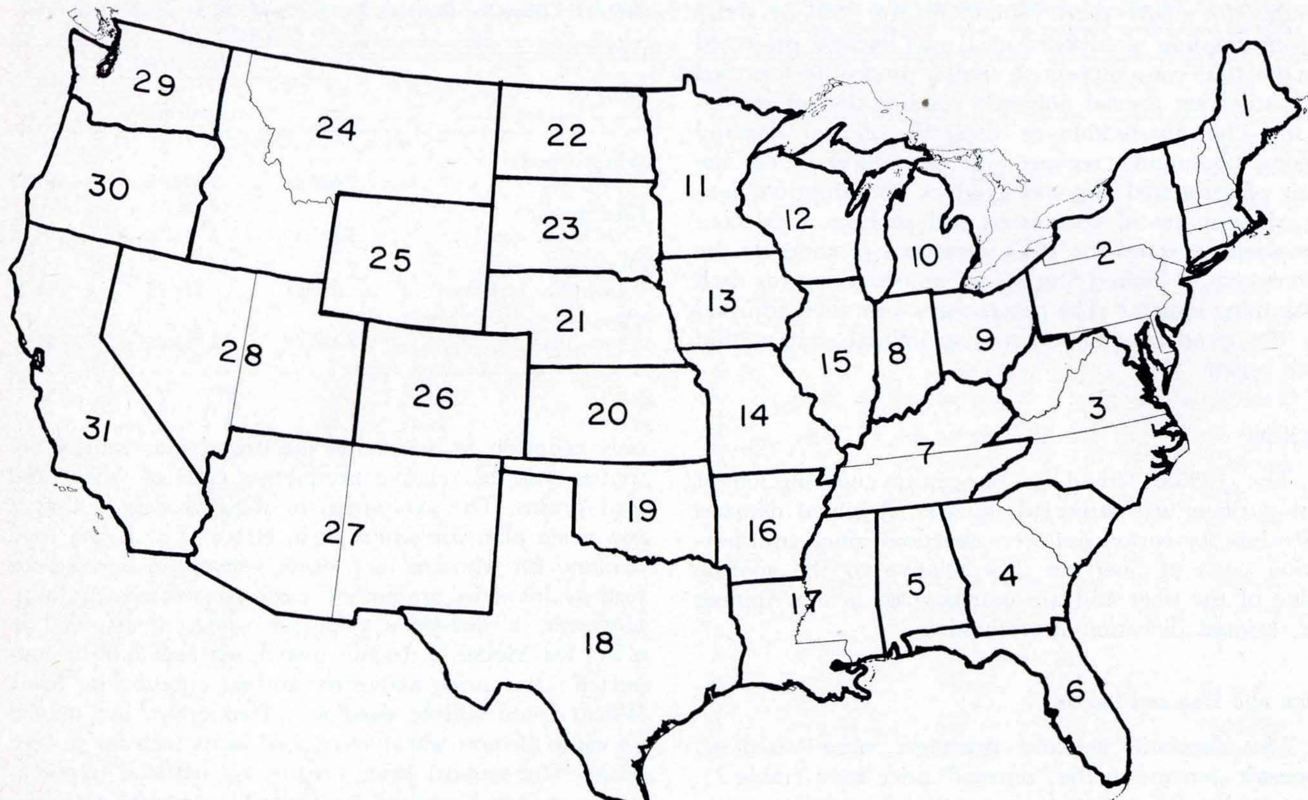

Fig. 2. Spatial location of consuming regions.

regions. The regional demand restraints, reflecting expected consumption patterns for 1965, are based on projected livestock production patterns, historical industrial uses, average patterns of export, population, per-capita consumption and normal price levels. The 1965 United States population was estimated to be 193.6 million persons.[14]

Exports

Exports for commodities were assumed equal to average levels of the years 1957-61. Data[15] for every major port were used to compute the normal export levels, which then became a portion of the total demand for the respective consuming regions.

Wheat

The total demand for wheat was computed to include both domestic and export requirements. Wheat for domestic purposes was broken into five categories: (1) flour and cereal consumption, (2) industrial uses, (3) military procurements, (4) net exports of flour and (5) wheat commonly used for feed. The average percentage of United States flour production by states was used to distribute the estimated total domestic wheat demand among consuming regions. Regional flour production during the 1950-60 decade was expressed as a percentage of total flour production. These percentages were then multiplied by the aggregate domestic wheat demand to make the regional allocations. This procedure accurately accounts for about 97 percent of wheat consumption at the level of domestic processing.

Feed grains

Regional feed-grain demands are a composite of requirements for corn, oats, barley, grain sorghums and wheat used for feed. The total regional demand for feed grains also includes exports and domestic consumption. Domestic consumption of feed grains, while dominated by livestock needs, also includes some disappearance for processed cereals and industrial uses.

The 1965 total food-demand restraint of each feed grain was estimated by projecting per-capita consumption rates and multiplying them by the estimated 1965 population. Demand restraints were then distributed to consuming regions by Census of Manufacturers records of processing and value of shipments for these grains.[16] Aggregate 1965 livestock needs for feed grains were estimated by projecting the 1956-62 trend in total feed-unit consumption of the four major crops. The distribution over consuming regions was accomplished on the basis of estimated grain consumption in each region.

Oilmeals

The domestic soybean consumption has increased

[14] United States Bureau of Census. Current population reports, population estimates. U.S. Dept. Commerce. Series P-25, No. 180. 1957. United States Bureau of Census. Current population reports, population estimates. U.S. Dept. Commerce. Series P-25, No. 187. 1958.

[15] U.S. Dept. Agr. Grain Market News. 1956-61.

[16] U.S. Dept. Agr. Cotton Situation. CS-202. 1962.

steadily for many years. Therefore, the 1951-61 trend in consumption of soybean meal was linearly projected for the 1965 consumption. A similar procedure was used for projecting annual domestic consumption of cottonmeal. The distribution of domestic oilmeal demand among consuming regions was accomplished on the basis of estimated regional livestock consumption. Jennings' estimates of cottonseed and soybean meal consumption by states for 1949 were used to compute the percentage of United States total consumption for each consuming region.[17] The percentages were then adjusted for the trend in grain-consuming animal units within each region.

Cotton

The 1950-61 trend in per-capita consumption of cotton fibers was projected to 1965. Regional demand restraints for cotton lint were not used, since transportation costs of fiber are low relative to the specific value of the fiber and are unimportant in determining the regional allocation of production.

Price and Demand Levels

The domestic demand restraints were based on domestic demand at the "normal" price level (table 2). To test the effect of various domestic demands at other price levels upon resource use, prices were assumed to change to the other levels. The effect of the price changes upon the total demand quantity of each product was then evaluated, and the various demand levels were used as restraints, under a constant set of acreage constraints, for indication of optimum regional production patterns.

In computing the demand restraints associated with each price level, a constant price elasticity of demand was assumed for each major commodity, based upon Brandow's estimates of demand and supply relationships.[18] These were -0.23 for feed grains and oilmeals, -0.02 for wheat and -0.40 for cotton lint. (Exports were considered constant, because the over-all level of exports depends more upon government policies and other nonquantitative factors than upon price.) The various total demands (table 2) were allocated to regions in the manner described for the "normal" demands. The several demand levels were used only in Model I, to compare the effects of changes in the relative level of farm prices upon patterns of production and cropland requirements.

Wheat—Feed-Grain Transfer Costs

Models I and III have zero costs on the intraregional transfer of wheat into feed grain. In these models, the only criterion to determine the use of the transfer activities was the relative production costs of wheat and feed grains. The assumpion in these models is that a two-price plan for wheat is in effect (i.e., if the food demand for wheat is met, other wheat can be used for feed grains if its production costs are sufficiently low). However, a one-price plan for wheat is assumed in effect for Model II. In this model, wheat would be supported at a price above its normal equilibrium level. Wheat could still be used as a feed grain, but only if its value of food wheat were paid in its transfer to feed grain. The support price creates an artificial opportunity cost for wheat used for feed. The transfer activities thus are charged a "cost," in general equal to the difference between the projected prices of wheat and corn within the respective consuming regions. To estimate the prices of corn and wheat in each consuming region (table 3) the average product price in each state, based on the national average for 1965 ($1.10 and $1.95 per bushel for corn and wheat, respectively), was converted to a regional basis.

Table 2. Domestic demands for commodities at three price levels.

Crop	Price level 1	3 (normal)	5
Wheat (food) (mil. bu.)	602.31	598.25	595.17
Feed grains (Mil. bu. corn)	5,817.12	5,418.30	5,124.52
Oilmeals (mil. bu. soybeans)	573.61	534.28	505.31
Cotton (mil. lbs.)	4,470.38	3,953.31	3,581.36

Transportation Data

Approximately 1,400 transportation activities are included in the programming model to allow commodity distribution possibilities and an optimum spatial allocation of production processes while satisfying regional demands for each major commodity. Transportation costs are involved only if commodities move between consuming regions. Transportation activities were specified for each of the regional demand aggregates (wheat, feed grains and oilmeals).

Rail rates were assumed to accurately reflect the costs of transporting wheat, feed grains and oilmeals among the various consuming regions. The lack of data for truck transportation and the difficulty of including combinations of rail and barge rates or barge and truck rates excluded the use of these rates. For this study, actual flat rail rates were computed from the 1962 Interstate Commerce Commission tariff schedule. Transportation rates were the only items included in the programming models not projected to 1965. The construction of these rates is complex and is dependent upon government policies. All rates used in this study

[17] R. D. Jennings. Animal units of livestock fed annually, 1909 to 1955. U.S. Dept. Agr. Stat. Bul. 194. 1956.

[18] G. E. Brandow. Interrelations among demands for farm products and implication for control of market supply. Pa. Agr. Exp. Sta. Bul. 680. 1961.

Table 3. Estimated prices of corn and wheat for price level number 3, by consuming region.

Region	Corn	Wheat	Difference
	(dollars per bushel)		
1	1.58	2.17	0.59
2	1.32	1.89	0.57
3	1.32	1.95	0.63
4	1.28	1.96	0.68
5	1.21	1.91	0.70
6	1.17	2.01	0.84
7	1.21	1.92	0.71
8	1.07	1.87	0.80
9	1.08	1.91	0.83
10	1.08	1.92	0.84
11	0.98	2.11	1.13
12	1.09	1.93	0.84
13	1.07	1.95	0.88
14	1.12	1.90	0.78
15	1.10	1.94	0.84
16	1.18	1.88	0.70
17	1.25	1.90	0.65
18	1.22	1.94	0.72
19	1.16	1.94	0.78
20	1.10	1.94	0.84
21	1.09	1.93	0.84
22	1.00	2.19	1.19
23	0.99	2.07	1.08
24	1.33	1.88	0.55
25	1.14	1.84	0.70
26	1.17	1.85	0.68
27	1.54	1.95	0.41
28	1.63	1.86	0.23
29	1.36	1.97	0.61
30	1.49	2.00	0.51
31	1.46	2.03	0.57
U. S. Av.	1.10	1.95	0.85

were for transportation of grains and oilmeals for domestic consumption.[19]

A city was designated within each consuming region to act as the location for export (import) from (to) that region to (from) all other regions. These points were selected with the objective of having them approximately centered with respect to the consumption distribution of the region. Since rail rates were used as transportation costs, it was necessary that each of these selected cities have access to railroad transportation. In most regions, these cities coincided approximately with the geographical center of the region. Several compromises among these criteria were necessary in making the final selection of cities shown in table 4.

[19] For use in the programming models, transportation rates were expressed in costs per hundred feed units. This procedure offered no difficulty in the transportation of wheat and oilmeals. However, the costs of transporting corn, oats, barley or grain sorghums were not necessarily the same either in weight or in feed units. Adjustments for the composite of the feed grains being transported were thus required. Since it was difficult to predict which producing regions within a consuming region would produce feed grains, it was equally difficult to predict the actual mix of feed grains being transported from a consuming region. As a compromise, the 1950-59 average production, by weight of the four feed grains, was used to estimate the feed units per pound of feed grains produced in each state. Likewise, if different rates existed for each of the crops, it was possible to weight the rates by the percentage of each crop grown.

Table 4. Points selected within consuming regions for determining transportation rates among all consuming regions.

Region	City	State
1	Boston	Massachusetts
2	Binghampton	New York
3	Richmond	Virginia
4	Augusta	Georgia
5	Montgomery	Alabama
6	Tallahassee	Florida
7	Nashville	Tennessee
8	Indianapolis	Indiana
9	Columbus	Ohio
10	Lansing	Michigan
11	Minneapolis	Minnesota
12	Madison	Wisconsin
13	Des Moines	Iowa
14	Jefferson City	Missouri
15	Peoria	Illinois
16	Little Rock	Arkansas
17	Jackson	Mississippi
18	Austin	Texas
19	Oklahoma City	Oklahoma
20	Abilene	Kansas
21	Kearney	Nebraska
22	Bismark	North Dakota
23	Pierre	South Dakota
24	Helena	Montana
25	Casper	Wyoming
26	Denver	Colorado
27	Phoenix	Arizona
28	Salt Lake City	Utah
29	Yakima	Washington
30	Bend	Oregon
31	Fresno	California

Transportation activities were included in the models only if there was opportunity for them to be used. It was reasonable to include activities for the movement of feed grains from the Corn Belt into the New England states, but the opposite would not be reasonable. Likewise, we would not expect wheat to be shipped into Kansas or Montana from the Corn Belt or the Southeast. Hence, the final number of transportation activities was 459 each for wheat and feed grains and 430 for oilmeals, giving a total of 1,348 transportation activities.

EMPIRICAL RESULTS

The three linear-programming models were used to generate 17 solutions. Code numbers (table 5) were used to identify each of the solutions. Solution 43 was considered a benchmark solution, since normal prices were used and no crop-control program was assumed. It was used as a comparison for most other solutions of Model I and for several solutions of models II and III.

Table 5. Percentages of base acreages and total cropland and assumed price level of each solution.[a]

	Solution code number	Total land	Cotton base	Wheat base	Feed grain base	Price level[b]
Model I	40	100	100	unl.[c]	100	3
	43	100	100	100	100	3
	47	100	100	90	100	3
	41	100	100	100	100	1
	45	100	100	100	100	5
	51	100	100	100	unl.	3
	52	100	100	100	97.5	3
	53	100	100	100	95.0	3
	54	100	100	100	92.5	3
	36	100	200	unl.	unl.	3
Model II	402	100	100	unl.	100	3
	432	100	100	100	100	3
Model III	403	100	100	unl.	100	3
	433	100	100	100	100	3
	473	100	100	90	100	3
	513	100	100	100	unl.	3
	543	100	100	100	92.5	3

[a] Soybean production was limited to 40 percent of total cropland in each region where grown, except as noted earlier in the text.

[b] These are the same price levels explained for table 2.

[c] **Unlimited** implies that no restrictions, other than total cropland, were used to limit production of that crop.

Solutions 40 and 47 were a study of the possibilities of land retirement programs for wheat. Solutions 51 to 54 were designed to observe methods of controlling feed-grain supplies. The effects of changes in the price level of farm products are evident in the results of solutions 41 (low price level and large demand quantity), 43 (normal price level and demand quantity) and 45 (high price level and small demand quantity). A simulated two-price plan for wheat was used throughout the solutions of Model I.

Solution 36, from Model I, was aimed at no particular crop. Production restraints for this solution were assumed to be physical rather than institutional. Soybeans, again, were limited to 40 percent of total cropland, and cotton was limited to 200 percent of its base acreage. Wheat and feed grains were limited only by cropland availability. The results of this solution estimate the expected long-run equilibrium effects of having a minimum of government influence in agricultural production decisions (i.e., the production result if free markets were used as a policy).

Model II simulated a one-price plan for wheat, as compared with a two-price plan for Model I. The acreage restraints for solutions 402 and 432 under Model II were the same as for their counterpart solutions 40 and 43 under Model I. Thus, the effects of the price assumption for wheat can be isolated by comparing these two sets of results.

Model III emphasized different land qualities within a producing region. The total land restraint for each region was divided into three parts, depicting the three land qualities. The demand and resource constraints of solutions in this model correspond exactly to solutions of Model I. (Solution 403 corresponds to solution 40 in Model I, while solution 513 corresponds to 51, etc.)

A specific price level and the resulting demand have been specified in every model solution. Each solution is a simulated expression of a particular land-retirement program (except solution 36 as just explained). Both mandatory and voluntary land-retirement methods, sometimes in combination, are considered in the simulated program. For example, solution 47 forces the retirement of 10 percent of the wheat base in every region. Further restriction of wheat production was necessary in some producing regions to cause aggregate production to equal aggregate demand. This additional retirement of wheat land can be termed voluntary. It could be brought about by incentive payments to farmers in the short run or by normal adjustments to equilibrium prices in the long run.

The discussion that follows explains and interprets the results of the various programming solutions indicated in table 5. Only the more relevant and important aspects of each solution and their implications are discussed in this report.[20] The discussion relates especially to regional patterns of land use, programmed equilibrium prices of products and factors, and interregional product flows resulting from each major program alternative. Some of the basic solutions are presented and discussed in detail. Others are described only as they differ from the basic solutions.

Results of Model I

Model I: Benchmark solution 43

Solution 43 has been designated as a benchmark situation and will be used as a basis for comparison with results of several other simulated production programs or policies. The results under solution 43 simulate those that might be approximated under the long-run equilibrium adjustment of agriculture to a competitive market, or to a voluntary farm program resulting in land withdrawal at lowest public cost (with production just equal to national requirements at the "normal" price level in both cases). No crop of the study in any region could exceed 100 percent of its historic maximum (base) acreage. Soybeans, as in all model solutions, were restricted to not more than 40 percent of available cropland in each region, except as noted earlier.

Model I, as well as others, assumes that demand is exactly satisfied from current production, although normal stocks also could be carried at the price level specified in table 5. The regional crop acreages indicated, including the land withdrawn from production, could result from market equilibrium forces or voluntary reductions in crop production through incentive payments in the most efficient national pattern. However, the model also could be consistent with other assumptions: It could be assumed that total demand is greater than

[20] The detailed results of all solutions are available from Earl O. Heady, Department of Economics and Sociology, Iowa State University, Ames, Iowa.

production generated within the model and that the difference is supplied by changes in stocks of farm products. Similarly, it might be assumed that the regional production quotas are restraints on actual units of production rather than on acreage. (Since fixed coefficients of production were used in the programming model, this assumption would not affect producing patterns.)

Wheat, beyond that required for food and exports, can be used for livestock feed at no expense above the normal production costs.

Allocation of production and surplus land. The regional pattern of land use under solution 43 is shown in fig. 3. Most producing regions produce at least one crop under this benchmark solution. Although crops were limited to 100 percent of their base acreages, adjustment of crop production within and among producing regions could still occur. Only 80 percent of the total base acreages of wheat and feed grains was necessary to meet the specified demand requirements, given the "normal" level of prices, for 1965. About 76 percent of the total cotton base was required. Soybeans, with an upward trend in demand over recent years, required more than the historical base acreage for 1965. Approximately 82 percent of the 223.9-million base acres of cropland for wheat, feed grains, cotton and soybeans was needed to satisfy all demands.

In comparison with the base acreage, 40.5 million acres are not needed to meet the projected national demands for 1965. Hence, 40.5-million acres of surplus land can be considered as surplus, for the stated price level, and could be shifted to other uses. This amount of land is surplus for the specified crops if crops were allocated among regions—with production to "just match demand." The allocation would be most efficient in terms of the objective function used in the study. Of course, the amount of surplus land does not exceed by 40.5 million acres the acreage used for production at the time of the study. Some land had already been diverted through the feed-grain program, the Conservation Reserve and wheat and cotton allotment programs. However, the 40.5-million acres is one expression or measurement of the extent of excess capacity in the United States field-crop economy for 1965.

A comparison of actual crop production in 1962 with the pattern of crop production suggested by benchmark solution 43 is provided in table 6. Where differences between derived production patterns and the actual 1962 production patterns occur, the time trend mainly is toward the location of production suggested by the model. Given time and the removal of artificial barriers to shifts of production, such as quotas on wheat and feed grains holding them to their historic locations, the actual production patterns will approach those of solution 43.

The largest discrepencies between the model solution

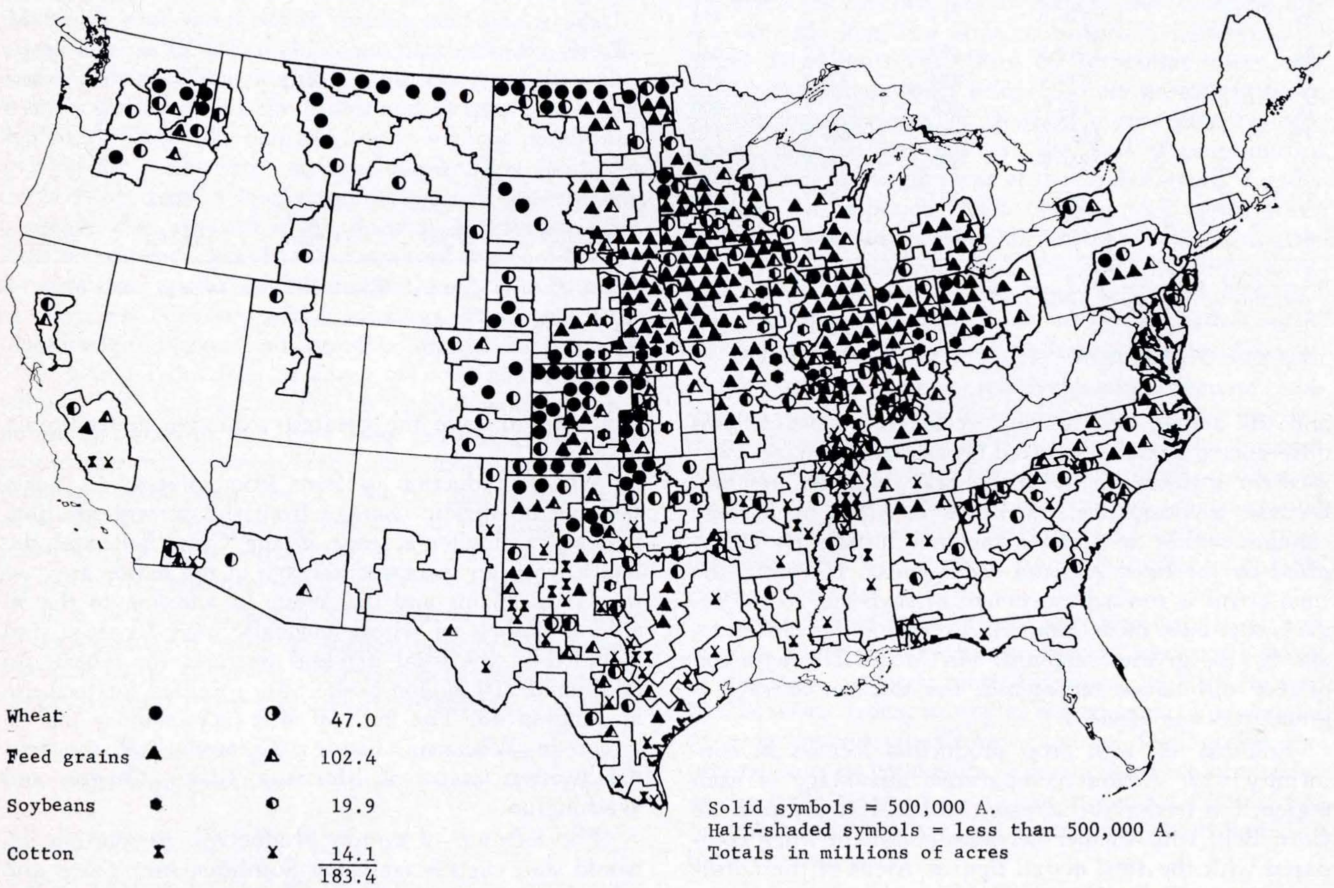

Fig. 3. Model I—Regional location and acreage of crop production for solution 43.

Table 6. Acreage[a] (thousands) of wheat, feed grains, cotton and soybeans in 1962 compared with solution 43, by consuming region.

