Projections of U. S. Agricultural Capacity and Interregional Adjustments in Production and Land Use With Spatial Programming Models

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Surplus commodity supplies and capacity have characterized American agriculture for the last 35 years. Attempts to restrain this growing capacity and to dampen its effect on farm income have been reflected in price-support programs and acreage-diversion policies. Acreage diversion has been applied largely over all regions. Consequently, interregional shifts in land use have not kept pace with changes in the comparative advantage of different regions resulting from differential rates of change in technology, transportation costs, population growth and demand.

This study has been made to help determine the magnitude of interregional shifts in grain production and land use implied for the future under specified conditions of technological improvement and population or demand growth. It also is directed towards measurement of potential surplus capacity of American agriculture in the decade ahead. Finally, the analysis projects conditions of interregional competition in crop production under assumptions allowing increased exports, further development of the St. Lawrence Seaway, alternative rates of technological improvement in various agricultural regions and an advance in the technology of southern agriculture to the level of that in other regions of the nation.

The study is the fourth in a series dealing with the apparent overcapacity of agriculture and the relative advantage of different producing regions in the United States.[2] The crops included are wheat, corn, grain sorghums, barley, oats, soybeans and cotton. In contrast to previous studies, however, data of the current analysis are projected to 1975. The study employs spatial linear-programming models applied to projections of demand and technology for this point in time.

The objectives of the study are attained through the application of several empirical linear-programming models which deal directly with crop production but incorporate feed requirements for livestock production. Demand requirements, including domestic and export quantities, are expressed as discrete quantities for the 31 consuming regions. Programming models now under way will incorporate demand functions and livestock activities into the analysis. While the objective function used is one of minimizing the cost of producing and transporting a certain bill of goods, represented by national crop requirements, a parallel study being made is based on profit-maximization models and also considers the equation of supply and demand in a market equilibrium.

NATURE OF EMPIRICAL MODELS

Number of Regions, Producing, Transfer and Transportation Activities

This study is based on 144 producing regions (fig. 1) within the contiguous United States.[3] The programming regions are defined primarily on the basis of state economic areas, as indicated by the Agricultural Census prior to 1959. State economic areas are used in defining producing regions, since the type of farming and the land productivity within state economic areas are quite uniform. Also, many of the data necessary for studies of this type are reported on a county, state crop-reporting district or state economic area basis.

Historically, the 144 programming regions account for about 95, 97, 93, 84, 99, 99 and 99 percent of the United States production of wheat, corn, oats, barley,

[1] Project 1405 of the Iowa Agricultural and Home Economics Experiment Station, in cooperation with the Center for Agricultural and Economic Development and the Agricultural Adjustments Branch, Economic Research Service, United States Department of Agriculture.

[2] Alvin C. Egbert and Earl O. Heady. Regional adjustments in grain production—A linear programming analysis. U. S. Dept. Agr. Tech. Bul. 1241. (Suppl.) 1961; Earl O. Heady, Alvin C. Egbert 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; and Earl O. Heady and Norman K. Whittlesey. A programming analysis of interregional competition and surplus capacity of American agriculture. Iowa Agr. and Home Econ. Exp. Sta. Res. Bul. 538. 1965.

[3] For a discussion of the basis on selecting regions, see: 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.