Region	Wheat		Feed grains		Soybeans		Cotton		Unused land
	solution 43	1962	solution 43	1962	solution 43	1962	solution 43	1962	solution 43
	(thousands of acres)								
1	[b]	..	[b]	68	..[b]	..	..[b]	..	..
2	936.3	832	2,608.5	3,161	371.8	555	..	..	37.5
3	193.0	401	2,716.5	2,479	..	..	84.7	417.0	1,246.0
4	257.7	103	752.3	2,567	223.2	947	178.9	1,267.0	5,969.9
5	1.4	35	1,185.1	1,322	94.6	720	767.4	900.0	1,776.6
6	..	..	..	289	..	39	59.9	20.6	558.1
7	196.1	238	2,880.4	2,323	304.0	682	785.9	546.7	287.4
8	997.0	1,096	6,029.3	4,951	2,356.2	2,761	..	..	..
9	907.7	1,209	4,945.7	3,541	1,422.3	1,808	..	..	748.3
10	510.3	922	2,706.2	2,224	..	351	..	..	831.4
11	1,760.8	731	10,210.0	8,624	775.0	2,294	..	..	787.8
12	55.3	48	4,528.0	3,792	31.1	101	..	..	30.1
13	87.8	88	16,240.4	12,818	2,106.4	3,405	..	..	..
14	1,051.2	976	4,966.7	3,632	1,771.2	2,784	396.3	383.0	185.7
15	1,045.6	1,522	12,144.7	9,852	4,724.5	5,575	..	2.0	81.8
16	49.7	112	..	353	388.2	2,707	1,315.3	1,355.0	1,721.2
17	45.4	70	165.0	1,166	23.7	1,347	1,712.9	2,150.0	3,833.4
18	2,550.6	2,731	6,446.6	7,174	169.9	60	7,021.9	6,473.0	738.9
19	5,673.8	3,787	1,284.2	1,647	161.6	171	880.3	625.0	1,066.4
20	9,561.5	8,986	4,677.9	5,298	909.5	914	..	..	2,930.3
21	2,250.2	2,760	7,191.4	7,808	3,919.7	310	..	..	1,095.9
22	5,460.2	5,519	1,850.9	4,894	..	56	..	..	6,729.9
23	1,416.3	1,721	6,376.7	5,773	137.3	121	..	..	3,746.7
24	5,422.8	4,422	..[c]	2,881	..	..	..	..	3,530.6
25	125.1	213	..[c]	214	..	..	..	..	405.9
26	2,519.0	1,899	337.7	1,040	..	..	..	..	1,015.9
27	111.4	234	271.7	486	..	..	47.2	661.6	982.3
28	184.7	206	..[c]	200	..	..	..	3.5	99.0
29	2,627.6	1,697	508.8	752	..	..	..	..	75.4
30	750.9	680	217.8	581	..	..	..	..	..
31	257.3	307	1,189.7	1,924	..	..	863.1	809.6	..
Total	47,006.7	43,545	102,432.2	103,766	19,890.2	27,857	14,113.8	15,614.2	40,512.4

[a] Harvested acres for 1962 are shown. Taken from: Crop Production, 1962 Annual Summary. U.S. Dept. Agr. 1956-62. 1957-63.

[b] Recall that some production was included in the unmarked areas of fig. 1 and, thus, is not shown here.

[c] Wheat is indicated to be used extensively for a feed grain in these areas.

and the actual 1962 acreage occur for soybeans. This difference may have occurred because the demand specified for soybeans in the model was relatively low and because soybeans are responsive in yield to acreage changes within an area (a fact not sufficiently recognized by the fixed regional coefficients). However, the time trend is toward movement of soybeans to the regions that have model solutions exceeding the 1962 acreage by the greatest amount. (In Model III, with soil quality differences recognized, the soybean acreage is greater than in Model I.)

Solution 43, with crop production located in conformity with greatest comparative advantage of each region, has feed-grain acreages which shift towards the Corn Belt, with smaller acreages elsewhere when compared with the 1962 actual figures. Areas of the northearn Great Plains (North Dakota and Montana) are indicated to have the greatest reduction in feed-grain acreage.

Wheat-production patterns from solution 43, while showing no drastic changes from the current location, indicate a smaller acreage in the Corn Belt and the South, with an increased acreage in the major areas of the Great Plains and the West. In addition to the 50 million bushels of wheat normally used for feed and included in the total demand restraint for wheat, an additional 310 million bushels are specified for feed use in solution 43. The bulk of this increment would be grown in Wisconsin, Kansas, Colorado and the four northwestern states of Montana, Idaho, Oregon and Washington.

The location of cotton production, in solution 43, would shift slightly from the Southeast into Texas and Oklahoma. South Carolina and Georgia would have the greatest loss in acreage. Little cotton acreage was located in New Mexico and Arizona under solution 43.[21]

Interregional product flows. For solution 43, wheat is generally in surplus in the Great Plains states and Montana and in deficit supply elsewhere, fig. 4. North and South Dakota, Nebraska, Kansas and Oklahoma supply most of the excess demand for the eastern half of the United States. Likewise, Montana exports wheat to the Pacific coast regions. The general movement of feed grains (fig. 5) is from the Corn Belt into the southern and eastern states, with Illinois and Indiana being the largest exporters. Kansas and Montana export wheat for livestock feed.

Model I is sensitive with respect to the locational pattern of potential soybean production. Nebraska, because of combined advantages in production and location, serves as a main producer (fig. 3) and the main exporter (fig. 6) of oilmeals to the Pacific states. Nebraska regions also are indicated to export some oilmeals to the Southeast. Otherwise, the central Corn Belt serves as the main source of oilmeal imports by other regions, with Illinois as the largest producer and exporter of soybeans. Cottonseed meal, when available, is specified to satisfy oilmeal demands. However, none of the cotton-producing states exports oilmeals, and only soybean meal is indicated to move among consuming regions.

Figure 7 indicates the amount and location, given the price level specified, of surplus land under benchmark solution 43. It is highly concentrated in the Southeast and in the Great Plains regions. Concentration also is fairly great in the Lake States and along the Atlantic Seaboard. Under the demand and technology conditions used in the study, some far-reaching impacts would be forthcoming from a market equilibrium or government program that resulted in an optimal interregional allocation of production in the context of solution 43 and its specified restraints. Alternative land uses implied are grazing, forestry and recreation. Obviously, the magnitude of regional adjustments implied would cause some sharp reductions in farm incomes and resource values. Too, a large amount of capital would be required to facilitate the shift from existing production patterns to less intensive land use. Finally, entire communities would bear the impact of the adjustments, since the less intensive agriculture so resulting would mean smaller farm populations and a reduced demand for nonfarm goods and services in the specified regions.

It is not the purpose of this study to explore these second-round effects or to suggest policies that would alleviate them. However, the consequences of the shifts suggested are both obvious and important.

Land and quota prices. The "shadow prices" of a cost-minimizing linear-programming model indicate the marginal value of the limiting resources, against the uses specified in this study but not against other uses such as grazing and forestry.[22] Those shadow prices of land and crop quotas, shown in table 7, are termed "rental values" in the discussion that follows.

The rental values of cropland provide an estimate of the relative worth, given the objective function outlined earlier, of an additional unit of cropland in each producing region. If the imputed rental value is zero, cropland for the uses considered in this study was not a limiting factor, and an additional amount of cropland in the region would have no value for the uses specified. On the other hand, if the imputed value is greater than zero, an additional unit of cropland would have an annual rental price for the crops considered.

When restricting, the production quotas or base acreages (table 7) for wheat, feed grains, cotton and soybeans also have nonzero prices. These quota, or base acreage, prices are an estimate of the marginal value of each region's crop quota or base acreage for the individual crop. Programmed equilibrium, or derived product, prices are a reflection of the costs of production and transportation and, under a competitive-market model covering costs of production, would approximate the regional equilibrium price of products. (A small portion of costs, representing taxes and other fixed costs, is not included in the models. Hence, market equilibrium prices would be slightly higher than the levels shown. But this increment also would be offset, over the long run under competitive conditions, by larger farm units and, thus, by somewhat lower unit costs.) Derived product prices also are an indication of the relative efficiency of alternative governmental programs, because they indicate the level of programmed equilibrium prices (the cost of the "bill of goods") under varying assumptions with respect to government policies. Programmed equilibrium of derived prices in one region are determined as the cost, plus transportation, of the highest-cost region that supplies the demand quantity of the first region.

Derived prices for wheat are highest in the eastern states because of their relatively large demand constraints and the locational disadvantage in meeting them. The derived prices of wheat generally diminish westward and are lowest in the large wheat-producing areas of the Great Plains. Location and transportation charges mainly account for differences in wheat price between areas of the West and the highly populated areas of the East.

Derived feed-grain prices also diminish from east to west. However, the lowest derived feed-grain prices of the West are determined by wheat, and not by feed grains, where wheat is used as a feed grain. The derived or programmed equilibrium price of feed grains, expressed as corn equivalent, is about 80 cents per bushel in the large producing states of Iowa and Illinois. (As mentioned previously, a few fixed costs are excluded in these derivations.)

[21] The linear-programming model did not recognize the quality advantage for western-grown cotton. Also, a review of the coefficients of production used for cotton in Model I indicated that perhaps a slight revision of cotton yields was needed. Thus, the cotton yields for producing regions 121, 141, 142 and 143 were raised slightly, and the yield for region 140 was lowered slightly in models II and III.

[22] In general, it can be supposed that rental values are greater than zero (those shown in table 7) for the crops considered.

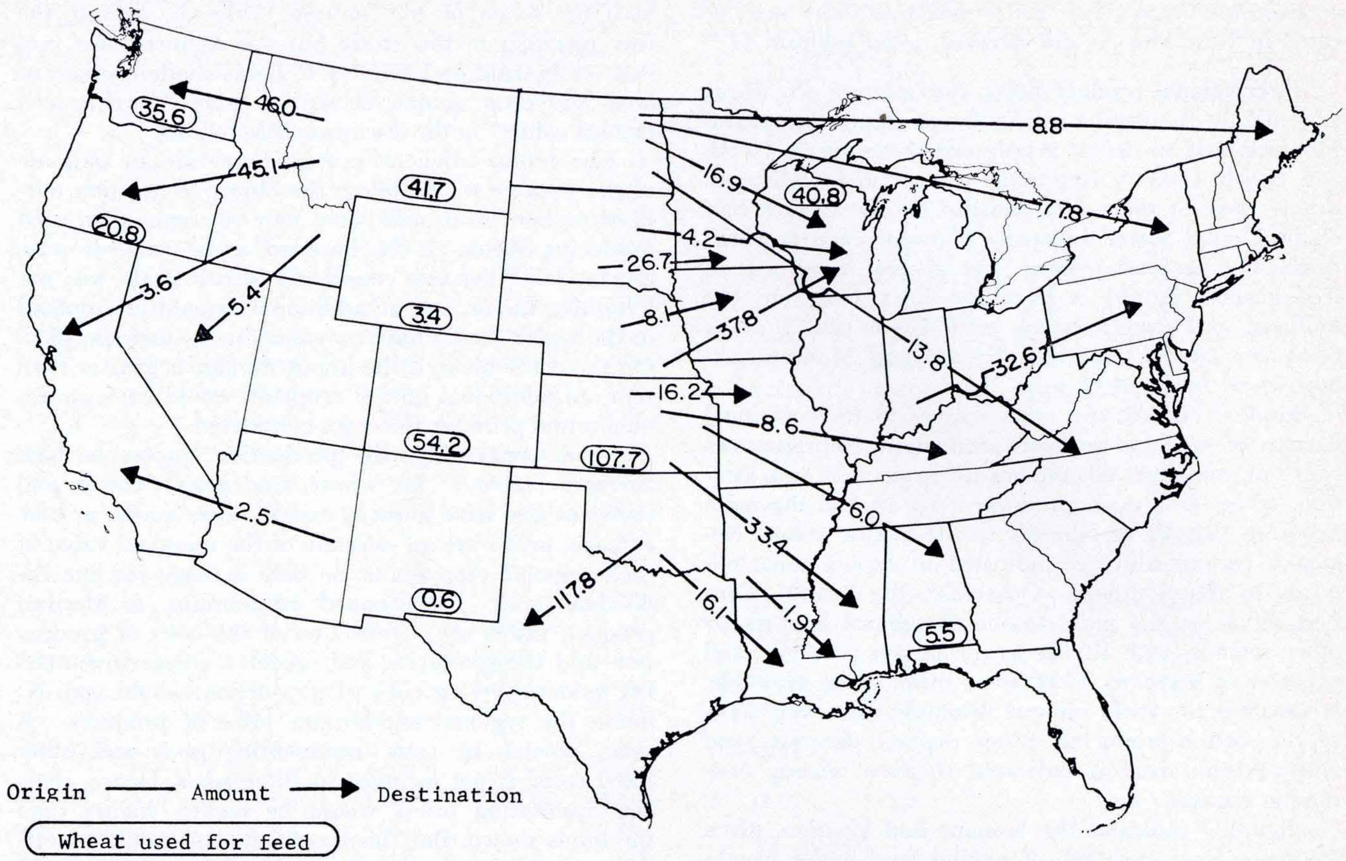

Fig. 4. Model I—Interregional flows of wheat under the conditions of solution 43(million bushels).

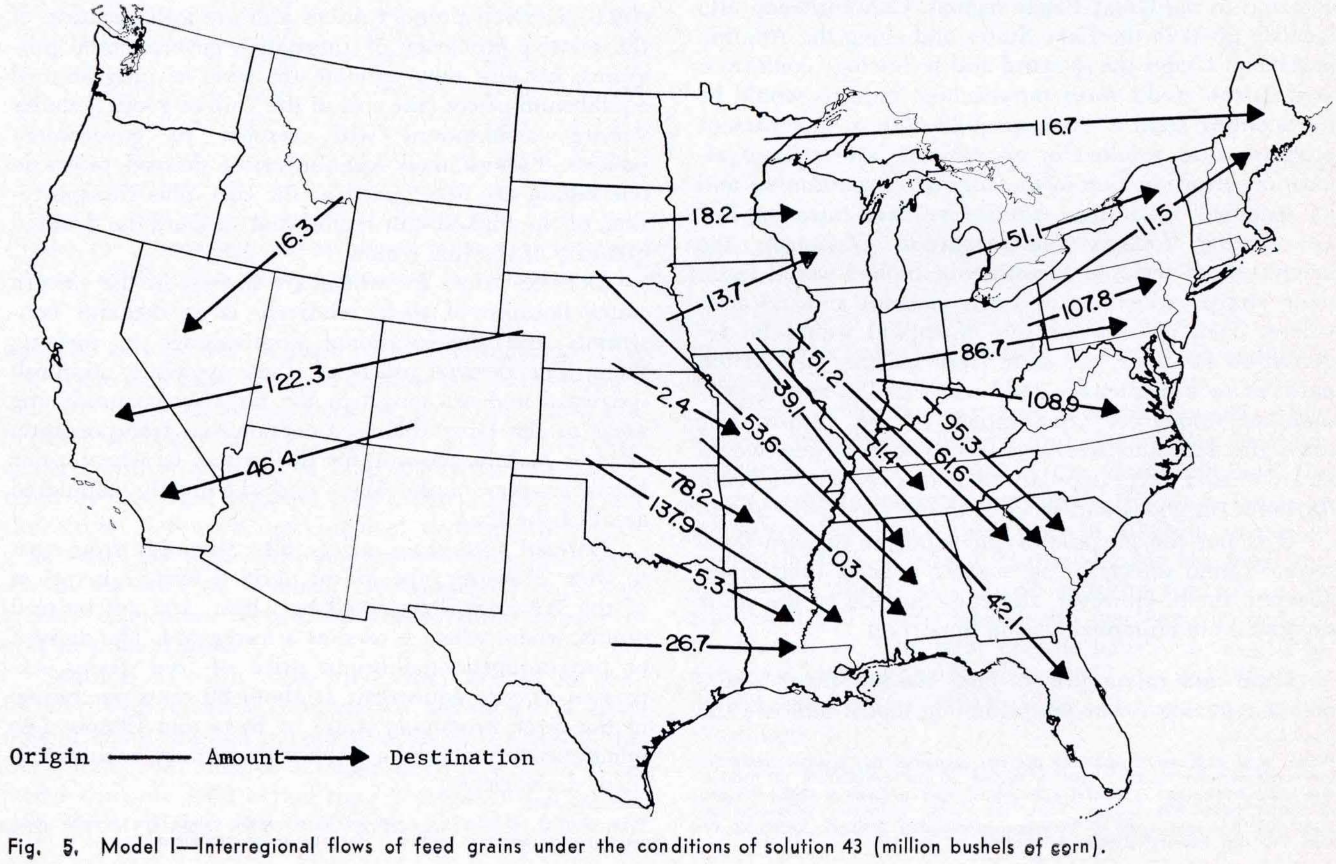

Fig. 5. Model I—Interregional flows of feed grains under the conditions of solution 43 (million bushels of corn).

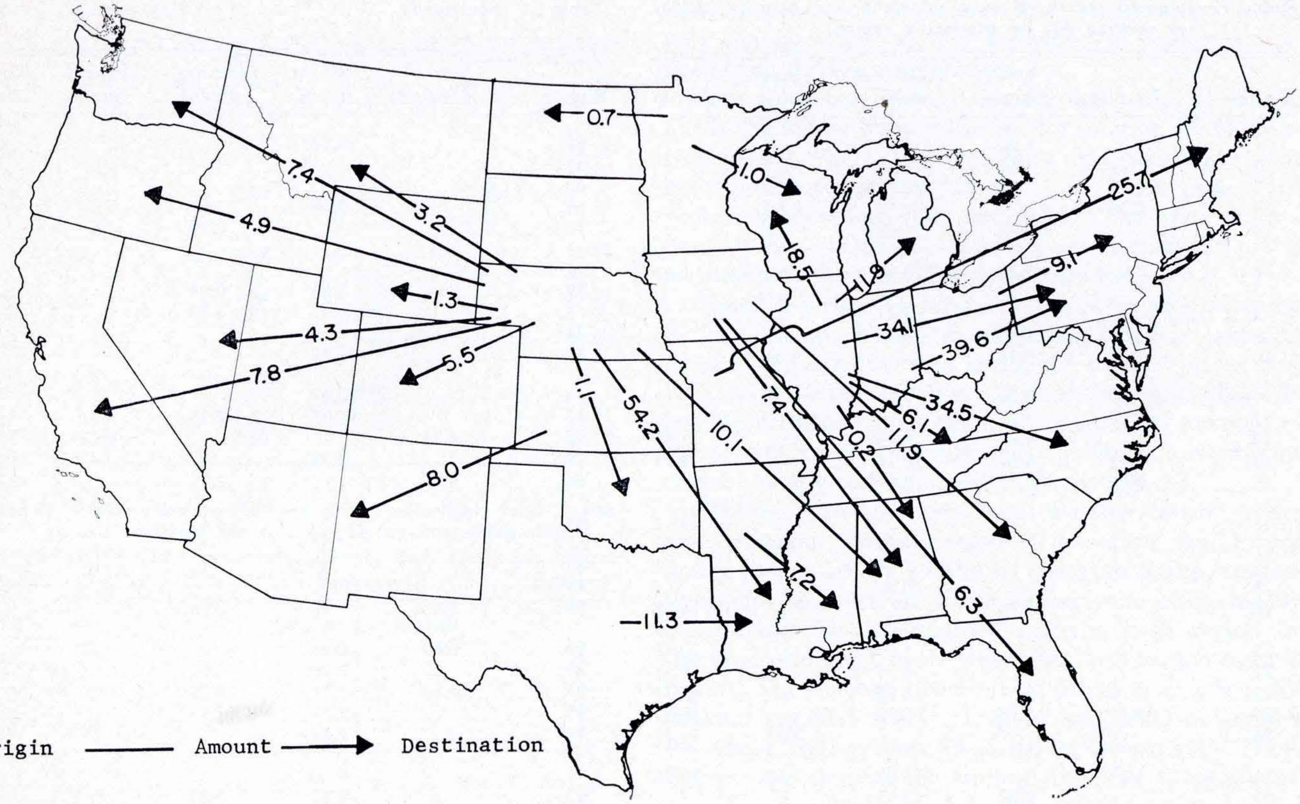

Fig. 6. Model I—Interregional flows of oilmeals under the conditions of solution 43 (million bushels of soybeans).

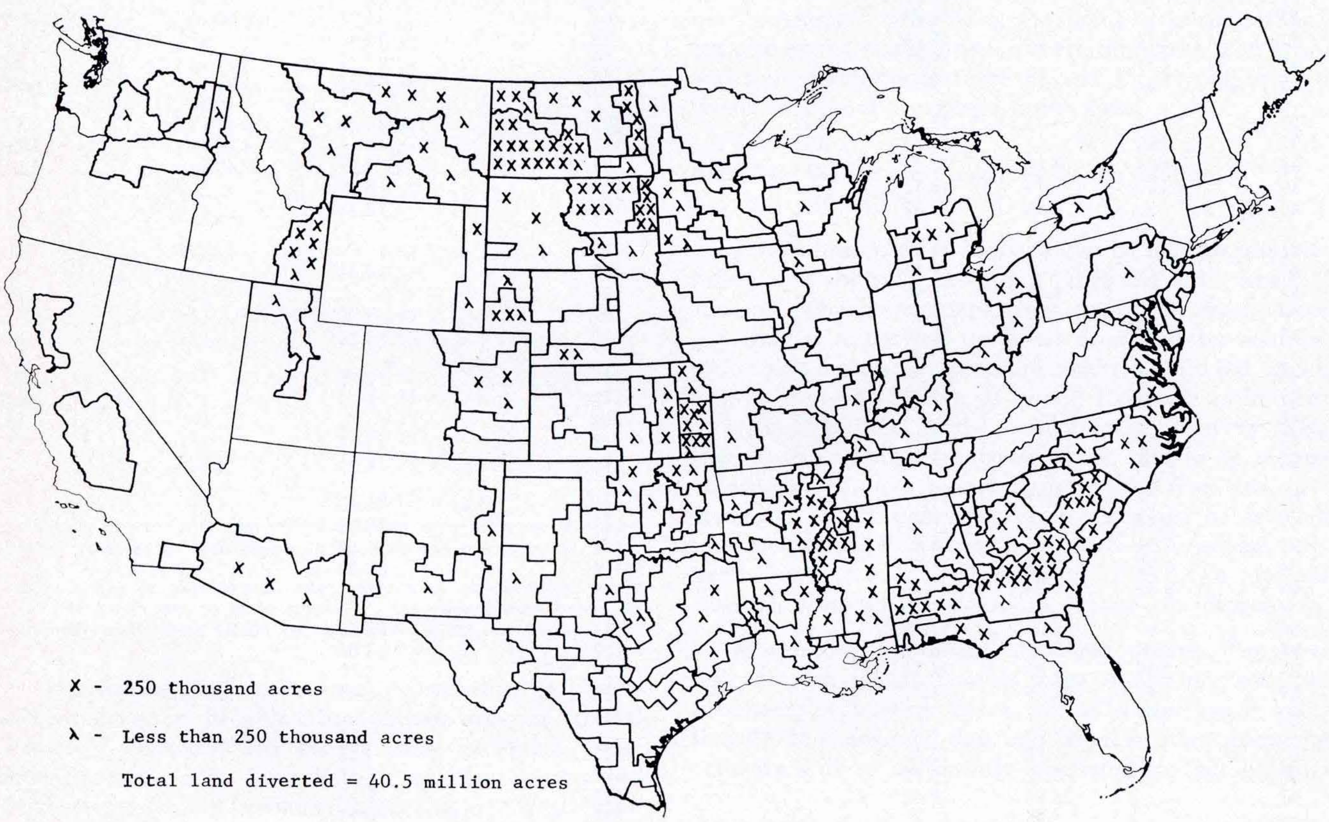

Fig. 7. Model I—Amount and location of surplus land under the conditions of solution 43.

Table 7. Imputed rental values of cropland and acreage quotas for solution 43, by producing region.

Table 7 (continued).

Region	Cropland	Wheat quota	Feed-grain quota	Soybean quota	Cotton quota
1	..	6.60	11.09	..	..
2	..	4.60	24.66	..	..
3	2.45	..	37.51	0.33	..
4	0.55	..	32.86	0.56	..
5	..	4.71	21.88	..	..
6	..	5.78	23.80	..	..
7	..	..	1.56	..	..
8	..	..	3.31	..	..
9	..	3.90	16.81	..	..
10	1.17	5.88	..	5.06	..
11	..	9.53	..	..	..
12	..	4.23	..	..	..
13	..	4.63	3.93	..	3.81
14	2.52	5.02	10.14	..	9.73
15	3.08	3.28	0.89	..	..
16	..	..	..	..	23.11
17	..	..	7.11	0.50	4.67
18	..	..	..	..	..
19	..	..	0.20	..	..
20	..	1.20	..	..	14.28
21	..	..	..	..	10.32
22	..	..	5.51	..	4.81
23	4.10	2.11	6.28	..	45.74
24	0.67	6.73	0.72	..	25.67
25	..	..	..	2.83	31.73
26	6.87	..	15.63	1.68	20.45
27	..	4.00	12.91	..	..
28	..	2.38	19.38	..	8.51
29	..	..	24.22	..	..
30	..	..	18.17	..	..
31	..	..	13.21	..	..
32	..	..	10.67	..	..
33	2.74	..	19.76	..	..
34	2.33	..	19.07	..	..
35	2.52	1.18	29.50	..	..
36	..	..	16.96	2.07	..
37	4.98	..	23.78	0.97	..
38	4.74	4.11	22.77	..	..
39	5.80	9.73	18.32	..	..
40	..	0.50	12.82	..	..
41	..	..	1.58	..	..
42	..	..	1.44	..	..
43	..	8.16	16.45	..	..
44	..	5.49	26.09	..	..
45	5.27	1.71	15.12	..	..
46	2.14	..	18.99	..	..
47	12.23	..	18.68	..	..
48	..	..	10.68	1.04	..
49	1.48	3.34	10.48	..	..
50	7.08	1.76	17.44	..	33.37
51	..	4.73	11.11	..	..
52	9.93	..	16.47	..	..
53	7.54	..	16.89	1.42	..
54	2.85	2.53	11.50	..	..
55	4.85	6.24	17.79	..	..
56	..	8.03	13.76	..	..
57	0.07	5.00	20.11	..	..
58	2.05	5.88	18.34	..	..
59	3.44	2.15	11.71	..	..
60	1.47	..	2.83	..	..
61	..	1.10	12.45	..	..
62	..	3.32	0.78	..	..
63	..	15.58	3.45	..	..
64	..	4.25	..	..	..
65	..	3.60	..	..	..
66	..	3.92	..	..	..
67	..	..	..	..	..
68	..	..	..	..	..
69	..	3.00	..	..	..
70	..	..	0.29	..	..
71	..	..	..	..	..
72	..	3.54	0.04	..	..
73	..	..	3.38	..	..
74	7.67	..	..	..	..
75	..	8.77	..	..	..
76	..	10.27	..	..	..
77	..	10.35	7.39	..	..
78	4.33	..	..	0.03	..
79	..	9.25	..	7.47	..
80	4.45	..	2.99	..	..
81	..	..	6.37	..	..
82	..	..	..	..	..
83	..	..	..	..	..
84	..	..	..	0.74	..
85	0.65	4.41	0.06	..	..
86	0.80	0.86	..	..	..
87	..	2.96	5.07	..	..
88	2.86	7.71	6.08	..	..
89	..	11.22	13.38	..	..
90	..	2.67	..	..	..
91	..	9.30	..	..	..
92	..	9.67	0.83	..	..
93	..	5.85	..	..	..
94	..	10.36	2.51	..	56.32
95	2.95	20.29	14.82	..	147.51
96	..	16.18	1.91	..	53.05
97	..	18.71	6.00	..	121.44
98	..	12.40	..	7.77	25.78
99	..	13.47	4.13	..	11.20
100	..	20.31	1.29	..	40.52
101	..	19.75	0.47	..	30.71
102	..	..	4.20	..	55.58
103	..	9.93	9.40	..	78.71
104	..	4.12	..	..	..
105	..	3.24	..	..	..
106	..	..	..	..	..
107	..	0.38	..	..	..
108	..	..	..	..	..
109	..	9.28	..	..	..
110	..	3.28	..	..	..
111	..	8.55	..	..	..
112	..	8.09	..	..	28.30
113	..	..	..	..	..
114	..	14.95	..	..	..
115	..	4.33	..	..	..
116	11.21	15.40	..	..	..
117	..	15.93	6.03	..	..
118	..	18.58	5.62	..	..
119	..	13.03	..	..	..
120	..	35.11	5.94	..	..
121	..	23.46	10.24	..	73.60
122	..	3.06	..	..	..
123	..	5.10	..	..	..
124	..	5.24	..	..	..
125	..	..	..	..	19.68
126	..	4.52	..	..	..
127	..	5.55	..	..	61.95
128	..	5.15	..	..	20.64
129	..	0.93	..	..	..
130	..	..	..	..	39.03

Table 7 (continued).

Region	Cropland	Wheat quota	Feed-grain quota	Soybean quota	Cotton quota
131.........	..	..	..	..	..
132.........	..	..	..	..	32.36
133.........	..	..	..	..	45.42
134.........	..	5.99	0.27	20.26	..
135.........	..	6.17	..	3.11	..
136.........	..	6.29	..	..	15.45
137.........	.	..	5.67	..	89.20
138.........	..	11.68	2.72	..	29.53
139.........	..	4.91	2.21	..	51.70
140.........	..	..	5.80	..	166.88
141.........	..	..	..	..	..
142.........	..	18.05	32.92	..	..
143.........	..	39.42	7.59	..	66.51
144.........	..	3.80	..	..	29.47

Table 8. Programmed equilibrium prices of wheat, feed grains and soybeans for solution 43, by consuming region.

Region	Wheat	Feed grains[a]	Soybeans[b]
		(dollars per bushel)	
1	1.44	1.27	1.21
2	1.39	1.22	1.26
3	1.41	1.24	1.27
4	1.47	1.30	1.15
5	1.48	1.28	1.12
6	1.47	1.30	1.16
7	1.34	1.14	1.04
8	1.06	0.92	1.00
9	1.10	0.95	1.03
10	1.09	0.90	1.12
11	1.08	0.73	0.87
12	1.10	0.98	1.02
13	1.08	0.78	0.86
14	1.09	0.94	0.91
15	1.07	0.80	0.91
16	1.17	0.80	0.96
17	1.38	1.08	1.08
18	1.24	0.63	0.85
19	0.81	0.65	1.01
20	0.73	0.65	0.91
21	0.72	0.62	0.83
22	0.64	0.51	1.10
23	0.66	0.58	0.81
24	0.51	0.45	1.35
25	0.57	0.50	1.05
26	0.67	0.60	0.97
27	0.97	0.86	1.33
28	1.03	0.85	1.35
29	0.87	0.77	1.35
30	0.96	0.85	1.35
31	1.31	1.10	1.35

[a] Feed-grain prices are expressed in corn-equivalent prices.

[b] Portion due to oilmeal uses only; value from oil extracted would need to be added to these amounts. (If soybeans were produced only for feed, these would be their only values.)

Derived oilmeal prices are expressed as soybean-equivalent prices in table 8 and include only the oilmeal values of soybeans, with the oil value excluded. These prices are lowest in Corn Belt areas where production of soybeans mainly is concentrated (fig. 3). West Coast states, supplied by Nebraska, all have about the same derived prices of soybeans. The programmed prices vary among states, mainly according to transportation costs from the Corn Belt source.

The national derived equilibrium price of cotton lint is $31.99 per hundredweight for solution 43. Cottonseed prices, when computed on a feed-unit equivalent basis, averaged about $28 per ton. These prices approach the present price structure. (The price of soybeans is low when compared with existing market prices because only the oilmeal value is included.)

Since the costs of production used in programming did not include items for marketing, housing, management and other overhead items, the derived prices may be around 10 percent lower than they would otherwise be. Nevertheless, their relative magnitudes among regions still reflect programmed equilibrium conditions and the relative advantage of different regions.

The estimated United States average "farm" prices (i.e., prices in producer regions) for wheat, feed grains and soybeans are 83, 83 and 93 cents per bushel, respectively, for solution 43. These figures were estimated by multiplying the programmed price in each region by the proportion of United States total production in each region. The average "consumer" prices (i.e., prices for demand regions) are $1.11, $0.92 and $1.07 per bushel for wheat, feed grains and soybeans, respectively. These figures are derived by multiplying the programmed equilibrium price in each region by the proportion of total product consumed in that region. The price of wheat increases approximately 34 percent between the "farm" level (i.e., from the point of production) and the "consumer" price (i.e., the point of consumption) because of the transportation costs. Similarly, feed-grain and soybean prices increase 11 and 15 percent, respectively, as a result of transportation costs.

Model I: Wheat programs reflected in solutions 40 and 47

Two solutions from Model I can be used to simulate production-control programs directed at wheat.[23] Among others, two departures might be made from the mildly restrictive program simulated by solution 43: (a) A mandatory program might be selected which is even more restrictive. It would force the retirement of a fixed portion of the base acreage in every area, leaving the remaining surplus wheat land to be retired voluntarily through monetary incentives from the government. (b) A voluntary program might be selected with no quotas for wheat and with government payments used to enlist participation. These two alternatives are simulated by solutions 47 and 40, respectively.

Mandatory retirement of wheat quotas. Ten percent of the wheat base acreage, uniformly over all producing regions, is forced out of production in solution 47. It is assumed that additional surplus-producing capacity will be voluntarily restricted so that produc-

[23] In discussion of solutions 40 and 47, output comparisons will be made with solution 43 unless otherwise stated.

tion will exactly meet demand at the assumed price level (level three or normal prices). The voluntary portion of the wheat-land retirement would be brought about by incentive payments from the government.

Under the plan suggested by solution 47, 44.3 million acres are used for wheat production, 105.1 million acres for feed grains and 19.9 million acres for soybeans (table 9). Cotton acreage is unchanged from solution 43. The production patterns suggested by this solution are illustrated in fig. 8. (Figures for interregional movements of products are not shown, since the patterns are changed only slightly as compared with solution 43.)

Since solution 47 requires that all regions reduce wheat acreage by 10 percent from their base, with a national wheat base acreage of 58.5 million acres, wheat must be reduced by at least the mandatory requirement of 5.9 million acres. But since the remaining 52.6 acres would, if planted to wheat, exceed the demands for domestic and export constraints, additional land must be withheld from wheat. The model allows the additional acreage to be withdrawn at the most efficient locations; namely, in regions distributed such that the national costs of producing the indicated bill of goods is at a minimum—subject to the requirement that all regions reduce wheat acreage by a minimum of 10 percent.

Since 10 percent of wheat land in every region is forcibly retired by solution 47, national production costs are minimized by use of 2.7 million fewer total acres for wheat production than under solution 43 (compare table 9 with table 6). This is a 5.7-percent reduction in the acres of wheat grown, or a 6.4-percent reduction in amount of wheat produced. The same amount of wheat is used for food, but less is used for feed. Feed-grain acreage increases by exactly 2.7 million acres under solution 47. Most of the increased feed-grain acreage occurs in Nebraska, Kansas and North Dakota.

Soybean production is not greatly affected by the regionally-forced reduction plan for wheat. While about 28.5 thousand fewer acres are needed for soybean production, Nebraska has a substantial decrease in soybean production. A decline is required in Nebraska so that feed grains can be produced most efficiently within the context of a 10-percent wheat acreage reduction in all regions. The total surplus land indicated by solution 47—40.6 million acres—is practically the same as that indicated by solution 43. The distribution of unused land for solution 47 also is quite similar to that for solution 43. However, as fig. 9 shows, unused land would decline in such regions as northeast Colorado and southern Nebraska but would increase in Washington, Oregon, northern Montana, northern Oklahoma, western Missouri and other scattered regions.

Derived product prices are not greatly changed by the regional wheat quotas used as restraints in solution 47. Derived wheat prices are increased, compared

Table 9. Acreage (thousands) of wheat, feed grains, cotton and soybeans in 1962 compared with solution 47, by consuming region.

Region	Wheat	Feed grains	Soybeans	Cotton	Total used	Total unused
1....	..	..	..	..	..	..
2....	844.3	2,608.5	371.8	..	3,824.6	129.5
3....	237.4	2,716.5	..	84.7	3,038.6	1,201.6
4....	232.0	753.5	231.1	178.9	1,395.5	5,986.5
5....	1.3	1,185.1	94.6	767.4	2,048.4	1,776.7
6....	..	..	..	59.9	59.9	558.1
7....	176.5	2,880.4	308.1	785.9	4,150.9	302.9
8....	899.1	6,029.3	2,454.1	..	9,382.5	..
9....	907.8	4,945.7	1,422.2	..	7,275.7	748.3
10....	507.4	2,706.2	..	..	3,213.6	834.3
11....	1,584.8	10,210.0	778.3	..	12,573.1	960.5
12....	49.7	4,528.0	32.1	..	4,609.8	34.7
13....	79.0	16,240.4	2,115.2	..	18,434.6	..
14....	1,010.8	4,966.7	1,773.2	396.3	8,147.0	224.1
15....	1,046.7	12,144.7	4,760.4	..	17,951.8	44.8
16....	44.8	..	388.2	1,315.3	1,748.3	1,726.1
17....	40.9	165.0	24.4	1,712.9	1,943.2	3,837.2
18....	2,295.6	6,446.6	298.7	7,021.9	16,062.8	865.1
19....	5,106.3	1,284.2	161.6	880.3	7,432.4	1,633.9
20....	8,605.5	5,732.2	845.4	..	15,283.1	2,796.1
21....	2,025.2	7,921.1	3,564.7	..	13,511.0	946.2
22....	5,963.3	2,760.2	..	..	8,723.5	5,317.5
23....	1,274.6	6,376.7	137.3	..	7,788.6	3,888.4
24....	5,262.4	..	..	..	5,262.4	3,691.0
25....	269.1	..	..	..	269.1	261.9
26....	2,267.2	337.7	..	..	2,604.9	1,267.7
27....	100.3	288.3	..	47.2	435.8	976.8
28....	166.2	..	..	..	166.2	117.5
29....	2,364.9	508.8	..	..	2,873.7	338.1
30....	675.8	218.0	..	..	893.8	74.9
31....	231.6	1,189.7	..	863.1	2,284.4	25.7
Total ..	44,270.4	105,143.5	19,861.5	14,113.8	183,389.2	40,566.1

with solution 43, by 1 or 2 cents per bushel in the eastern half of the United States and by about 6 cents in the western states. Feed-grain prices, expressed in corn-equivalent prices, are changed even less—2 cents per bushel being the maximum change in any region. Derived regional soybean prices are increased by about the same amount as feed-grain prices. Derived soybean prices decrease, however, in Kansas, Oklahoma, New Mexico and Arizona because of the forced shift in wheat acreages. Kansas, substituting soybeans for wheat, is able to export oilmeals to the states just mentioned and to lower the programmed equilibrium price for soybeans in these consuming regions.

Unlimited wheat acreage under solution 40. Solution 43, the benchmark situation, requires all regions to restrain wheat acreage to the 1953 base level. Solution 47 requires that all 144 regions reduce their wheat acreage by 10 percent or more, relative to solution 43. In contrast, solution 40 allows all acreage restrictions to be lifted on wheat in all regions. This crop can be extended to the limit of all cropland in any region, although other feed grains and cotton cannot exceed the 1953, or base, level and soybean acreage cannot exceed 40 percent of the land in any region. Total national wheat production in solution 40 is limited to the

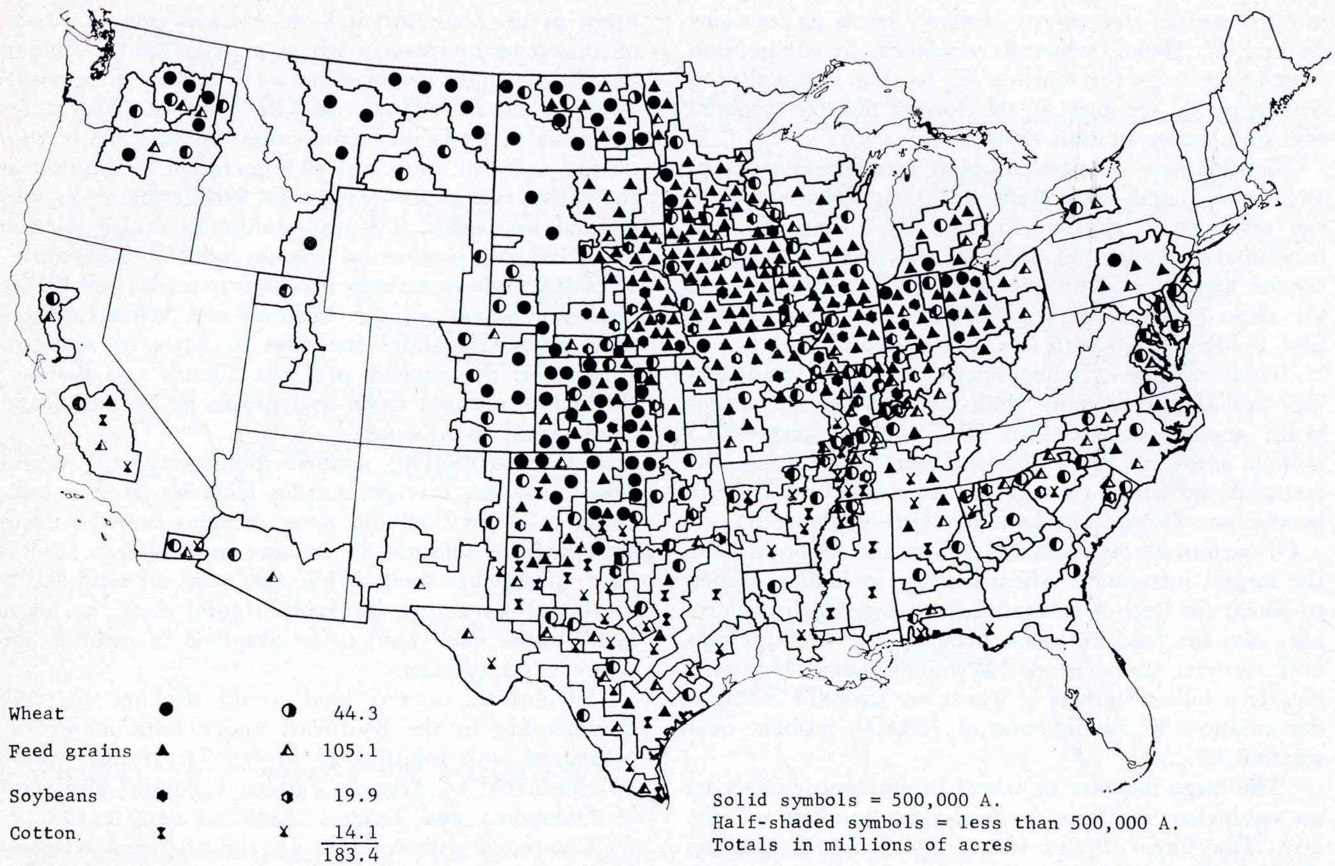

Fig. 8. Model I—Regional location and acreage of crop production for solution 47.

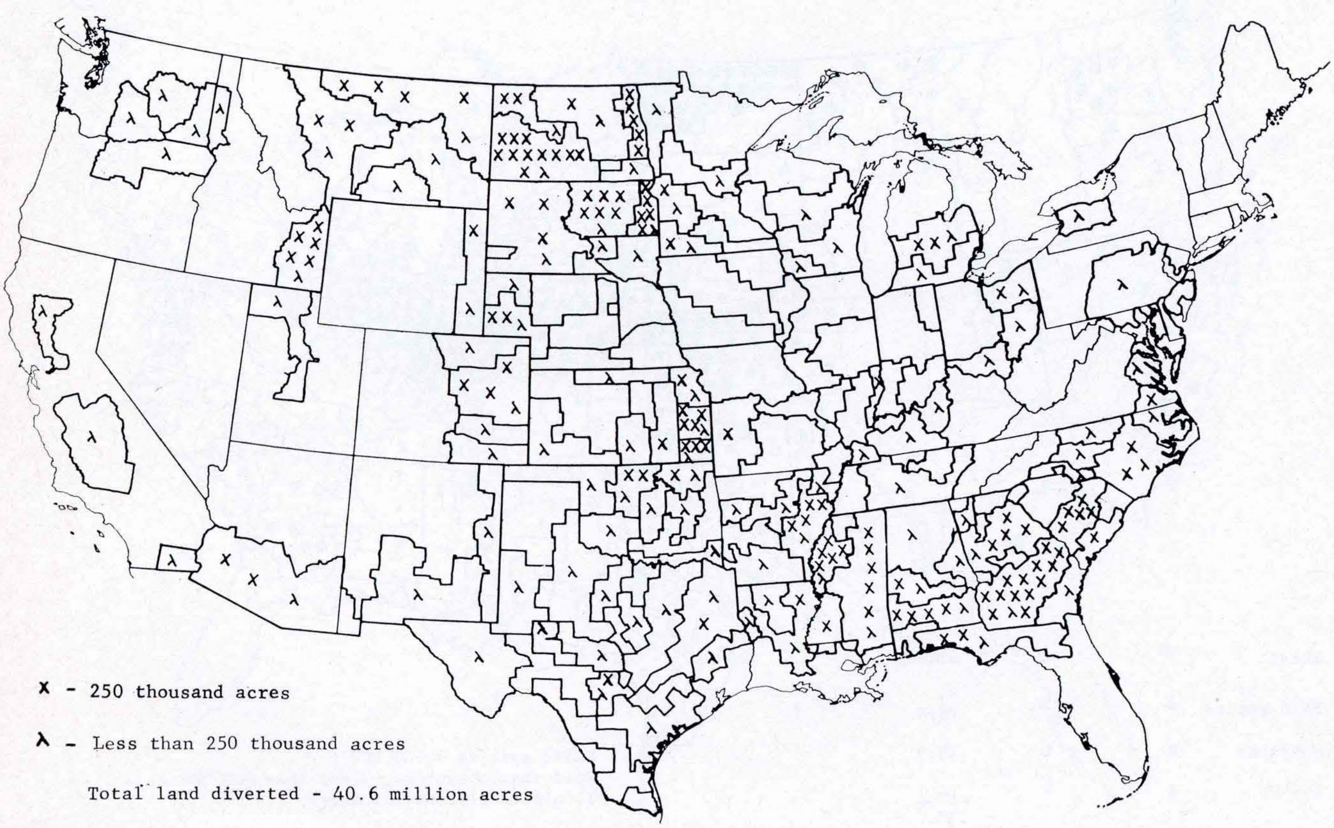

Fig. 9. Model I—Amount and location of surplus land under the conditions of solution 47.

same domestic and export demand levels as solutions 43 and 47. Hence, wheat is produced, in competition with other crops for solution 40, so that national crop requirements are met at the lowest possible production and transportation costs.

Considerable changes in crop production patterns and unused land result with relaxation of wheat acreage restraints in solution 40 (fig. 10). Compared with benchmark solution 43, the use of wheat for feed increases greatly, and the interregional flows of products are altered accordingly as evidenced in comparison of figs. 11, 12 and 13 with figs. 4, 5 and 6.

Total acreage of wheat increases to 73.7 million—26.7 million acres more than for solution 43. Feed-grain acreage decreases to 78.0 million acres—24.5 million acres less than for solution 43. Lifting the restraints on wheat acreage has little effect on soybean production. Cotton production is left unchanged.

Of eastern states, South Carolina and Georgia have the largest increase in wheat acreage as land is shifted to wheat for feed. A substantial increase in wheat acreage, also for feed purposes, occurs in all Great Plains and western states except Wyoming and Montana. Nearly a billion bushels of wheat are used for feed under solution 40, an increase of 700,000 bushels over solution 43.

The large increase in wheat production is offset by an equivalent decrease in feed-grain production (fig. 10). The Great Plains states, from North Dakota through Texas, have the largest reductions in feed-grain production. Although these states generally have an offsetting increase in wheat acreage, South Dakota and Kansas have net losses in total land used for crops. Areas of the Lake States and the Southeast also suffer decreases in feed-grain production, but the major producing areas of the Corn Belt maintain feed grain at the same level as in solution 43. Wheat mainly is substituted for barley and grain sorghums under solution 40, while corn production remains relatively constant.

Total soybean acreage is relatively unaffected by the change in wheat acreage. Missouri and Nebraska, however, have substantial increases in acres of soybeans (mainly at the expense of Ohio, Illinois and Kansas) as land is released from feed grains in Nebraska and from wheat in Missouri.

Under solution 40, with no specific regional restrictions on wheat acreage, surplus land for crops is indicated to be 38.2 million acres. Surplus acreage drops slightly from solution 43 because more wheat land is used to produce feed. While the land so used has a locational advantage in transportation costs, its lower yields cause more land to be absorbed in meeting the nation's requirements.

Surplus or unused land would decline (fig. 14) considerably in the Southeast under solution 40 (as compared with solution 43 in fig. 7). It also would be eliminated in Arizona, eastern Colorado and most of Oklahoma and Texas.

Compared with solution 43, the programmed equilibrium prices change considerably under solution 40.

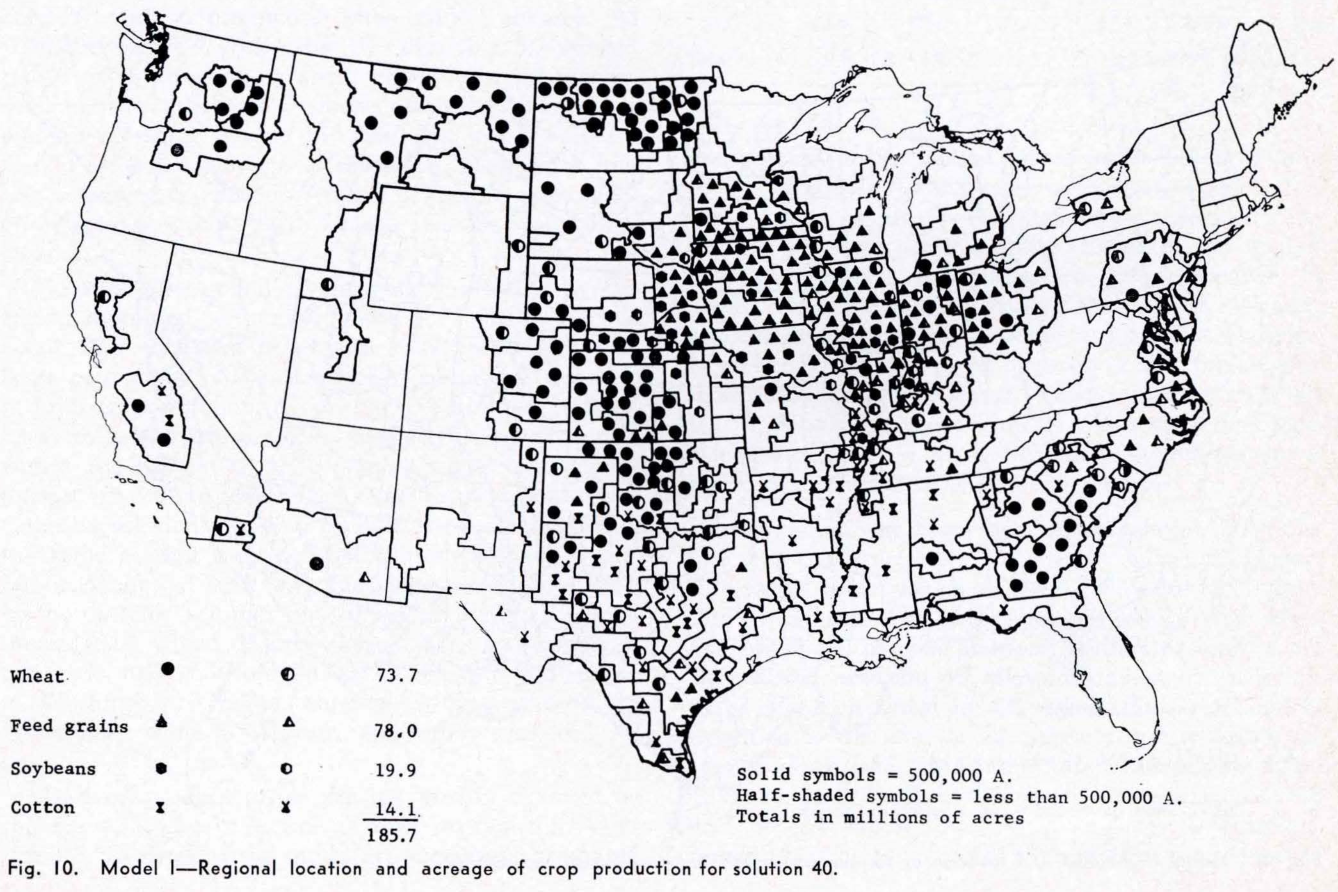

Fig. 10. Model I—Regional location and acreage of crop production for solution 40.

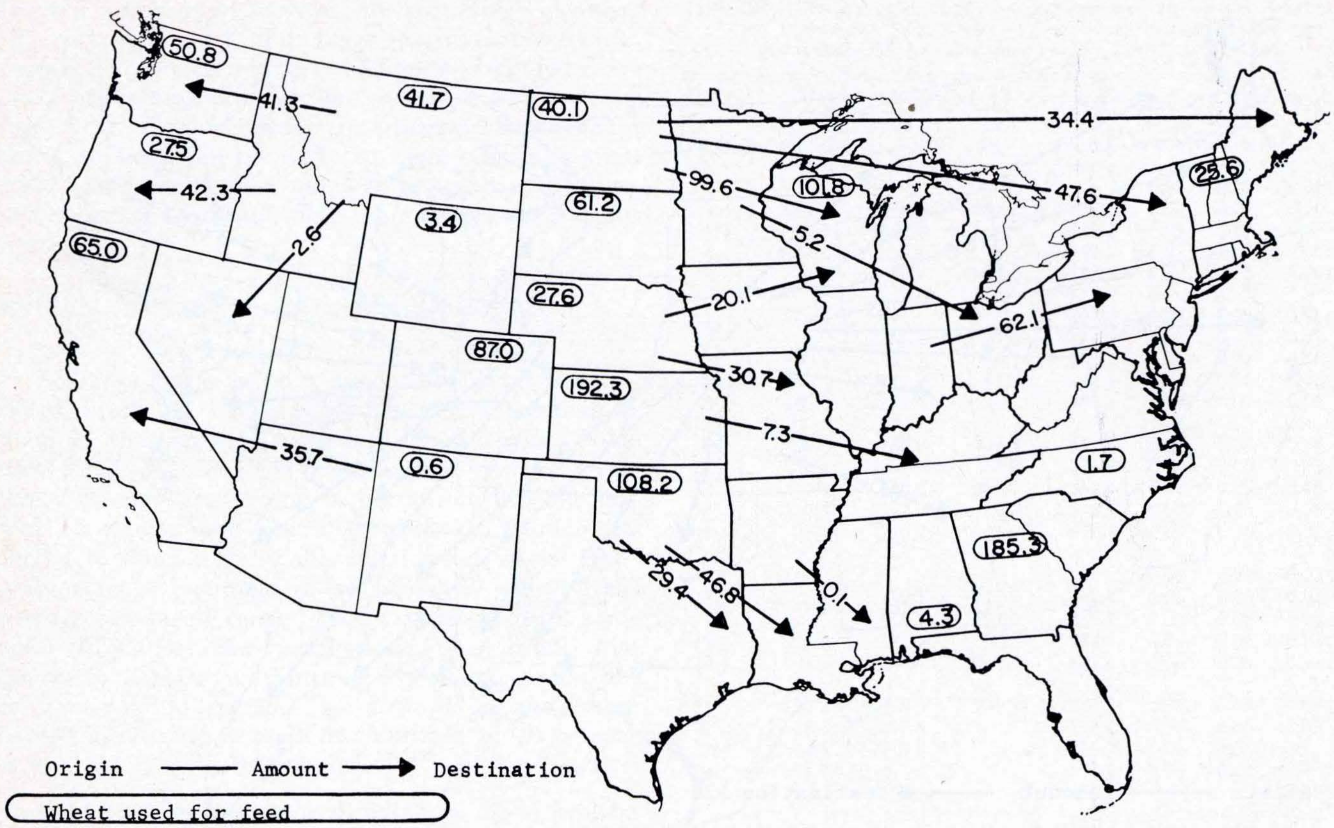

Fig. 11. Model I—Interregional flows of wheat under the conditions of solution 40 (million bushels).

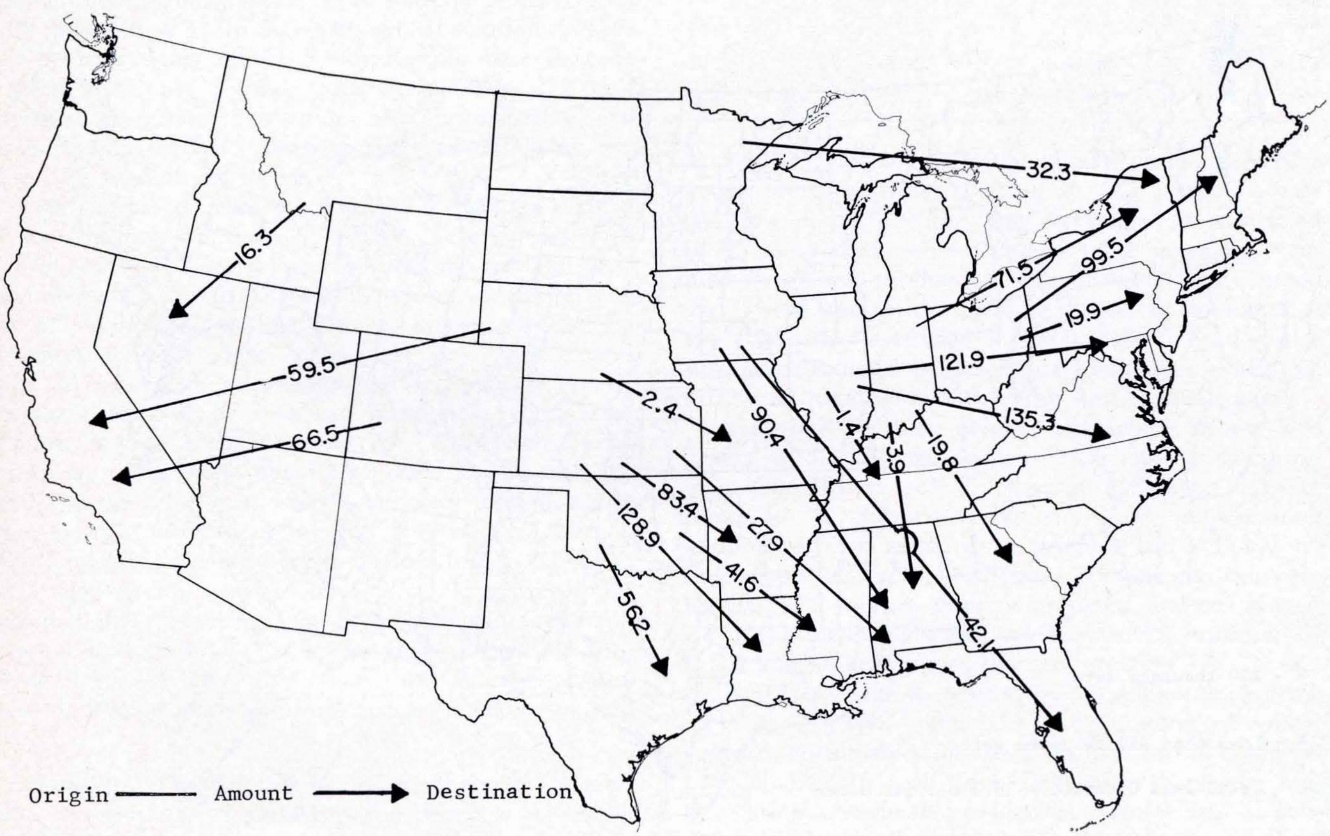

Fig. 12. Model I—Interregional flows of feed grains under the conditions of solution 40 (million bushels of corn).

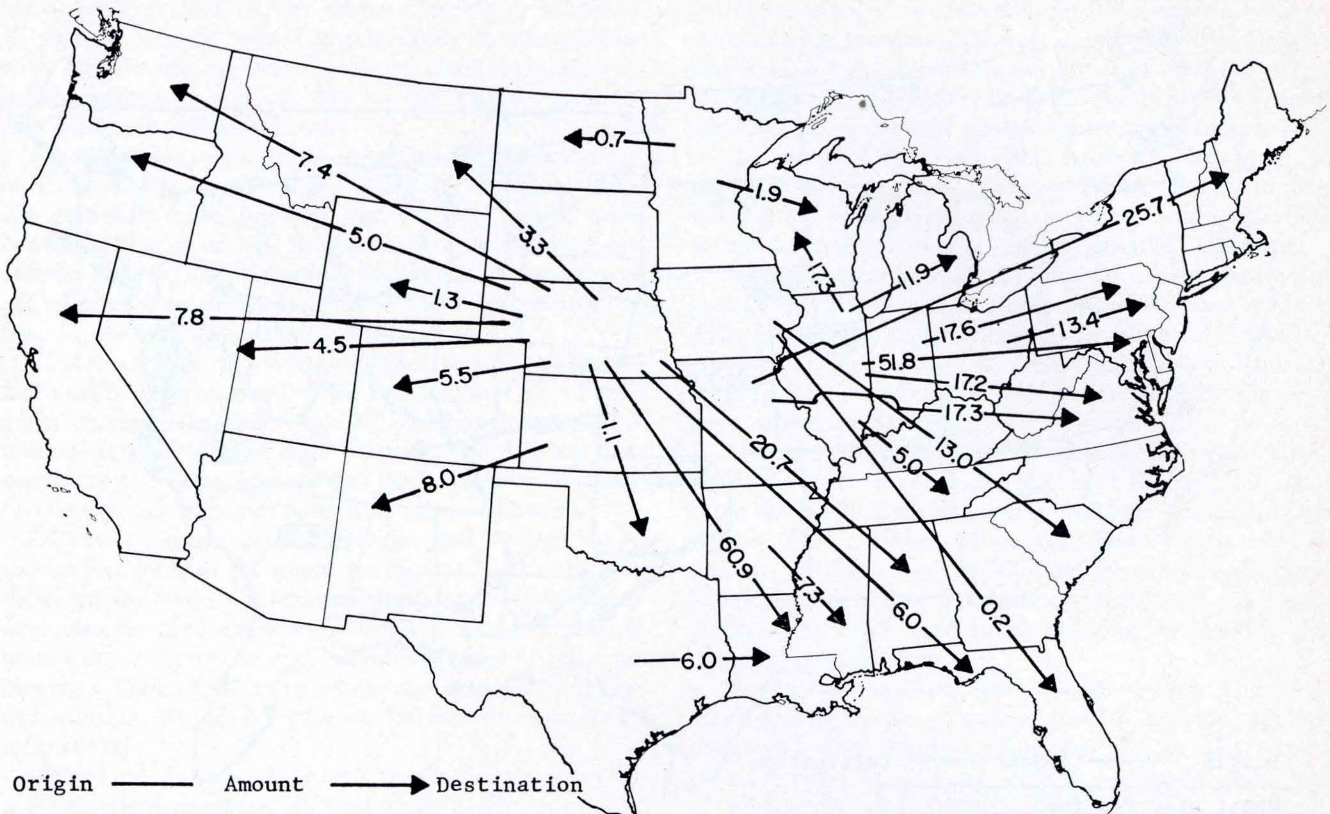

Fig. 13. Model I—Interregional flows of oilmeals under the conditions of solution 40 (million bushels of soybeans).

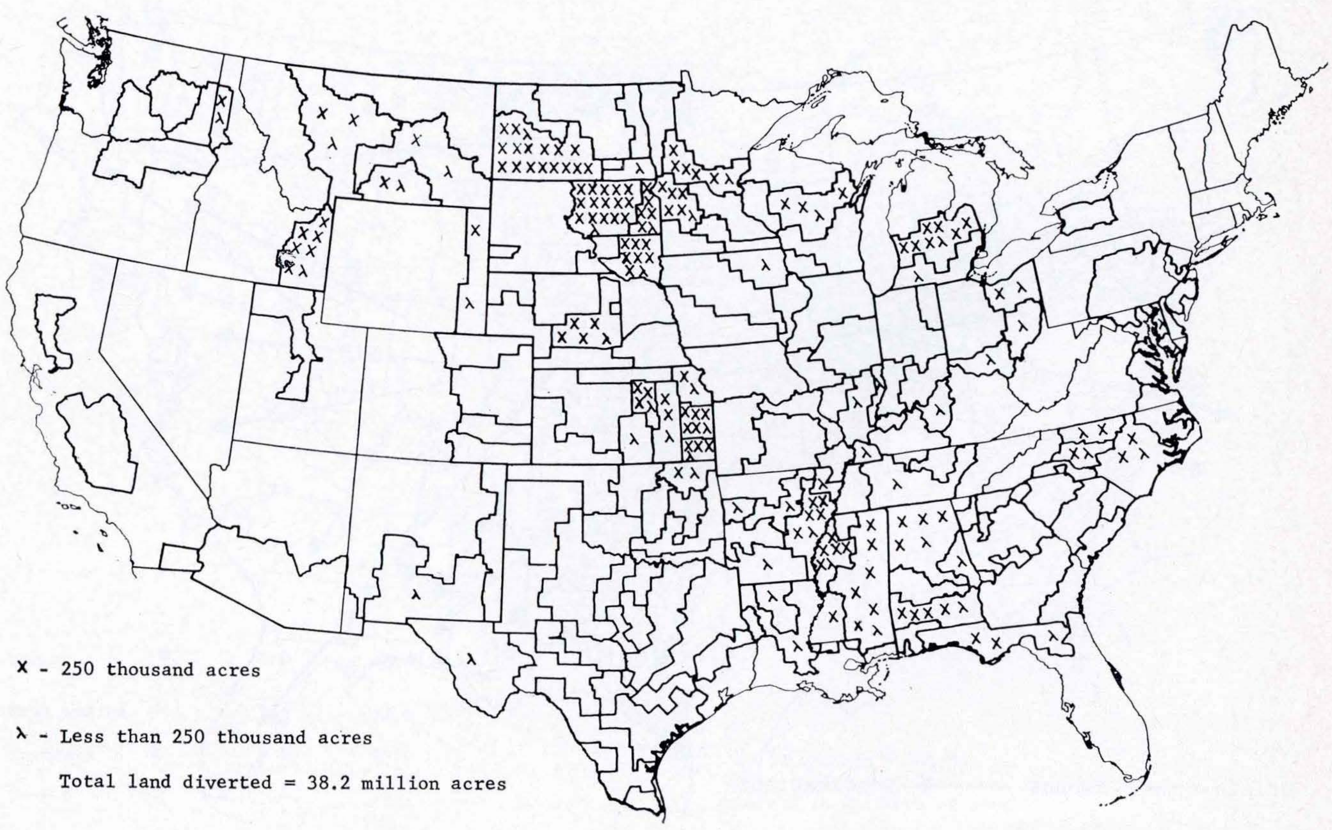

Fig. 14. Model I—Amount and location of surplus land under the conditions of solution 40.

Derived wheat prices decrease by an average of about 15 cents per bushel, thus suggesting a more efficient pattern of production under solution 40. Imputed feed-grain prices also decrease, but relatively less so than for wheat. Derived feed-grain prices decline because wheat for feed can be produced more efficiently than other grains. Feed-grain prices drop by about 10 cents per bushel of corn-equivalent grain in most producing regions.

Model I: Feed-grain programs reflected in solutions 51-54

Solutions 51-54 involve various simulated production controls for feed grains. Benchmark solution 43 required that no crop exceed its base acreage. Solutions 52, 53 and 54 allow other crops to remain at this level but cause feed grains to be restrained below this base acreage of benchmark solution 43. Solution 51, similar to solution 40 of the wheat series, allows feed-grain acreage restraints to be abolished. (Feed-grain acreage cannot, of course, exceed total cropland acreage.) In all solutions emphasizing feed grains, the quotas or acreage restraints of wheat and cotton are constant at 100 percent (see table 5) of their base level. Likewise, soybeans were restricted to 40 percent of total cropland in each region.

Feed-grain quotas reduced. Solutions 52-54, will be analyzed as a group because of their similarity. The feed-grain base was reduced by increments of 2.5 percent in going from solution 43 to solution 54 (i.e., from 100 in solution 43 to 92.5 percent in solution 54). A 2.5-percent reduction of the feed-grain base in each region represents a total reduction of about 3.2 million acres. Thus, in solution 54, approximately 9.6 million acres of feed grains are considered to be retired by mandatory means.

As compared with solution 43; the major change under solution 52 is a 2.2-million acre increase in wheat, to serve as a means of meeting national feed requirements. North Dakota increases wheat acreage by 1.5 million acres. The changes are progressive, up to those represented by solution 54 (see table 10 and fig. 15) where wheat acreage also is expanded greatly in the eastern Corn Belt and throughout the Great Plains. Soybeans shift towards the Corn Belt as an efficient replacement for feed grains. Approximately 470 million bushels of wheat are used as feed under solution 54, an increase of 160 million over solution 43. Typically, the derived equilibrium prices for wheat and feed grains increase by 6-7 cents as feed-grain production is restrained in more efficient producing regions and as wheat on lower yielding lands is substituted for livestock feed. The total acreage of surplus or unused land is 36.1 million acres under solution 54.

Table 10. Change in acreage and programmed equilibrium prices of wheat, feed grains and soybeans from solution 43 to solution 54, by consuming region.

	Acres (thousands)				Programmed prices ($/bu.)		
Region	Wheat	Feed grains	Soybean	Total	Wheat	Feed grains	Soybean
1....	..	..	..	..	0.07	0.07	−0.06
2....	164.5	−195.6	−182.1	−213.2	0.06	0.07	−0.06
3....	70.7	−203.9	..	−133.2	0.06	0.07	−0.05
4....	..	35.8	36.2	72.0	0.07	0.07	−0.05
5....	−0.9	−88.9	−94.6	−184.4	0.06	0.05	−0.06
6....	..	491.1	..	491.1	0.07	0.07	−0.06
7....	..	−216.1	41.0	−211.2	0.06	0.07	−0.05
8....	402.1	−452.2	50.1	..	0.06	0.07	−0.05
9....	350.9	−370.9	−86.7	−136.8	0.06	0.06	−0.05
10....	695.0	−202.9	..	492.1	0.03	0.07	−0.05
11....	29.8	−765.8	214.4	−521.6	0.06	0.07	−0.04
12....	..	−339.6	53.8	−285.8	0.06	0.05	−0.05
13....	1.9	−1,218.0	853.7	−362.4	0.07	0.07	−0.05
14....	267.3	−372.5	12.7	−92.5	0.06	0.05	−0.06
15....	−22.2	−910.9	26.2	−876.7	−0.04	0.06	−0.06
16....	..	..	..	..	0.06	0.06	−0.03
17....	..	330.1	−23.7	342.5	0.06	0.06	−0.03
18....	..	−434.2	107.0	−327.2	0.06	0.05	−0.03
19....	..	322.4	..	322.4	0.06	0.05	−0.03
20....	193.2	624.4	−360.0	457.6	0.06	0.06	0.01
21....	133.2	1,140.9	−986.9	287.1	0.06	0.05	−0.03
22....	2,525.6	1,687.6	..	4,213.2	0.07	0.05	−0.05
23....	1,594.4	−478.2	..	1,116.2	0.06	0.05	..
24....	151.2	..	..	151.2	0.01	0.01	−0.03
25....	..	..	..	..	..	..	−0.03
26....	..	−25.3	..	−25.3	0.06	0.05	−0.03
27....	..	−1.1	..	−1.1	0.02	0.02	−0.01
28....	..	..	..	..	0.01	0.02	−0.03
29....	..	−38.1	..	−38.1	0.01	0.01	−0.03
30....	..	−16.1	..	−16.1	0.01	0.01	−0.03
31....	..	−89.2	..	−89.2	0.01	0.06	−0.03
Total	6,556.7	−1,787.2	−338.9	4,430.6	..	..	..

Feed-grain quotas absent as represented in solution 51. Solution 51 simulates conditions in which no production restraints apply to feed grains, and their acreage is restrained only by available cropland. Wheat and cotton production are held at their respective base acreages in each region, and soybeans are restricted to no more than 40 percent of total cropland (see table 5). Wheat production, after meeting food demand and where competitive, can be raised up to limits of the base wheat acreage in each region. Feed grains then are produced in competition with feed wheat, in sufficient quantity to satisfy the feed-grain demand.

Removing the base acreage restriction allows feed grains to be distributed more efficiently among regions (fig. 16 and table 11) than in the benchmark solution (fig. 3). Consequently, only 176.0 million acres of cropland are required to produce the national requirements of wheat, feed grains, cotton and oilmeals, leaving 47.9 million acres of cropland unused. Hence, the total surplus acreage represented by solution 51 is 7.4 million acres more than for solution 43.

Wheat acreage is reduced by 5.4 million acres from solution 43. With only 41.6 million acres of wheat grown, wheat used for feed declines to 141 million bushels. Eastern and Corn Belt states have the biggest losses in wheat production. Kansas has a substantial drop in wheat production, but feed grains and

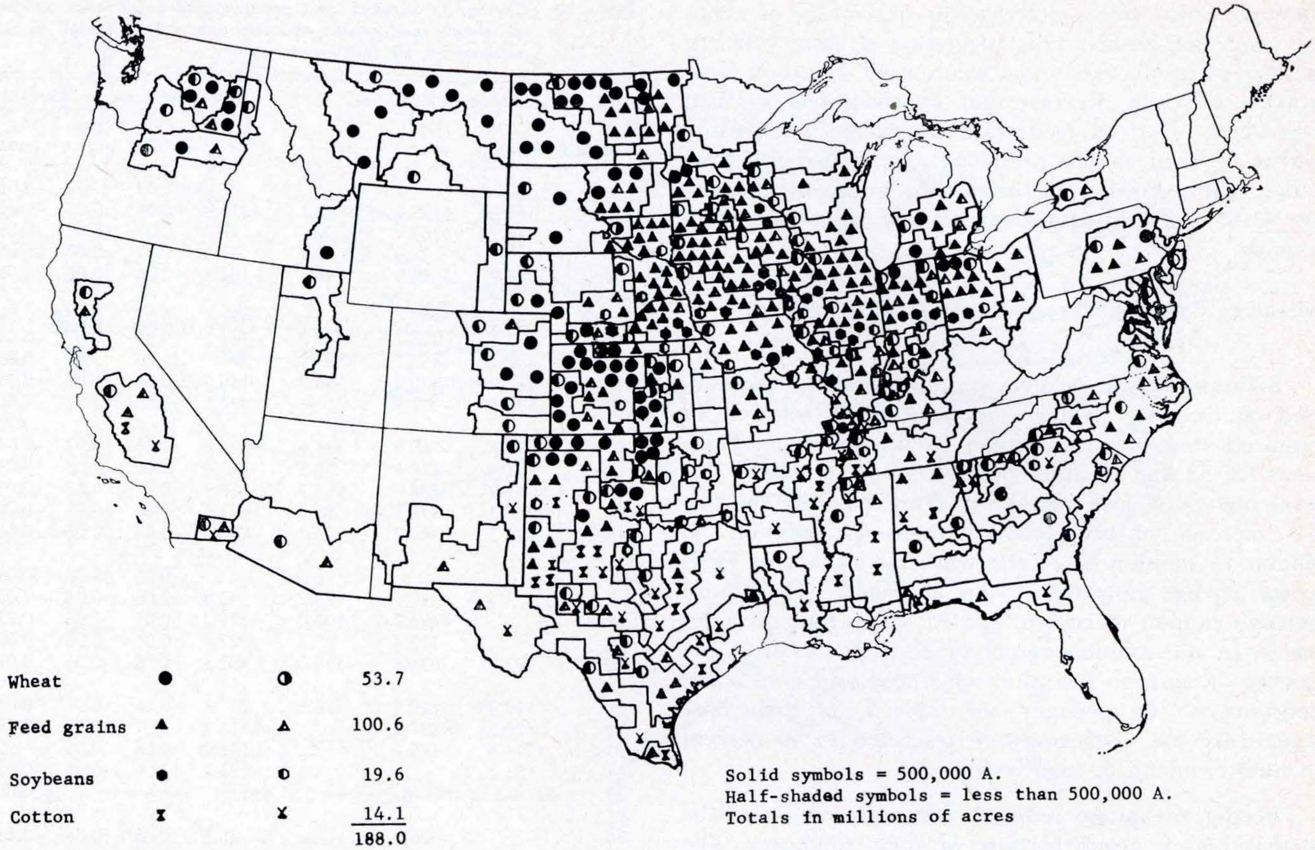

Fig. 15. Model I—Regional location and acreage of crop production for solution 54.

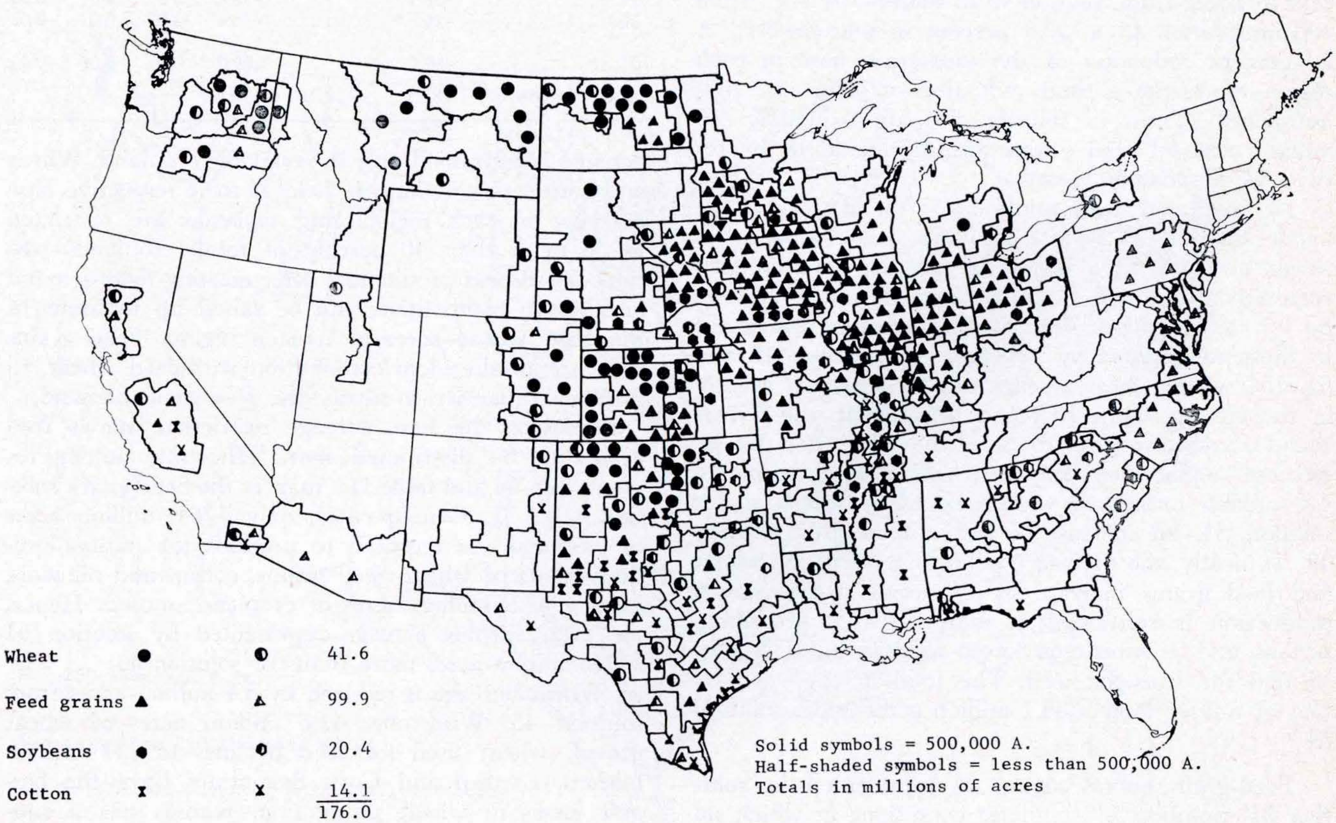

Fig. 16. Model I—Regional location and acreage of crop production for solution 51.

Table 11. Change in acreage and programmed equilibrium prices of wheat, feed grains and soybeans from solution 43 to solution 51, by consuuming region.

Region	Acreage (thousands)				Programmed prices ($/bu.)		
	Wheat	Feed grains	Soy-bean	Total	Wheat	Feed grains	Soy-bean
1....	..	..	..	..	0.01	–0.20	0.12
2....	–665.1	1,074.4	–371.8	37.5	..	–0.20	0.12
3....	–68.2	425.6	..	357.4	0.01	–0.20	0.12
4....	–184.5	–527.3	387.3	–324.5	–0.18	–0.20	0.11
5....	..	–1,185.1	..	–1,177.1	–0.03	–0.19	0.05
6....	..	..	..	..	–0.22	–0.19	0.05
7....	–179.2	–801.0	178.5	–808.9	–0.03	–0.20	0.13
8....	–794.9	2,655.1	–1,860.2	..	..	–0.20	0.18
9....	–618.5	1,335.6	–376.6	340.5	0.07	–0.21	0.21
10....	–29.2	–1,114.8	139.8	–1,004.2	..	–0.18	0.13
11....	–977.7	–1,237.7	77.6	–2,139.8	0.02	–0.20	0.13
12....	–11.7	–920.9	–31.1	–963.7	..	–0.18	0.13
13....	–12.1	337.8	–325.7	..	0.01	–0.19	0.14
14....	–667.2	861.5	–8.6	185.7	–0.03	–0.23	0.11
15....	51.9	109.4	–79.4	81.9	0.08	–0.21	0.12
16....	..	..	799.6	799.6	–0.04	–0.09	0.06
17....	..	–165.0	101.1	–63.9	–0.03	–0.09	0.05
18....	..	–361.5	351.1	–10.4	–0.04	–0.05	0.05
19....	..	–237.0	..	–237.0	–0.03	–0.04	..
20....	–1,130.5	869.2	645.6	384.3	–0.03	–0.09	..
21....	314.6	–1,208.5	893.9	..	..	–0.05	0.05
22....	..	..	..	..	0.01	..	0.12
23....	..	–2,968.6	..	–2,968.6	0.02	–0.09	..
24....	–409.3	..	..	–409.3	–0.02	–0.01	0.05
25....	..	..	..	..	..	..	0.06
26....	..	..	..	..	–0.05	–0.05	0.05
27....	–23.9	551.6	..	527.7	–0.01	–0.14	..
28....	..	..	..	..	–0.02	–0.02	0.05
29....	..	..	..	..	–0.02	–0.01	0.05
30....	..	..	..	..	–0.02	–0.01	0.05
31....	..	..	..	..	–0.01	–0.04	0.05
Total	–5,405.5	–2,509.2	521.1	–7,392.8	..	..	..

soybeans increase by an even greater acreage in this state. Illinois and Nebraska are the only states with an increase in wheat acreage.

Feed-grain acreage, though unrestricted, actually decreases by 2.5 million acres. A smaller acreage is possible because the improved interregional distribution of feed grains allows the national per-acre yield to rise. Feed grains become specialized in regions having an advantage in their production.

The increase in feed-grain acreage in the Corn Belt, forces soybeans into regions of lower per-acre yields. Hence, solution 51 requires about 0.5 million more soybean acres than does solution 43. Producing regions in Nebraska, Kansas and Arkansas have the greatest increase in soybean acreage. Indiana has the largest loss.

Cotton acreage shifts slightly in solution 51 compared with benchmark solution 43. A slight increase in acreage occurs in Alabama, and a slight decrease takes place in Kentucky.

Programmed equilibrium prices for feed grains are lowered substantially by the relaxation of base-acreage restraints on feed grains. The reduction ranges (table 11) from 9 to 20 cents per bushel in the eastern half of the United States because of the greater concentration of production in these regions. Derived feed-grain prices were changed by smaller amounts in western states since regions here continue to use substantial amounts of wheat for feed. Changes in derived wheat prices range from a decrease of 22 cents in Florida to an increase of 8 cents in Illinois. The derived prices also relate to the interregional flows shown in figs. 17, 18 and 19.

Model I: Market equilibrium of quotas or optimal interregional patterns under solution 36

Solution 36 was designed to approximate the long-run conditions approached under a competitive market (but with production restrained to the given demand levels and the prices indicated in table 5) or under government programs that result in an optimal interregional allocation of crop production and land use.

Negotiable marketing quotas are another possible means of deriving a production pattern corresponding to solution 36. Production quotas, equaling the previously specified total national demand for each product, would be issued to farmers of the nation. Initially, these quotas would be allocated on the basis of historical crop production on each farm. Quotas would then be traded among farmers until they were held by the most efficient producers. The farmers capable of getting the highest net return per unit of production would eventually bid the production quotas from less efficient producers.

To simulate the conditions of markets or government programs just outlined for solution 36, separate acreage restrictions for wheat and feed grains were removed. Physical characteristics of the producing regions were assumed to limit soybean production to 40 percent of available cropland. Total cropland restrictions by regions were retained.

Production patterns. Compared with solution 43, very large changes in crop production prevail under the conditions of solution 36. Total acreage for the crops declines to 176.9 million acres. Surplus acreage, land not needed to satisfy 1965 demands at price level 3, increases to 47.1 million acres. Considering all models and solutions analyzed, we consider this quantity to best characterize surplus capacity (for wheat, feed grains, cotton and soybeans) in 1965, given the "normal" level of prices.

Wheat production is increased to 55.0 million acres (table 12). Approximately 487 million bushels of wheat are used for feed, an increase of 177 million bushels over solution 43. Wheat production shifts from the Corn Belt into the Great Plains and western states (fig. 20). Kansas is the only Great Plains state with a decrease in wheat acreage, but the decrease is offset by an increase in feed-grain production. Producing regions in North Dakota, Colorado and South Dakota have the largest increases in wheat acreage.

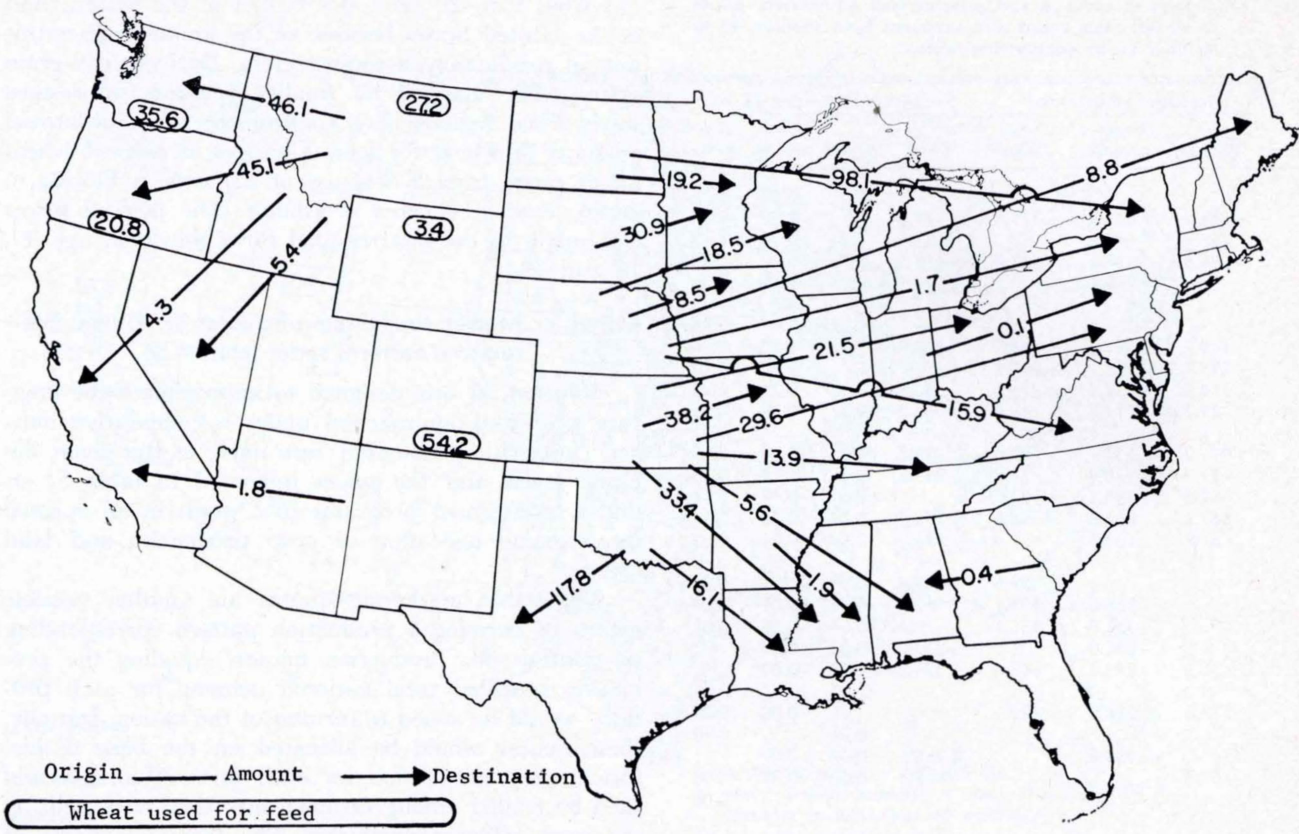

Fig. 17. Model I—Interregional flows of wheat under the conditions of solution 51 (million bushels).

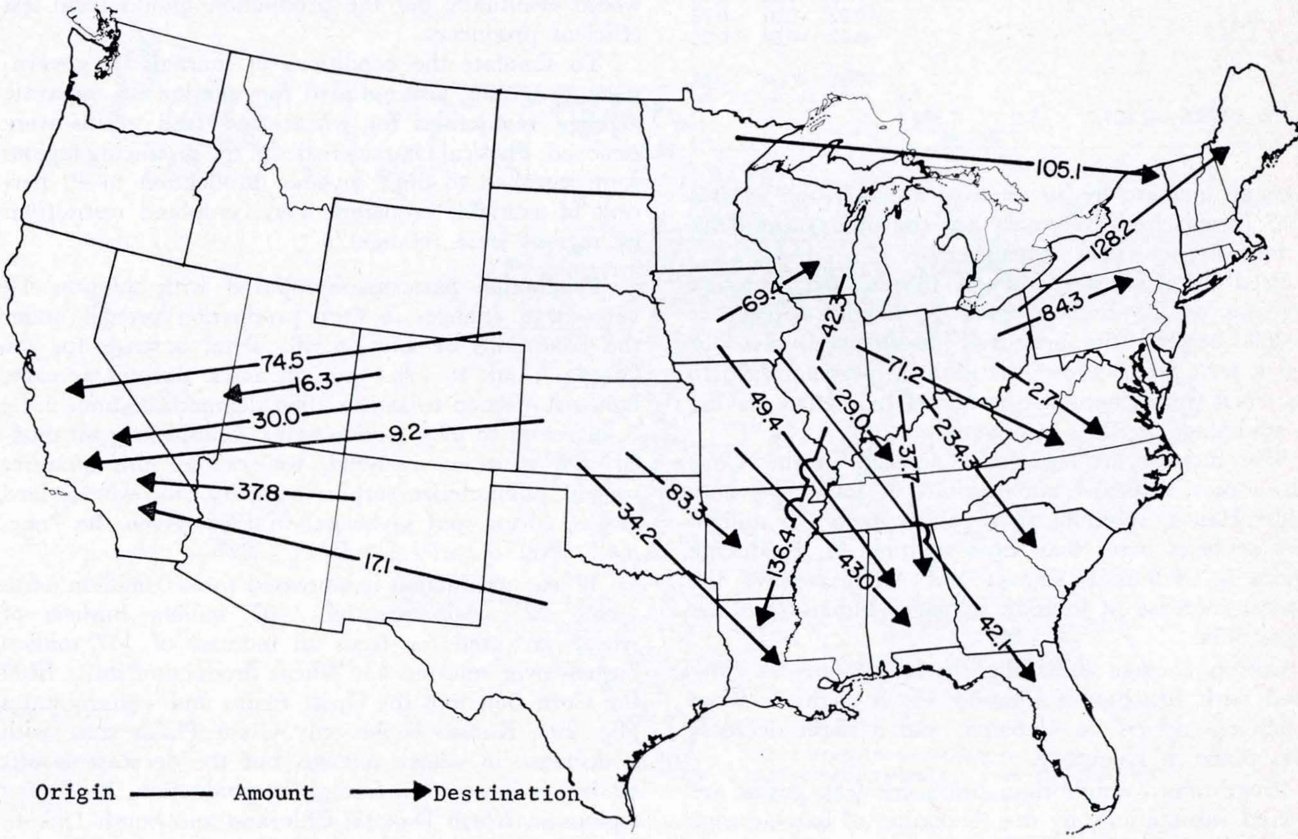

Fig. 18. Model I—Interregional flows of feed grains under the conditions of solution 51 (million bushels of corn).

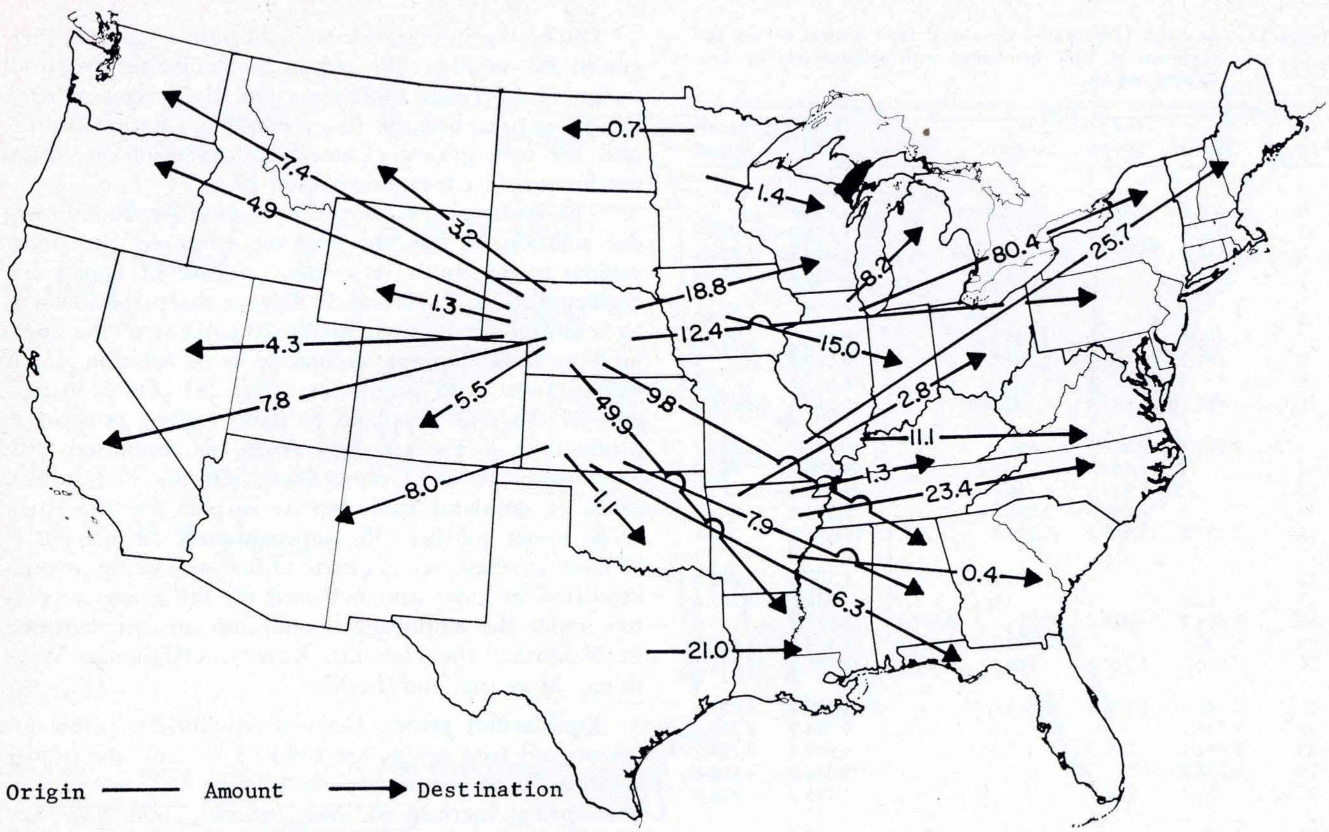

Fig. 19. Model I—Interregional flows of oilmeals under the conditions of solution 51 (million bushels of soybeans).

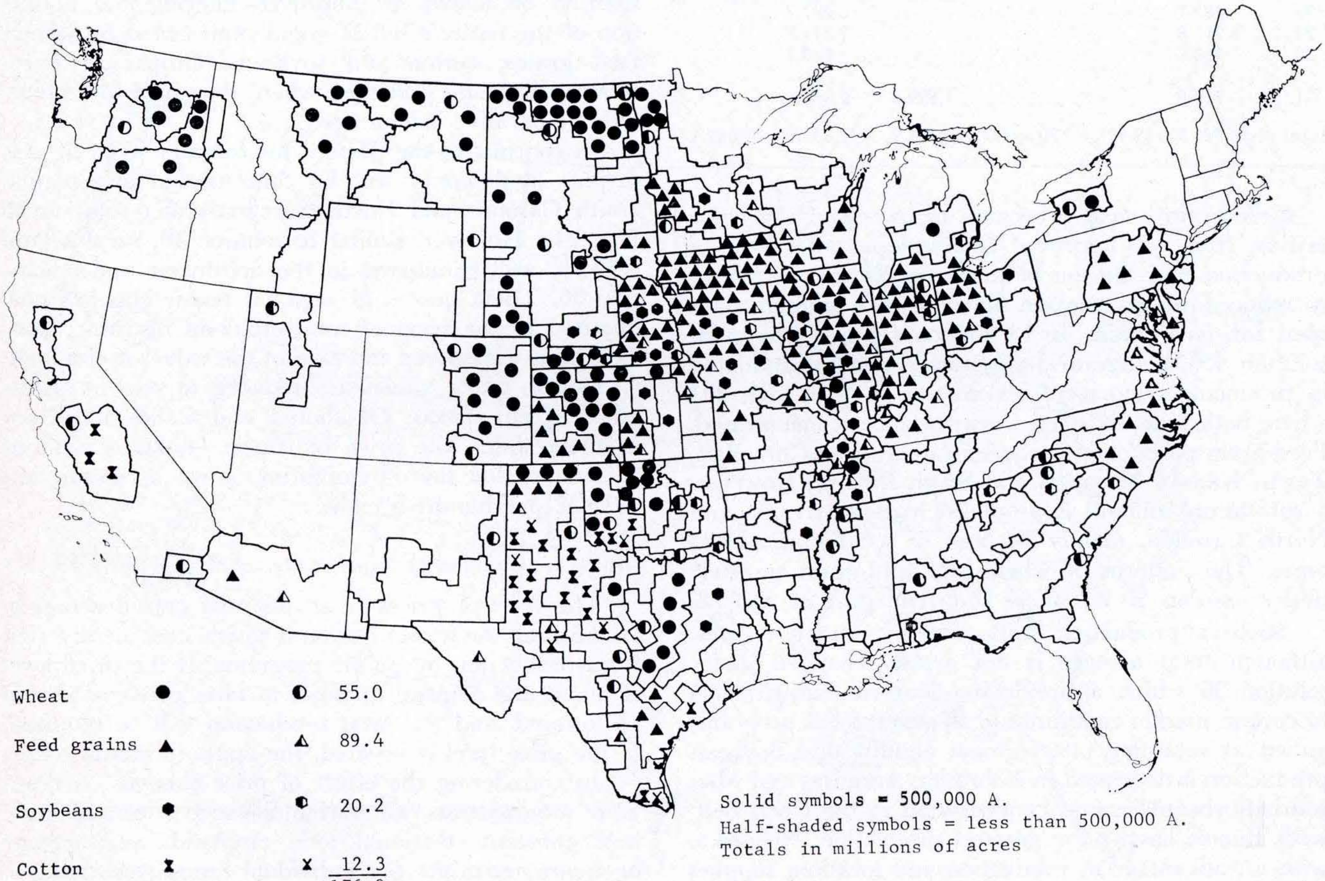

Fig. 20. Model I—Regional location and acreage of crop production for solution 36.

Table 12. Acreage (thousands) of wheat, feed grains, cotton and soybeans in 1962 compared with solution 36, by consuming region.

Region	Wheat	Feed grains	Soy-beans	Cotton	Total used	Total unused
1....	..	..	..	..	..	..
2....	602.6	3,351.5	..	..	3,954.1	..
3....	332.2	3,142.1	..	..	3,474.3	765.9
4....	336.8	347.0	475.8	..	1,159.6	6,222.4
5....	236.0	..	94.6	..	330.6	3,494.5
6....	..	..	..	..	..	618.0
7....	486.9	2,260.8	482.5	..	3,230.2	1,223.6
8....	199.2	8,687.3	496.0	..	9,382.5	..
9....	..	5,771.5	1,140.7	..	6,912.2	1,111.8
10....	481.1	1,591.4	139.8	..	2,212.3	1,835.6
11....	2,559.1	7,534.7	852.6	..	10,946.4	2,587.2
12....	..	3,650.7	..	..	3,650.7	993.8
13....	..	16,653.9	1,780.7	..	18,434.6	..
14....	..	6,045.6	2,325.5	..	8,371.1	..
15....	1,103.8	11,581.1	5,226.6	..	17,911.5	85.1
16....	..	..	1,187.8	..	1,187.8	2,286.6
17....	552.8	..	..	..	552.8	5,227.6
18....	3,589.2	4,424.0	..	8,914.7	16,927.9	..
19....	6,780.1	..	77.8	1,760.6	8,618.5	447.8
20....	7,020.3	6,763.5	962.7	..	14,746.5	3,332.7
21....	3,346.2	5,200.1	4,813.6	..	13,359.9	1,097.3
22....	9,754.2	..	..	..	9,754.2	4,286.8
23....	2,717.1	1,592.7	137.3	..	4,447.1	7,229.9
24....	5,346.8	..	..	..	5,346.8	3,606.6
25....	125.1	..	..	..	125.1	405.9
26....	3,872.6	..	..	..	3,872.6	..
27....	366.1	823.3	..	..	1,189.4	223.2
28....	283.7	..	..	..	283.7	..
29....	3,211.8	..	..	..	3,211.8	..
30....	968.7	..	..	..	968.7	..
31....	710.5	..	..	1,599.6	2,310.1	..
Total	54,982.9	89,421.2	20,194.0	12,274.9	176,873.0	47,082.3

Feed-grain acreage, because of increased efficiency arising from an improved interregional allocation of production and the use of more feed wheat, is sharply reduced under solution 36. The 89.4 million acres used for feed grains is 13 million fewer than under solution 43. Feed-grain production is nearly eliminated in producing regions from Colorado on west (fig. 20) where both food and feed wheat becomes concentrated. Feed-grain production is concentrated in the Corn Belt, Texas, Kansas, Nebraska and South Dakota. However, a substantial amount is produced in Pennsylvania and North Carolina, mainly because of locational advantages. The patterns of wheat and feed-grain transfers under solution 30 are those shown in figs. 21 and 22.

Soybean production shifts slightly among regions, although total acreage is not greatly changed under solution 36 which approximates long-run adjustments to certain market conditions or to government programs aimed at retaining interregional equilibrium. Soybean production is decreased in Nebraska, Arkansas and Missouri. Soybeans remain concentrated in the Corn Belt, with Illinois having the greatest production. Nebraska, with an advantage in production and location, supplies most western states with oilmeals (fig. 23).

Under the interregional equilibrium conditions suggested by solution 36, cotton is eliminated from all states except Texas, Oklahoma and California. Arizona has no cotton, because its cropland is completely utilized for feed grains. (Later solutions result in cotton production in consuming region 27.)

The interregional allocation of crop production under solution 36 has the greatest effect on producing regions in the South. As evident in table 12, consuming regions 4, 5, 6, 7, 16 and 17 have a sharp reduction in agricultural production. About 20 percent of the cropland in these regions, compared with solution 43, is shifted from crop production (fig. 24). Only 30 percent of the total cropland in these regions remains in production of the specified crops, as compared with 79 percent for the United States. Of the 47.1 million acres of cropland indicated as surplus for the study crops under solution 36, approximately 38 percent is located in these six regions. Other producing regions indicated to have land not used for the grains or cotton under the equilibrium conditions are concentrated in Nebraska, the Dakotas, Kansas, Oklahoma, Wyoming, Montana and Idaho.

Equilibrium prices. Derived equilibrium prices for wheat and feed grains are reduced considerably under solution 36, as compared with solution 43. Derived soybean prices increase in most regions (table 13). The decline comes about since the model represented by solution 36 allows an improved interregional allocation of the nation's bill of goods represented by wheat, feed grains, cotton and soybeans. Crops are unrestrained in being produced where they have the greatest comparative advantage.

In contrast to the pattern for solution 40 in fig. 14, surplus land would still be concentrated in Georgia, South Carolina and North Carolina under solution 36 (fig. 24). However, similar to solution 40, surplus land is fairly well eliminated in the Southwest under solution 36. These quotas or regional restrictions are now imputed to the regional total cropland restraint; thus, causing a widespread increase in the value of cropland.

Cotton quota values are reduced to zero in all regions except Texas, Oklahoma and California. Even in these states, the price of cotton quotas is reduced because of the lower equilibrium price of cotton lint ($19.32 per hundredweight).

Model I: Demand changes under solutions 41 and 45

The level of prices is an essential consideration in establishing the amount of land which must be diverted from production by public programs. If the price level is raised, the demand quantity of farm products should be lowered, and less total production will be required. If the price level is lowered, the opposite should occur.

In considering the effect of price changes on cropland requirements, all variables except demand were held constant. Regional total cropland, and acreage or quota restraints for individual crops were held at the same level as for solution 43 (table 14). Demand

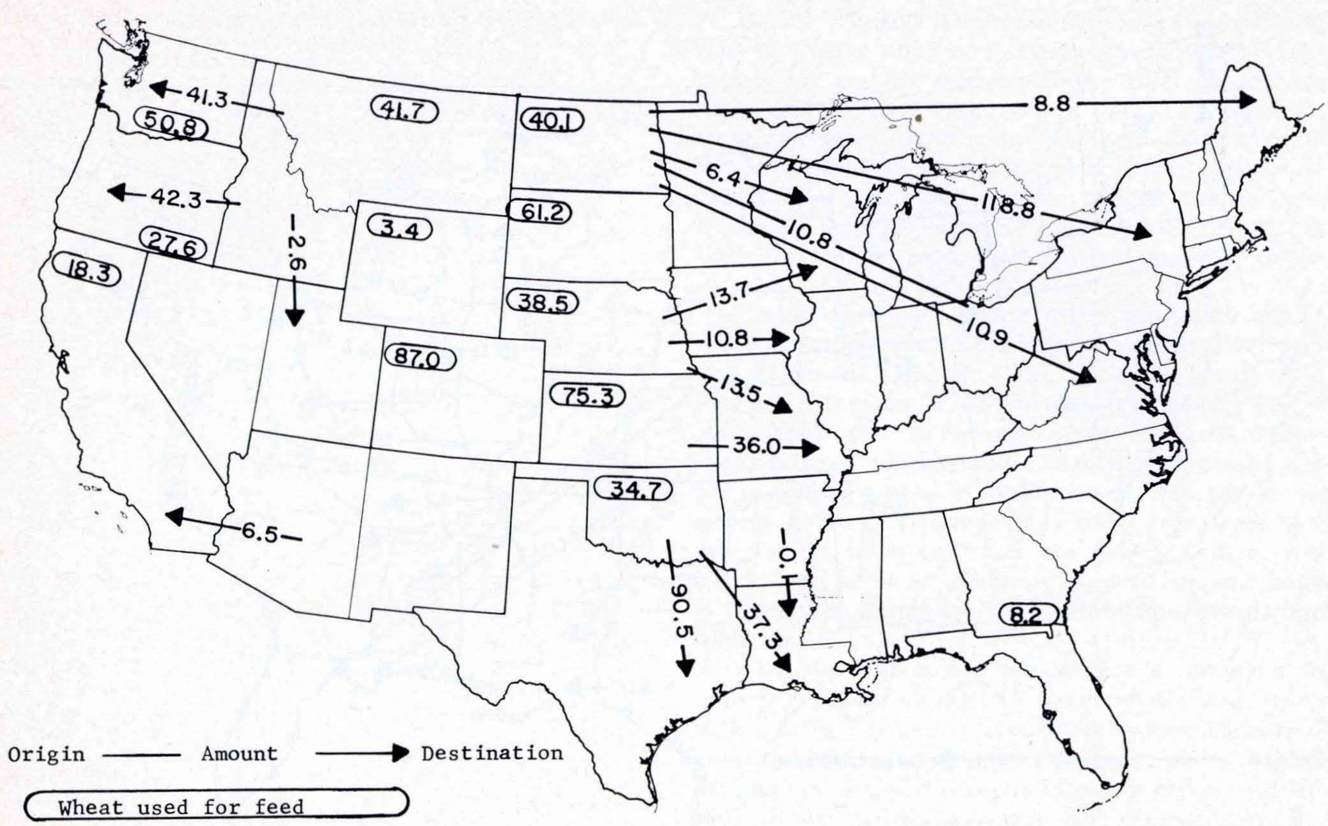

Fig. 21. Model I—Interregional flows of wheat under the conditions of solution 36 (million bushels).

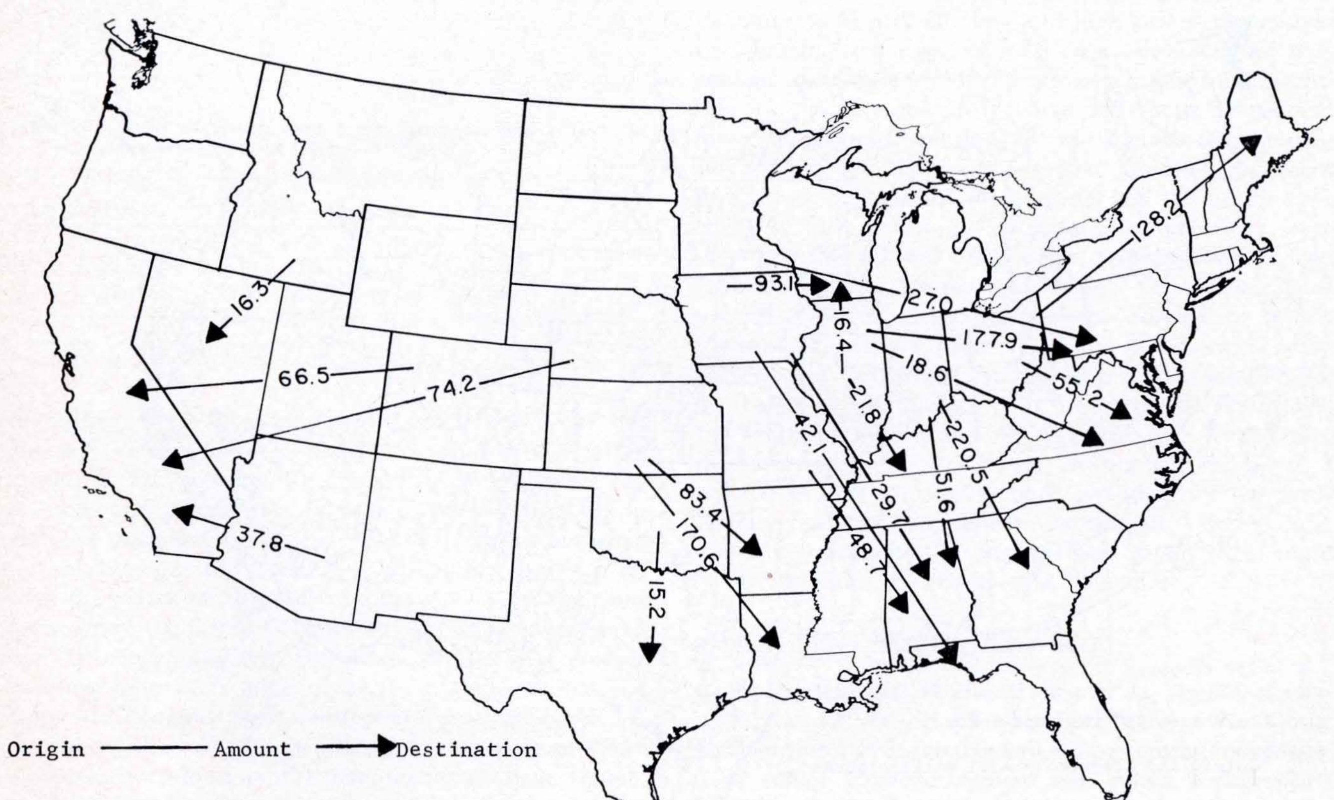

Fig. 22. Model I—Interregional flows of feed grains under the conditions of solution 36 (million bushels of corn).

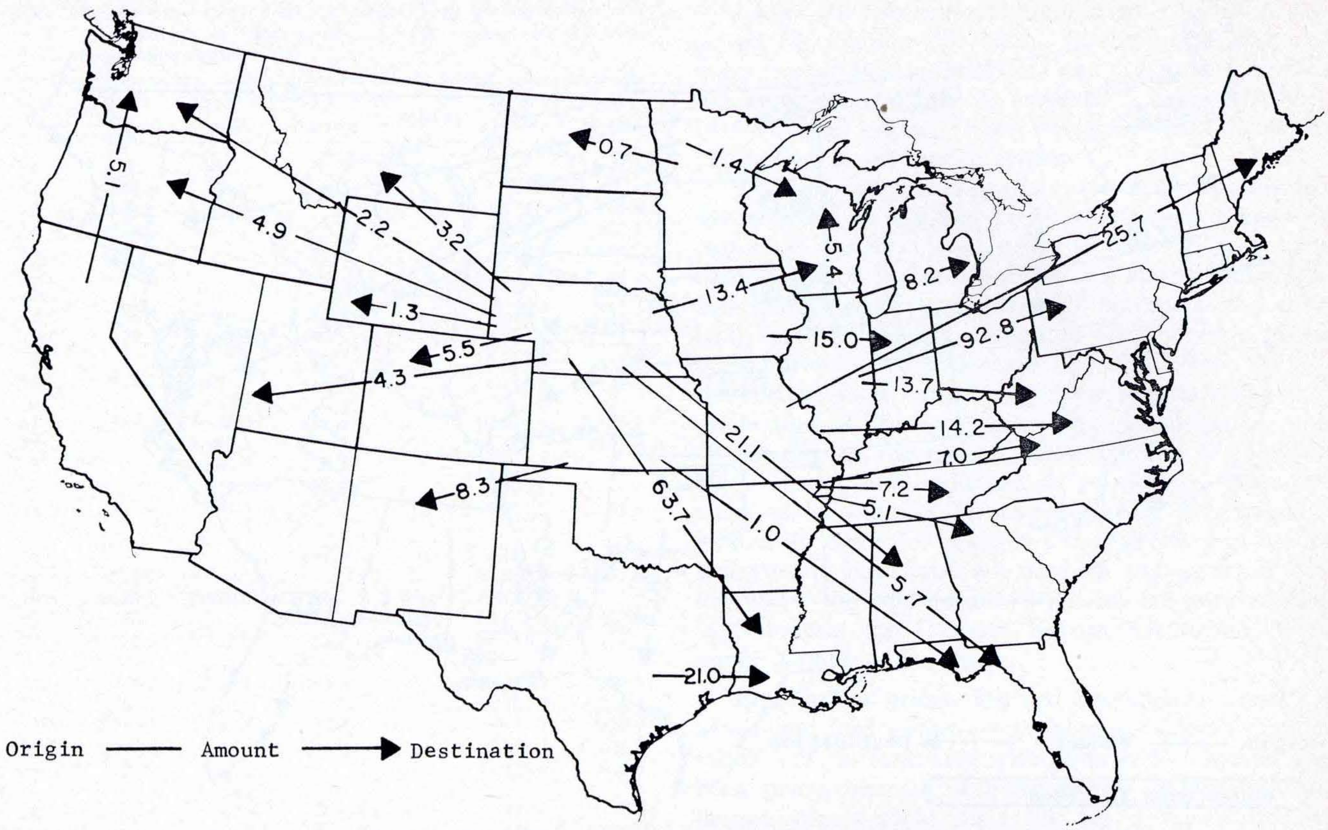

Fig. 23. Model I—Interregional flows of oilmeals under the conditions of solution 36 (million bushels of soybeans).

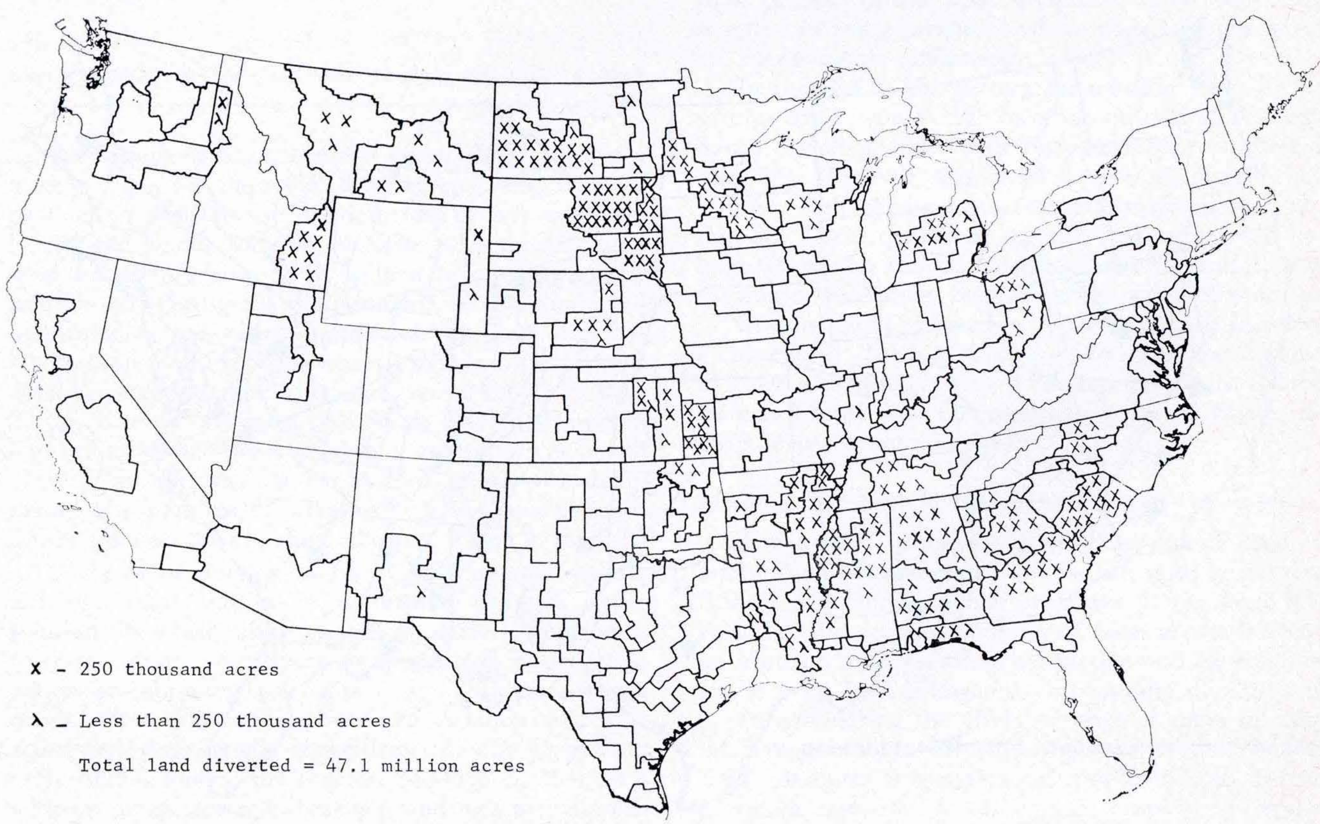

Fig. 24. Model I—Amount and location of surplus land under the conditions of solution 36.

Table 13. Change in programmed equilibrium prices of wheat, feed grains and soybeans from solution 43 to solution 36, by consuming region.

Region	Wheat	Feed grains	Soybeans
	(dollars per bushel)		
1	-0.15	-0.22	0.09
2	-0.15	-0.22	0.09
3	-0.15	-0.21	0.09
4	-0.25	-0.22	0.08
5	-0.20	-0.21	0.02
6	-0.24	-0.20	0.03
7	-0.15	-0.22	0.10
8	-0.12	-0.22	0.15
9	-0.05	-0.22	0.17
10	..	-0.19	0.10
11	-0.15	-0.21	0.10
12	-0.15	-0.20	0.10
13	-0.15	-0.20	0.11
14	-0.15	-0.25	0.08
15	-0.02	-0.22	0.09
16	-0.18	-0.12	0.03
17	-0.17	-0.13	0.02
18	-0.18	0.25	0.02
19	-0.17	-0.08	-0.08
20	-0.14	-0.13	-0.01
21	-0.15	-0.11	0.02
22	-0.15	-0.07	0.10
23	-0.11	-0.09	..
24	-0.13	-0.11	0.02
25	..	..	0.03
26	-0.12	-0.11	0.02
27	-0.19	-0.21	-0.01
28	-0.13	-0.11	0.02
29	-0.13	-0.11	0.02
30	-0.13	-0.11	0.02
31	-0.19	-0.11	-0.31

Table 14. Acres of wheat, feed grains, soybeans and cotton for the three demand levels.[a]

Solution	Wheat	Feed grains	Soybeans	Cotton	Cropland unused
41	53,066.2	109,496.7	21,205.4	15,538.2	24,602.6
43	47,006.7	102,432.2	19,890.1	14,113.8	40,512.6
45	46,365.0	94,137.4	18,984.0	13,111.3	51,357.7

[a] The only difference between the restraints of solutions 41, 43 and 45 were the differences in demand level.

quantities were then increased, and prices were decreased, for solution 41 relative to solution 43 (tables 2 and 5). For solution 45, demand quantities were decreased, and prices were increased, relative to solution 43. The assumed corn price was 80 cents per bushel for solution 41 and $1.40 per bushel for solution 45, with the prices of all other products varied proportionately from the levels of solution 43. (For solution 43 and all other solutions, the price level is that corresponding to a corn price of $1.10 in tables 2 and 5.) Domestic demand levels alone were assumed to be affected by the change in prices. (Some regions have a greater portion of export demand than others. Hence, regional demands are not all affected equally by the demand and price changes.)

Higher demand quantities and lower prices, solution 41. While areas of specialization are not changed greatly for any one crop under the different solutions, the residual effects expressed in unused cropland are quite important. Under the lower set of prices and larger demand quantities, surplus capacity as represented by unused land declines to 24.6 million acres. Under the higher prices and smaller quantities of solution 45, surplus capacity increases to 51.4 million acres.

Under solution 41 (lower prices and larger quantities), wheat acreage would expand mainly (over solution 43) in the Dakotas, Ohio, Michigan, North Carolina and Montana. Feed-grain acreage would expand most (table 15) in Nebraska, North Dakota, Mississippi, Kansas, Florida and Oklahoma. Soybean acreage would decrease in Nebraska in response to the greater feed-grain acreage but would expand in most other states where soybeans are grown. Cotton, with a total increase of 1.4 million acres, would expand largely in South Carolina, North Carolina, Georgia and Alabama.

With the 10.8-million-acre decline in cropland requirements under solution 45, the greatest change would be in feed grains and cotton. Large reductions in feed-grain production, as compared with the price level under solution 43, would occur in South Dakota, Michigan, Minnesota and Alabama. The central Corn Belt would have little change in feed grains (table 16).

Because of the very low price elasticities of demand for the commodities in question, the quantities involved in solutions 41 and 45 (low and high prices, respectively) change from those of solution 43 by a smaller percentage than price. With the lower prices under solution 41, for example, prices average about 27 percent lower than under solution 43, but increases in quantities are only 7.2 percent for feed grains, 8.0 percent for cotton, 5.9 percent for oilmeals and 0.4 percent for wheat. Under solution 45, changes in quantities were only 5.3, 4.3, 5.8 and 0.4 percent, respectively, for feed grains, oilmeals, cotton and wheat. Of course, solution 41 requires an increase in crop acreage to supply the greater demand quantities at the lower prices, while the opposite is true for the higher prices of solution 45.

Table 14 summarizes land use at the national level for solutions 41, 43 and 45 corresponding to the low, medium and high price levels, respectively, of tables 2 and 5. Illinois and Iowa both would have relatively large reductions in soybean production. For cotton, the large reduction in acreage and production would be in Alabama, Kentucky and Tennessee.

Model II: One-Price Plan for Wheat

In contrast to Model I, Model II implies a one-price plan for wheat. All wheat produced under Model II would receive a relative price representing its historic food value. However, wheat also could be used for feed. As feed wheat, it would need to be priced in terms of its relative nutritive value as a feed grain.

Table 15. **Change in acreage (thousands) of wheat, feed grains, soybeans and cotton from solution 43 to solution 41, by consuming region.**

Region	Wheat	Feed grains	Soybeans	Cotton	Total used
1......	..	..	..	..	..
2......	..	..	..	..	..
3......	166.8	..	609.1	49.4	825.3
4......	..	269.1	114.7	1,309.9	169.4
5......	..	..	..	50.5	50.5
6......	..	530.9	..	..	530.9
7......	..	..	125.1	..	125.1
8......	..	..	..	..	..
9......	640.2	..	−203.1	..	437.1
10......	695.0	..	83.1	..	778.1
11......	29.8	..	360.1	..	389.9
12......	9.9	..	..	..	9.9
13......	..	..	..	..	..
14......	−134.7	..	134.7	..	..
15......	24.1	..	57.8	..	82.0
16......	..	..	799.6	..	799.6
17......	..	1,369.1	..	14.6	1,383.7
18......	..	53.2	360.4	..	413.6
19......	..	452.8	..	..	452.8
20......	64.6	895.1	70.7	..	1,030.4
21......	..	1,494.2	−1,207.1	..	287.1
22......	2,525.6	1,974.5	..	..	4,500.1
23......	1,594.4	..	10.1	..	1,604.5
24......	424.4	..	..	..	424.4
25......	19.5	..	..	..	19.5
26......	..	..	..	..	..
27......	..	25.7	..	..	25.7
28......	..	..	..	..	..
29......	..	..	..	..	..
30......	..	..	..	..	..
31......	..	..	..	..	..
Total	6,059.5	7,064.6	1,315.3	1,424.4	15,863.8

Table 16. **Change in acreage (thousands) of wheat, feed grains, cotton and soybeans from solution 43 to solution 45, by consuming region.**

Region	Wheat[a]	Feed grains	Soybeans	Cotton	Total used
1......	..	..	..	..	..
2......	−1.6	..	−132.6	..	−134.2
3......	..	−253.0	..	−84.7	−337.7
4......	−5.2	−270.2	..	..	−275.4
5......	..	−1,106.4	−94.6	−767.4	−1,968.4
6......	..	..	..	..	..
7......	..	..	..	−134.5	−134.5
8......	..	..	..	..	..
9......	−3.9	..	3.9	..	..
10......	−2.7	−1,160.9	..	..	−1,163.6
11......	..	−1,178.8	..	..	−1,178.8
12......	..	−180.5	..	..	−180.5
13......	..	..	−169.9	..	−169.9
14......	99.3	..	−99.3	..	..
15......	−30.9	..	−582.0	..	−612.9
16......	..	..	..	..	..
17......	−2.2	−85.3	−23.7	−15.9	−127.2
18......	..	−92.4	..	..	−92.4
19......	..	−87.9	..	..	−87.9
20......	..	−597.2	−49.7	..	−646.9
21......	..	−249.3	249.3	..	..
22......	..	−100.3	..	..	−100.3
23......	..	−2,932.6	−7.5	..	−2,940.1
24......	−680.2	..	..	..	−680.2
25......	−14.4	..	..	..	−14.4
26......	..	..	..	..	..
27......	..	..	..	..	..
28......	..	..	..	..	..
29......	..	..	..	..	..
30......	..	..	..	..	..
31......	..	..	..	..	..
Total	−641.7	−8,294.7	−906.1	1,002.6	−10,845.1

Thus, there would be a transfer cost involved in shifting wheat to feed. This transfer cost would be equal to the differences in prices for wheat in food and feed uses. This cost, added to the production costs of wheat in its use as feed, would also be included in the objective function. Hence, under Model I as compared with other models, wheat must bear a penalty in the transfer cost attaching to its feed use. The charge placed on the use of feed wheat was different for each region and was based upon historic regional differences between prices received for wheat and prices received for corn (see table 3). The charge averaged 85 cents per bushel for the United States.

Two solution from Model II assess the effect of a one-price plan for wheat. The production and demand constraints for these two solutions, 402 and 432, are identical to solutions 40 and 43, respectively, under Model I and allow comparison of parallel outcomes under a one-price and a two-price plan for wheat.

A summary of the aggregate effects of applying the one-price wheat plan is given in table 17. Wheat acreage and production are considerably smaller under the two one-price plans for wheat where a transfer cost, perhaps paid through treasury outlays, is involved in using wheat for feed. Both solution 40 (a two-price plan) and solution 402 (a one-price plan) leave wheat unrestricted in its competition for cropland, although other crops are restrained to their historic maximum acreage. The one-price plan (solution 402) would cause wheat acreage to decrease by 32.5 million acres. Simultaneously, acreage would be increased by 29.4 million for feed grains, 1.4 million for soybeans and 4.9 million for unused or surplus land. Indicated feed use of wheat declines by more than 0.8 million bushels. Under solution 43 (a two-price plan) and solution 432

Table 17. **Production of wheat, feed grains, oilmeals and cotton compared under one- and two-price plans for wheat.[a]**

Solution	Wheat	Feed grains	Soybeans	Cotton	Cropland unused	Wheat for feed
	(thousands of acres)					(mil. bu.)
40.....	73,714.6	77,981.2	19,910.4	14,113.8	38,235.2	1,024.0
402.....	41,227.2	107,317.7	21,382.4	10,882.9	43,145.1	146.8
43.....	47,006.7	102,432.2	19,890.1	14,113.8	40,512.6	310.3
432.....	39,085.0	110,214.1	19,750.8	12,607.0	42,298.4	76.4

[a] Solutions 402 and 432 were identical in every way to solutions 40 and 43, respectively, except for the difference in the price assumption for wheat.

(a one-price plan), wheat is restricted to its historic maximum acreage in each of the 144 producing regions. Again, however, the acreages of wheat and cotton are less under the one-price plan, and the acreages of feed grains and soybeans are greater, than under the two-price plan. The penalty represented by the transfer cost of wheat to feed under the one-price plan causes the national pattern of production to be less efficient in a cost sense, but it reduces acreage required for crops, because land used for feed grain has a higher yield per acre than that otherwise used for wheat.

Most of the change in wheat production, under solution 432 as compared with 43, comes about in the eastern half of the United States where nearly every state shows a loss in wheat production (fig. 25). Kansas is the only western state showing a significant drop in wheat production under solution 432, although it continues to be the greatest wheat-producing state. Producing regions in Montana, Oklahoma and Colorado have reductions in wheat production but show increases in feed-grain production. Feed grains also are substituted for wheat in Louisiana and Mississippi. Most of the Corn Belt and eastern states are indicated to produce to the limit of their feed-grain quota or acreage restraints under solution 43 and cannot expand acreage under solution 432. However, Mississippi and Louisiana increase feed-grain production by about 1.4 million acres. The remainder of the change in feed-grain production occurs in the Great Plains and western states where nearly every producing region has more feed grains under solution 432 than under 43. The spatial location of soybean production is appreciably affected by the application of the one-price plan on wheat. However, the total acreage of soybeans is affected very little. A general shift of soybean production from Kansas and Nebraska into Missouri and the eastern part of the Corn Belt is indicated in fig. 25. The shift eastward results partly from a decrease in cotton production over the Southeast. Mainly, however, the increased need for feed grains in the West caused soybeans to shift out of these areas and into the regions of the East.

Results of Model III

The major objective of Model III is to analyze the realism and usefulness of programming models that incorporate intraregional soil-quality differences. Even regions of least productive soils have some good cropland, and the most productive regions have some poor cropland. Model III allows the intraregional selection and use of cropland, based on potential soil productivity as well as interregional allocations of production for optimal attainment of the national objective.

Solution 403 of Model III is the counterpart of solution 40 for Model I where only one class of land is considered per region. Likewise, solution 433 is the counterpart of solution 43 under Model I. A corres-

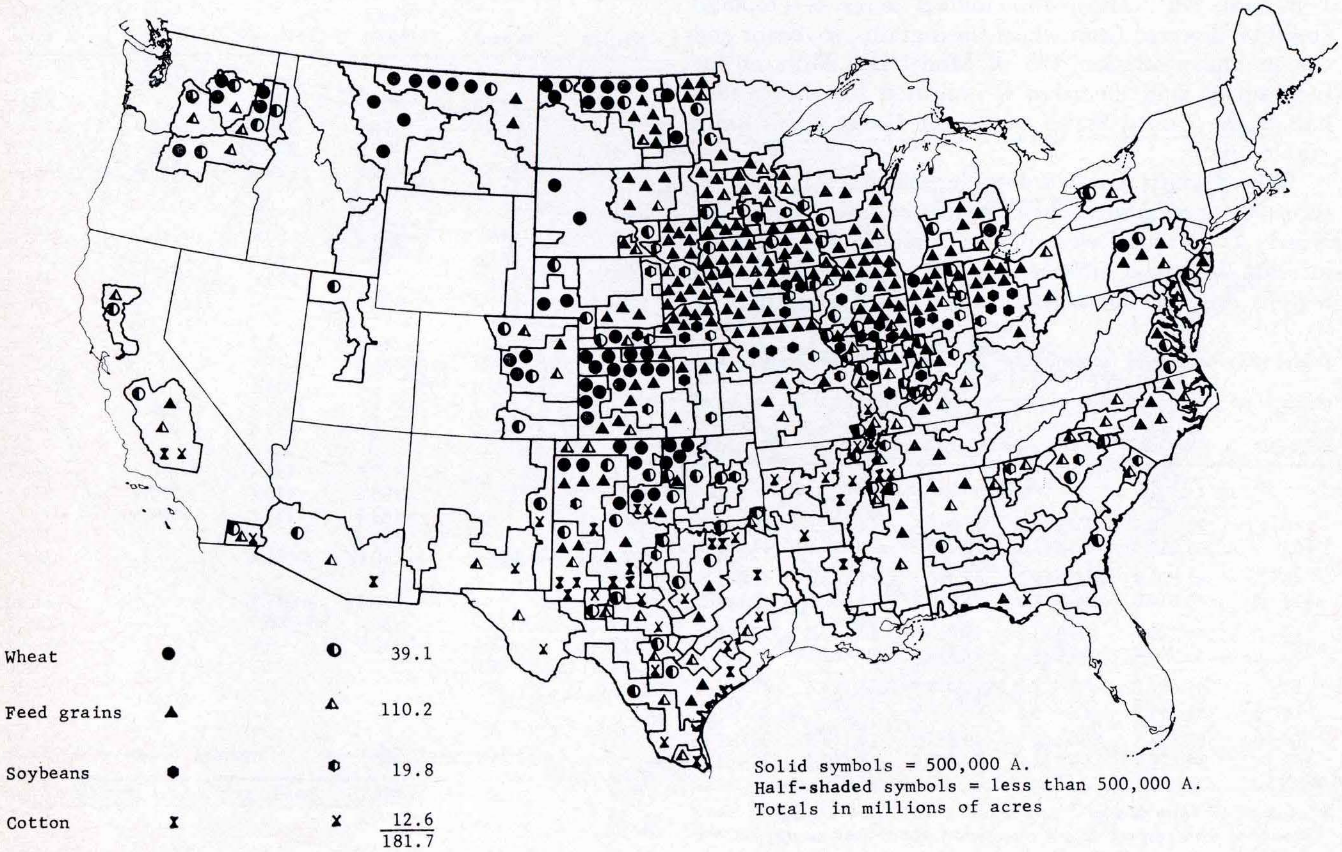

Fig. 25. Model II—Regional location and acreage of crop production for solution 432.

ponding relationship holds for the remaining solutions of Model III. (Solution 433 is the counterpart of 43, 473 is the counterpart of 47, etc.) The production and transportation patterns resulting from solutions of Model III are similar to corresponding solutions of Model I. The results often must be examined in detail to recognize broad differences among consuming regions. Most of the changes brought about by this model were small for any single region. However, several aggregate changes were evident among producing regions. Results from Model III and from similar solutions of Model I are summarized in table 18. Total cropland used is much less in Model III than in Model I. Wheat, feed grains and cotton acreages are generally reduced, while soybean acreage is increased.

Model III: Benchmark solution 433

Solution 433 under Model III is the counterpart of benchmark solution 43 under Model I. In both solutions, or restraints for acreage quotas of wheat, feed grains and cotton for this solution are set at 100 percent of their respective base levels or historic maxima. Prices and demand quantities are at the "normal" level. Soybeans are restrained to 40 percent of total cropland.

Approximately 8.2 million fewer acres are specified to attain the national bill of goods when intraregional differences in soil productivity are incorporated in the programming model (Model III compared with Model I in table 18). Thus, 48.7 million acres of cropland could be diverted from wheat, feed grains, soybeans and cotton under solution 433 of Model III. Most of the increase in land diversion is indicated for the eastern half of the United States and in the Great Plains states (table 19).

Wheat shifts westward under Model III, both in terms of acres and bushels (compare figs. 26 and 3). Nearly every state west of the Missouri river has an increase in wheat production; the opposite is true in regions east of the Missouri River. Consideration of land quality differentials allows western states to more fully exploit their comparative advantage in wheat production. In total, however, wheat acreage is reduced by 1.2 million acres (table 18). Consequently, as a result of the relocation of wheat production, a somewhat different pattern of transportation is required to attain demand for wheat in consuming regions (fig. 27 as compared with fig. 4).

Wheat used for feed is reduced to 280 million bushels under Model III. Wisconsin has the largest decrease, 40.8 million bushels, in use of feed wheat. Kansas has a small decrease while Colorado, Arizona, New Mexico, Washington and Oregon use greater amounts of wheat for feed. The construction of Model III better reflects comparative advantage of wheat production relative to feed-grain production in the West and Great Plains.

Feed-grain production is increased slightly to offset the lower utilization of feed wheat, under Model III, even though the acreage of feed grains is decreased by nearly 5.8 million acres. Corn Belt states, with their comparative advantage in these crops, replace feed-grain production in other regions. Feed grains move onto the more productive soils of the Corn Belt, the less productive land which otherwise would shift other crops or be diverted to non-crop use. Higher average

Table 18. Results of comparable solutions from Model III and Model I.[a]

Solution	Wheat	Feed grains	Soybeans	Cotton	Cropland unused
		(thousands of acres)			
40	73,714.6	77,981.2	19,910.4	14,113.8	38,235.2
403	63,855.1	80,657.3	20,918.7	11,421.9	47,102.3
43	47,006.7	102,432.2	19,890.1	14,113.8	40,512.6
433	45,834.0	96,672.3	21,319.9	11,462.0	48,667.3
47	44,270.4	105,143.5	19,861.5	14,113.8	40,566.1
473	43,992.4	98,037.2	21,466.3	11,462.5	48,997.1
51	41,601.2	99,922.9	20,411.2	14,114.6	47,905.4
513	41,494.8	97,344.2	21,315.6	11,449.5	52,351.4
54	53,563.4	100,644.9	19,551.2	14,113.8	36,082.0
543	49,525.4	96,231.8	21,193.9	11,463.2	45,901.2

[a] Solution 40 from Model I and solution 403 from Model III were identical with respect to all restraining conditions except for the assumption regarding cropland qualities within producing regions. The other four sets of solutions are similarly comparable.

Table 19. Change in acreage (thousands) of wheat, feed grains, soybeans and cotton from solution 43, Model I, to solution 433, Model III, by consuming region.

Region	Wheat	Feed grains	Soybeans	Cotton	Total used
1	..	..	..	..	..
2	−477.9	..	−9.8	..	−488.0
3	5.5	94.7	380.6	−84.7	206.7
4	..	−91.5	271.0	−178.9	0.6
5	..	−68.7	−29.0	−767.4	−865.1
6	..	15.9	..	..	15.9
7	−196.1	−305.0	50.8	−246.0	−696.3
8	−561.6	..	−183.6	..	−745.2
9	−583.7	..	895.6	..	312.0
10	−71.3	−480.7	..	..	−552.0
11	101.1	−745.5	−13.2	..	−859.8
12	−55.3	−786.6	−31.1	..	−873.0
13	−87.8	..	−1,208.6	..	−1,296.4
14	−575.9	..	607.6	−65.7	−34.0
15	−57.0	..	−639.4	..	−696.3
16	..	..	438.4	−170.3	268.1
17	..	950.6	440.4	1,710.9	319.9
18	..	−948.6	333.1	−104.6	−720.1
19	..	−197.4	..	..	−197.4
20	−95.3	−430.8	−156.4	..	−682.5
21	..	−915.3	249.2	..	−666.0
22	1,183.2	−160.7	40.2	..	1,062.7
23	477.5	−1,038.9	−5.8	..	−567.2
24	18.0	..	..	..	18.0
25	16.1	..	..	..	16.1
26	..	..	..	..	..
27	−10.1	..	..	676.6	666.6
28	..	..	..	..	..
29	..	−455.0	..	..	−455.0
30	..	0.2	..	..	0.2
Total	−1,172.8	−5,759.8	1,430.8	−2,651.8	−8,154.7

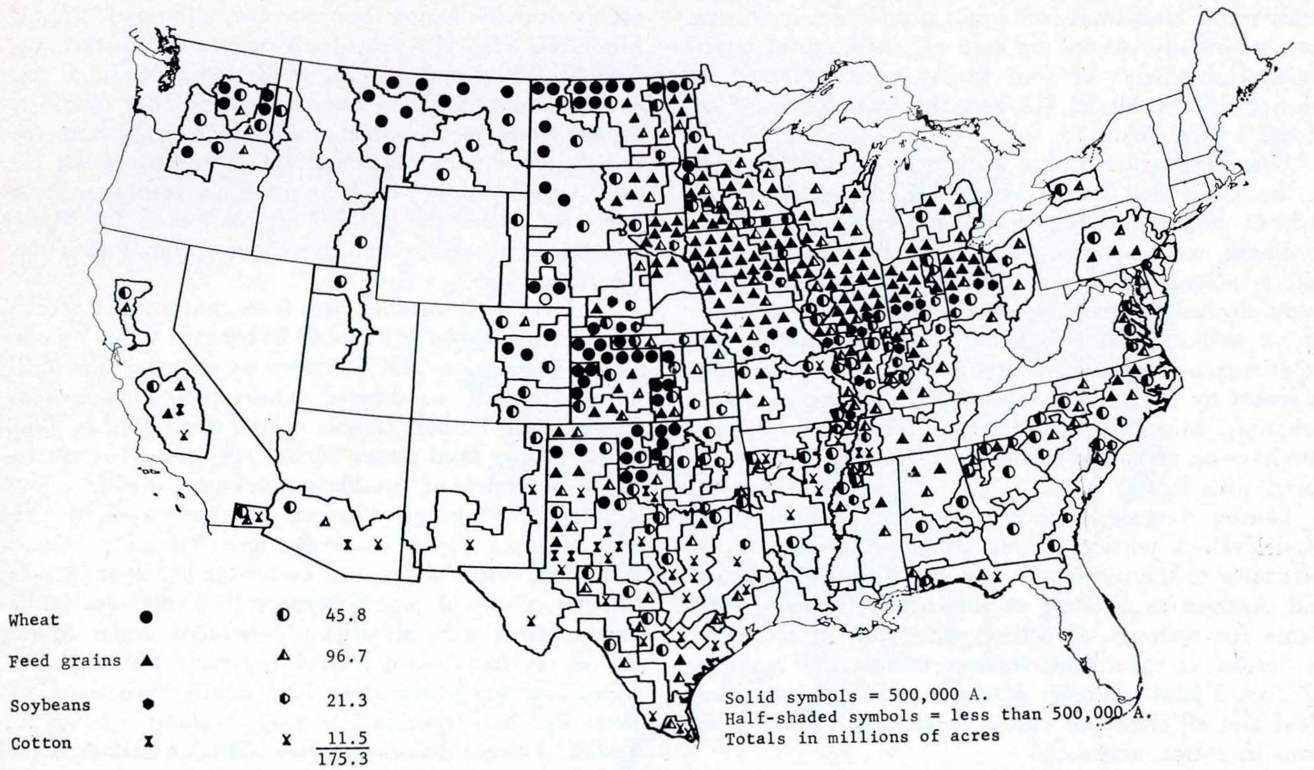

Fig. 26. Model III—Regional location and acreage of crop production for solution 433.

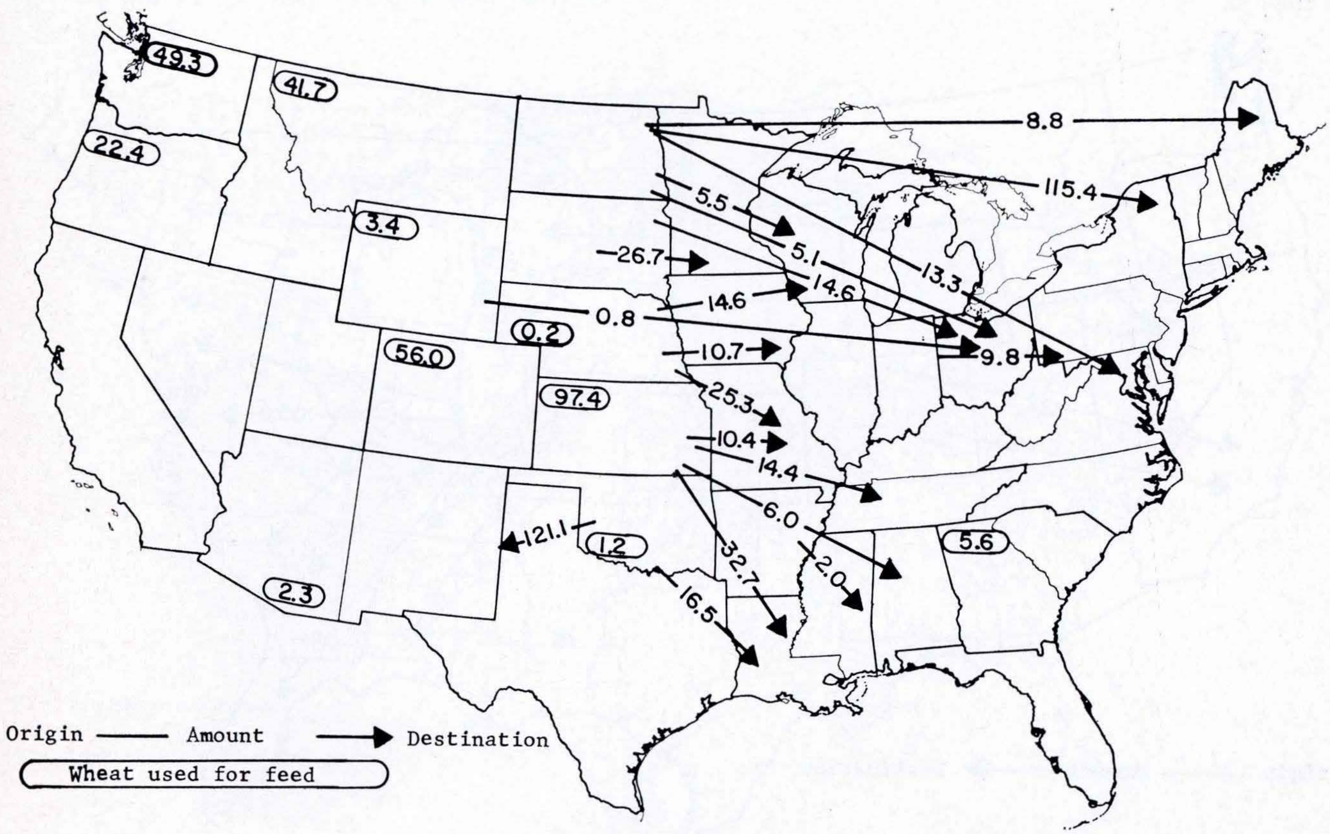

Fig. 27. Model III—Interregional flows of wheat under the conditions of solution 433 (million bushels).

yields result, and total feed-grain production is greater than previously. As in the case of wheat, total interregional shipments of feed grains were increased in solution 433 of Model III over that of solution 43 of Model I (fig. 28).

Since feed grains utilize a majority of the best land in the Corn Belt under Model III, the efficiency of soybean production is reduced in these regions. Accordingly, total acreage of soybeans increases to 21.3 million acres—the highest level of any solution in the study. Soybean acreage in Iowa is indicated to decrease by 1.2 million acres. Producing regions in Illinois also experience a decrease in soybeans, while acreage in Ohio increases by 0.9 million acres. Such southern states as Arkansas, Missouri, Missisippi, Louisiana and Texas also have an expanded soybean acreage (fig. 26 as compared with fig. 3).

Cotton acreage is reduced by 2.7 million under Model III. A portion of this decrease, however, is attributable to the movement of cotton into New Mexico and Arizona as a result of different technical coefficients for cotton.[24] All other states have a reduction in cotton acreage. Since cotton utilizes the majority of Class I land wherever cotton is produced, increased yield and efficiency of cotton production causes a big drop in cotton acreage.

Under Model III, with land differentiated by classes within regions, the surplus land is spread much more evenly over the nation. For example, solution 433 under Model III (fig. 30) provides a picture that is different from its counterpart, solution 43 under Model I (fig. 7). Few regions fail to have some land that would be shifted from cotton, wheat, feed grains or soybeans under the conditions of Model III. Thus, while the impact would not be as deep on some communities as suggested under the pattern of solution 43 for Model I in fig. 7, it would touch upon more communities over the nation.

Derived equilibrium prices for wheat are not greatly affected by Model III (table 20). Since Ohio reduces wheat production and increases imports by about 21 million bushels, its derived wheat price increases by 9 cents per bushel. Illinois, with wheat pushed onto lower quality land under Model III, has a 10-cent increase in its derived equilibrium price for wheat.

Since feed grains account for more than 50 percent of total cropland acreage included in the model and since they utilize the better-quality land at the expense of wheat and soybeans, their derived equilibrium prices were significantly reduced under Model III as compared with Model I. Nearly all Corn Belt states and states importing feed grains from the Corn Belt (fig. 28) experience a drop of about 5 cents per bushel. Texas, Oklahoma, New Mexico and Arizona, each allowing cotton to utilize Class 1 land, have increases in derived feed-grain prices. North Dakota, because of a large increase in wheat production, has a slight increase in derived feed-grain prices.

Derived oilmeal prices (see fig. 29 for the soy-

[24] From the results of Model II, cotton acreage was reduced by 1.5 million acres as a result of the new production coefficients. The remaining 1.2-million-acre drop in this solution is attributable to the characteristics of Model III.

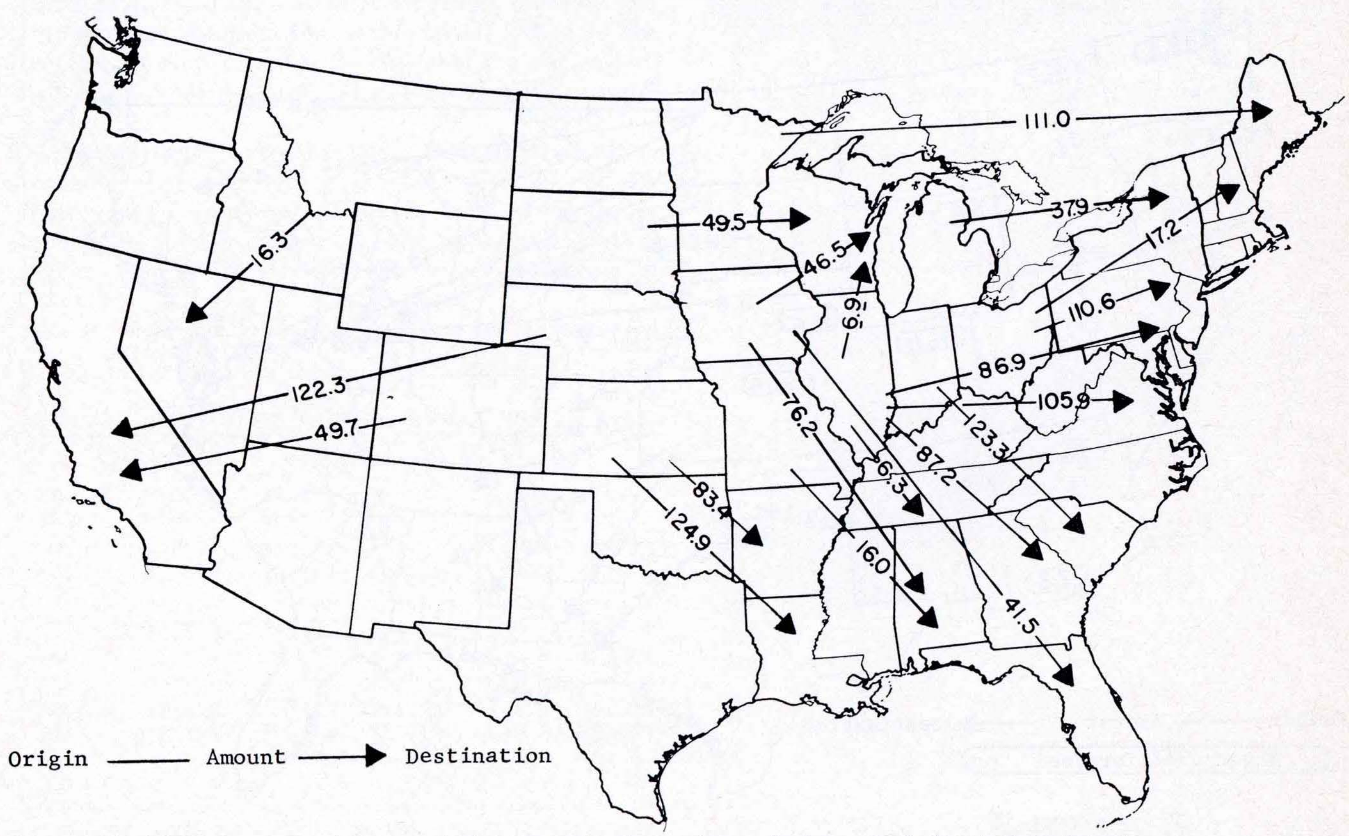

Fig. 28. Model III—Interregional flows of feed grains under the conditions of solution 433 (million bushels of corn).

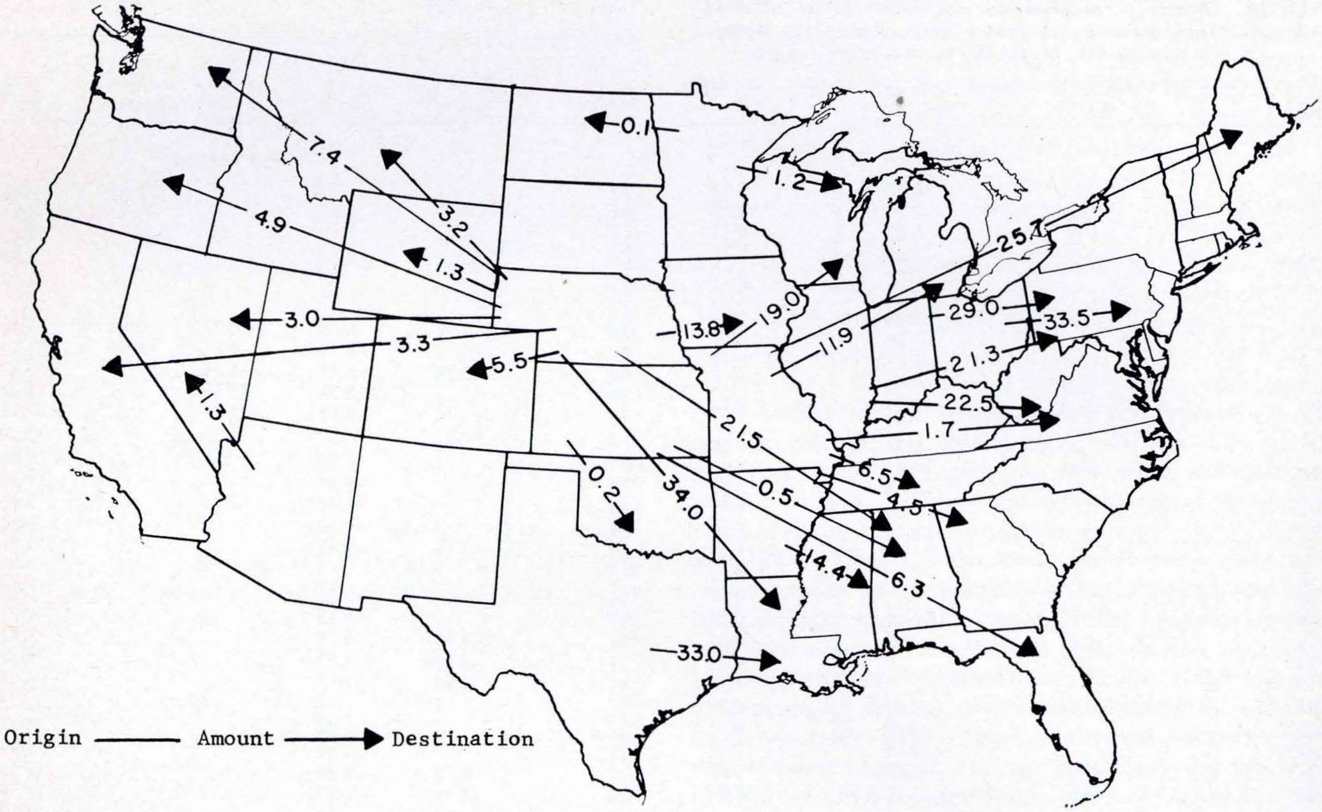

Fig. 29. Model III—Interregional flows of oilmeals under the conditions of solution 433 (million bushels of soybeans).

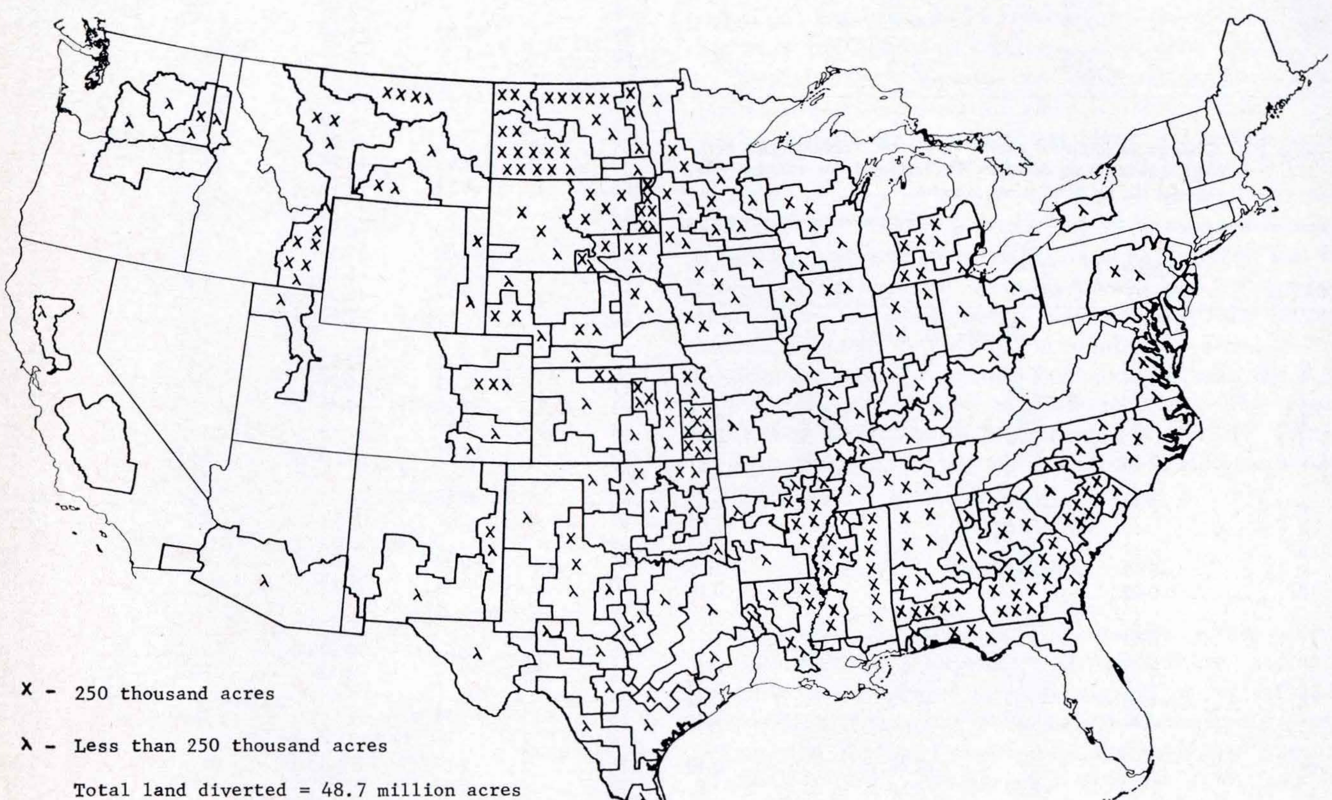

Fig. 30. Model III—Amount and location of surplus land under the conditions of solution 433.

Table 20. Change in programmed equilibrium prices of wheat, feed grains and soybeans from solution 43, Model I, to solution 433, Model III, by consuming region.

Region	Wheat	Feed grains	Soybeans
	(dollars per bushel)		
1	−0.01	−0.05	0.11
2	−0.02	−0.05	0.12
3	−0.01	−0.04	0.11
4	−0.06	−0.05	0.11
5	..	−0.04	0.07
6	−0.05	−0.04	0.06
7	..	−0.05	0.12
8	−0.01	−0.05	0.12
9	0.09	−0.05	0.12
10	−0.02	−0.04	0.12
11	..	−0.04	0.12
12	−0.01	−0.03	0.12
13	..	−0.04	0.22
14	..	−0.08	0.11
15	0.10	−0.05	0.11
16	..	..	0.07
17	..	..	0.07
18	..	0.02	0.07
19	0.01	0.08	0.02
20	..	..	0.02
21	−0.01	0.01	0.07
22	..	0.02	0.12
23	..	−0.03	0.12
24	−0.03	−0.02	0.07
25	−0.01	..	0.07
26	0.02	0.01	0.07
27	0.04	0.04	−0.14
28	−0.03	−0.02	0.07
29	−0.03	−0.02	0.07
30	−0.03	−0.02	0.07
31	−0.03	0.02	0.07

Table 21. Change in imputed rental values of cropland and acreage quotas from solution 43, Model I, to solution 433, Model III, by producing regions.

Region	Wheat quota	Feed-grain quota	Cotton quota	Soybean quota	Crop-land[a]
		(dollars per acre)			
1	−6.60	−7.76	..	..	7.16
2	−4.60	−8.38	..	..	7.74
3	..	−8.56	..	−0.33	6.53
4	..	−5.20	..	−0.56	3.81
5	2.38	1.60	..	5.41	..
6	0.74	−1.21	..	4.00	0.07
7	..	−1.56	..	..	3.13
8	..	0.85	..	..	0.34
9	−2.59	−3.97	..	..	3.55
10	−0.02	..	..	3.20	−0.19
11	0.53	..	..	..	..
12	0.55	..	..	−0.50	..
13	−2.71	−3.93	−3.81	..	3.42
14	−4.60	−4.57	−9.73	..	3.62
15	−1.48	−0.89	..	..	1.42
16	..	..	−15.45	..	0.40
17	..	−3.67	−4.67	..	..
18	..	..	..	..	..
19	..	−0.20	..	0.88	1.30
20	1.44	0.27	−14.28	−0.65	..

Table 21 (continued).

Region	Wheat quota	Feed-grain quota	Cotton quota	Soybean quota	Crop-land[a]
		(dollars per acre)			
21	..	..	..	7.55	1.82
22	..	−5.51	..	..	5.23
23	−2.11	−5.78	..	..	8.88
24	−0.47	−0.72	..	..	1.85
25	..	..	..	..	2.53
26	4.22	−0.61	−10.32	−2.07	−3.40
27	−4.00	−8.36	−4.81	−0.97	7.33
28	−2.38	−8.14	−45.74	..	7.08
29	..	−15.21	−25.67	..	12.22
30	..	−9.12	−31.73	..	7.49
31	..	−6.05	−20.45	..	5.03
32	..	−4.63	..	..	3.57
33	..	−6.48	−8.51	..	3.43
34	..	−9.60	..	..	8.10
35	−1.18	−4.43	..	..	3.51
36	..	−6.20	..	..	5.29
37	..	−6.13	..	..	−2.75
38	−4.11	−5.79	..	..	4.49
39	−5.03	−7.27	..	..	4.82
40	−0.50	−7.63	..	..	6.06
41	..	−1.58	..	..	2.04
42	..	−1.44	..	..	2.27
43	−8.16	−16.45	..	..	15.32
44	−5.49	−18.07	..	..	16.64
45	−0.15	−6.74	..	..	4.18
46	..	−16.56	..	..	14.02
47	..	−6.94	..	..	4.15
48	..	−5.39	..	0.60	3.72
49	−1.00	−6.52	..	..	4.96
50	−1.76	−8.73	−30.63	..	4.77
51	−1.49	−4.66	..	..	21.92
52	..	−8.80	..	..	4.96
53	..	−6.56	..	−0.07	3.99
54	−2.53	−10.99	..	..	8.97
55	−6.24	−10.16	..	..	8.08
56	−4.37	−6.54	..	..	4.69
57	−5.00	−9.40	..	..	7.65
58	−2.76	−5.15	..	..	3.62
59	−2.15	−10.21	..	..	9.06
60	..	−2.83	..	..	7.89
61	−1.10	−2.92	..	..	1.54
62	1.23	−0.78	..	..	1.46
63	−1.20	−3.45	..	..	2.57
64	0.47	..	..	..	..
65	−0.61	..	..	..	0.86
66	−0.83	..	..	..	0.89
67	..	..	..	..	0.46
68	..	..	..	0.60	..
69	−0.32	..	..	..	0.35
70	..	0.17	..	..	0.10
71	..	..	..	..	..
72	0.68	−0.04	..	..	..
73	..	−3.38	..	..	2.88
74	..	..	..	1.52	0.87
75	−1.36	..	..	..	1.76
76	−2.27	..	..	..	2.64
77	−0.87	−1.33	..	..	2.11
78	..	..	..	0.68	1.91
79	−2.81	..	..	−0.19	2.94
80	..	−2.29	..	..	3.35

Table 21 (continued).

Region	Wheat quota	Feed-grain quota	Cotton quota	Soybean quota	Cropland[a]
	(dollars per acre)				
81..........	..	−1.02	..	..	2.60
82..........	..	..	..	..	..
83..........	..	..	..	..	0.18
84..........	..	..	..	0.08	1.67
85..........	−0.86	−0.06	..	..	1.39
86..........	−0.86	..	..	..	1.16
87..........	−2.96	−2.75	..	..	3.05
88..........	−3.01	−2.00	..	..	2.98
89..........	−5.16	−5.34	..	..	5.49
90..........	1.12	..	..	..	..
91..........	−1.46	..	..	..	2.47
92..........	−2.38	−0.83	..	..	2.84
93..........	−1.68	..	..	..	2.44
94..........	−5.14	−2.27	−21.26	..	4.31
95..........	−10.31	−8.57	−55.73	..	10.45
96..........	−3.04	−1.91	−24.55	..	9.39
97..........	−6.01	−5.09	−49.83	0.24	15.18
98..........	−2.16	..	−16.57	..	2.45
99..........	0.05	−0.30	−11.20	..	1.35
100..........	−0.82	−1.29	−19.86	..	2.29
101..........	0.09	−0.47	−19.53	..	1.66
102..........	..	−4.20	−24.86	..	5.38
103..........	−7.71	−9.40	−39.51	..	10.34
104..........	−3.09	..	..	..	2.50
105..........	−0.26	..	..	..	0.32
106..........	..	..	..	..	0.16
107..........	−0.38	..	..	..	0.65
108..........	..	..	..	..	0.47
109..........	−1.74	..	..	..	2.16
110..........	0.94	..	..	..	..
111..........	−0.36	..	..	..	0.71
112..........	1.41	..	−28.30	..	1.04
113..........	..	..	..	..	..
114..........	0.89	..	..	..	..
115..........	−1.46	..	..	..	1.37
116..........	2.01	2.86	..	..	−2.63
117..........	−6.50	−6.03	..	..	6.04
118..........	−5.80	−5.62	..	..	5.42
119..........	−6.21	..	..	..	5.43
120..........	−5.84	−5.94	..	..	6.43
121..........	−10.86	−10.24	40.23	..	8.71
122..........	7.39	..	..	..	..
123..........	1.20	..	..	..	..
124..........	3.57	..	..	..	..
125..........	..	..	−19.68	..	..
126..........	2.44	0.18	..	..	..
127..........	−0.64	..	−34.35	..	1.90
128..........	3.27	..	−20.64	..	..
129..........	4.15	..	..	..	..
130..........	..	..	−25.08	..	..
131..........	..	..	..	..	..
132..........	..	..	−17.41	..	0.97
133..........	..	..	−29.62	..	7.11
134..........	−2.18	−0.27	..	−1.53	3.76
135..........	0.94	..	..	1.67	..
136..........	4.42	..	−5.49	..	..
137..........	..	−5.67	−43.91	..	6.84
138..........	−3.24	−2.72	−25.47	..	3.55
139..........	−2.54	−2.21	−25.00	..	2.81
140..........	..	−5.80	−166.88	..	46.74
141..........	..	..	..	..	33.32
142..........	−18.05	−20.17	29.72	..	22.58
143..........	−7.48	−4.69	−39.71	..	22.43
143..........	4.59	..	−12.55	..	0.57
Total	−174.32	−454.40	−932.84	19.56	594.90

[a] The regional average value of cropland used for solution 433 was the weighted average of imputed values for the three classes of cropland in each region.

bean oilmeal flows between regions) increase in all regions except one under Model III, because lower yields and higher acreages are required as soybeans are pushed onto the less productive land in most producing regions. Soybeans, where grown, compete quite closely with feed grains for cropland. (Feed grains generally command the better qualities of land, causing the soybean yields to be reduced from Model I.) Total cottonseed production is not changed under Model III, but a larger percentage is concentrated in the western states. Consequently, oilmeal prices are substantially reduced in these states. The derived equilibrium price of cotton is lowered from $31.99 per hundredweight for solution 43 to $24.43 under Model III. (The cotton price is reduced by $3.82 in going from solution 43 to 432 as a result of the change in production coefficients for producing in regions of Texas, Arizona and New Mexico. The remaining $3.74 results from the shift of cotton onto the higher producing land of each region.)

Rental values imputed to cropland and acreage quotas are changed significantly by Model III. Cropland restraints are tripled under Model III, while acreage quota restraints are unchanged. This ratio, of land qualities relative to acreage quotas, is probably more realistic than that represented by previous models. As a result, cropland constraints become limiting much more frequently, and acreage quotas less frequently, than in the previous models. Consequently, the rental values imputed to production quotas or acreage restraints for individual crops were reduced, and the imputed values of cropland generally increased. The magnitudes of these changes are reflected in table 21. These differences may be compared with the original values for solution 43, Model I, shown in table 7.

SUMMARY

This study has been made to analyze certain facets of interregional competition in agriculture and to appraise the extent of surplus capacity as represented by cropland that can be shifted from wheat, feed grains, cotton and soybeans in meeting domestic and export demands in 1965. Another purpose of the study was to determine the interregional shifts in agricultural production that might be expected if the nation's "bill of

goods" in required wheat, feed grains, cotton and soybeans were produced most efficiently under current technologies and farming practices. Finally, we attempted to identify individual producing regions that would need to shift from crop production to less intensive uses of land, such as grazing, forestry or recreation.

Linear-programming models, including 962 equations and 2,682 real variables and based on 144 spatially separated producing regions, were constructed to analyze the needed adjustments in resource use. These regions were defined to recognize the variations in technology, soil productivity and climatic conditions existing across the United States. Each producing region has four potential producing activities (wheat, feed grains, soybeans and cotton) from which projected demand requirements are met. The inclusion of potential activities in a region rests solely on the cropping history of the region. The programming regions used account for about 95 percent of the United States production of the four crops.

Also, 31 spatially separated demand regions, encompassing 48 states, are delineated and used in the analysis. Demands for wheat, feed grains and oilmeals are specified to reflect the projected trend in commodity requirements for each consuming region. A single national demand is used for cotton lint. Transportation activities allow the designation of commodity movement among consuming regions and are used to insure an optimum allocation of production in meeting the regional demand requirements. The objective function of each programming model includes minimization of the total costs of producing and transporting commodities. A transfer activity in each consuming region allows wheat to be used for livestock feed at a cost varying upward from zero. This activity also provides the possibility of considering single- or multiple-price plans for wheat, as alternative policy programs.

Cropland is considered the limiting factor of crop production in each producing region. Regional acreage quotas (historic maximum acreages) for specific crops are used to simulate different land-retirement or supply-control schemes. Soybeans, in all solutions, are limited to the use of 40 percent of available cropland in each region.

Models I and II each were constructed under the assumption of homogeneous land within the programming regions. Regional productivity of each crop thus is reflected by a fixed coefficient of production. The two models differ in the pricing scheme employed for wheat. Model I uses a multiple-price plan for wheat. The food-wheat demand can be satisfied at a price above the equilibrium value of wheat, while feed wheat is utilized at its value as feed. Model II supposes all wheat to be supported at a price above the equilibrium value of wheat. Model III relaxes the assumption, used in Model I and Model II, of cropland homogeneity within producing regions. Regional cropland constraints for Model III are divided into three categories on the basis of the estimated potential productivity of each.

In the programming models, 223.9 million acres of cropland are available for the production of feed grains, wheat, cotton and soybeans. Excess capacity is measured in terms of unused cropland (i.e., land formerly devoted to the four crops but not needed to meet 1965 demand requirements and which could be shifted to other crops). Surplus capacity so measured ranges from 24.6 million acres, for a mildly restrictive program on all crops and a very high product-demand level, to 52.3 million acres, for an unrestrictive feed-grain program and a normal demand level. Typically, the benchmark solution with single soil classes in each region indicates a national surplus capacity of 40.5 million acres for 1965. If soil differences within regions are recognized through use of Model III, this surplus capacity extends to 48.7 million acres.

If production were restrained to mesh exactly with demand levels at normal prices for 1965 and if production were allocated optimally among producing regions, many individual regions would need to shift almost entirely from the specified crops. These regions would be located mainly in the South and marginal areas of the Great Plains. Some land also would need to be diverted in fringe areas of the Corn Belt and other scattered regions of the nation. However, when intraregional soil differences are recognized, almost every producing region has some land that would need to be shifted from field crops. The amount would vary, of course, with the level of prices and the demand quantities to be attained. Under three solutions based on corn prices of 85 cents, $1.10 and $1.40 per bushel, with corresponding prices of other commodities, the amount of surplus land was indicated to be 24.6 million, 40.5 million and 51.4 million acres, respectively.

It must be concluded that conditions affecting the spatial allocation and amount of production of either wheat or feed grains may also substantially affect the other crop. There is considerable interaction of the two major commodities both in their competition for land use and in their substitution in consumption.

The spatial allocation of production appreciably affects the needed transportation of products. On the other hand, transportation charges had little effect on production allocation. Model III, with the advantage of using only the best land in each region, allows the greatest opportunities for adjusting the location of production. However, there is very little difference in transportation requirements of comparable solutions from Models I and III. Hence, comparative advantages in production seem to outweigh the influence of transportation costs. Using shadow prices as the criterion, transportation charges added an average of about 28-31 cents per bushel to derived wheat equilibrium prices, 9-10 cents per bushel to feed-grain prices and 13-15 cents per bushel to soybean prices.