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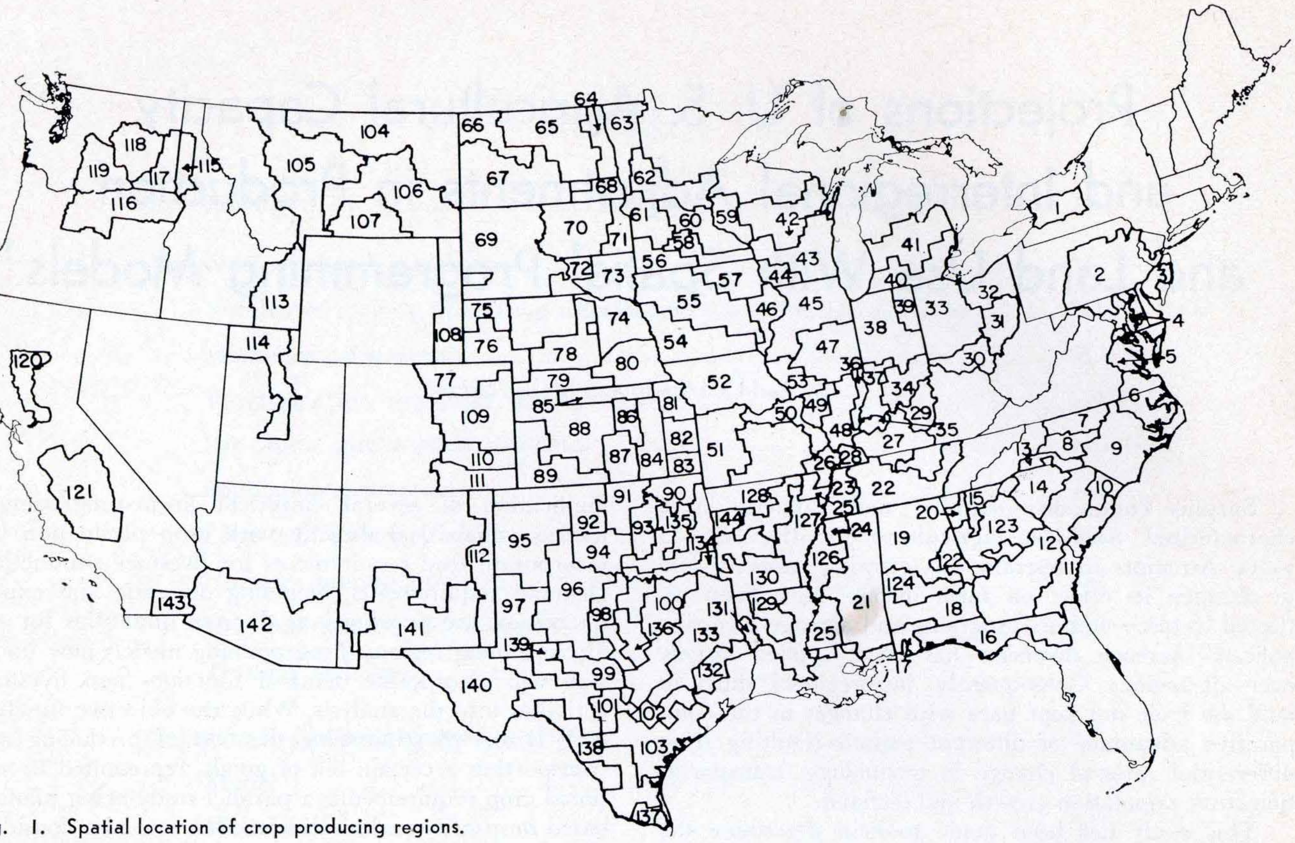

Fig. 1. Spatial location of crop producing regions.

grain sorghum, soybeans and cotton, respectively. Production not included in the 144 producing regions (i.e., regions without numbers in fig. 1) is termed "white-area" production. In the analysis, this "white-area" production is specified as part of the demand requirement for the region in which it occurs.

The models also include 31 spatially separated consuming (demand) regions (fig. 2) for the three final-product categories: wheat, feed grains and oilmeals. The feed-grain product category includes corn, grain sorghums, barley, oats and wheat used for feed. These crops are converted to a corn-equivalent basis in the analysis, rather than each being considered separately. Consuming regions follow state boundaries within the same geographic proximity. Most demand regions are unique to an individual state. Where they are not, the states are adjoining and economically related. Historic interregional movements of grain influenced the final selection of the boundaries for consuming regions.

Five production activities are possible for each producing region: wheat, feed-grain rotation, feed-grain and soybean rotation, soybeans and cotton. The models include a wheat-to-feed-grain transfer activity for each consuming region, allowing for the use of wheat for feed if it is the cheapest source of livestock nutrients. The models do not restrain the amount of wheat that can be used as feed.

Transportation activities for each of the three demand categories allow movement of grains among consuming regions. Theoretically, $31 \times 30 = 930$ transportation activities exist for each product category, making a potential of 2,790 transportation activities for the three product categories. However, some of these activities are eliminated by physical separation of the regions. Also, for example, the possibility of shipping oilmeals from consuming region 29 (Washington) to consuming region 16 (Arkansas) is eliminated since Washington has never produced soybeans or cotton, the two activities giving rise to the oilmeal product category. In final construction of the models, 1,376 transportation activities (459 each for wheat and feed grains and 428 for oilmeals) were used.

The transportation costs used are the 1962 "flat" railroad rates for the products in question. The points of trade (i.e., the points within each consuming region from which all importing or exporting is assumed to occur) were selected as the basis for computing these rates. The transportation rates were furnished by the Interstate Commerce Commission.

Each of the 31 consuming regions has separate demand restraints for wheat, feed grains and oilmeals. A single United States demand restraint is defined for cotton lint. Wheat, feed grains and oilmeals are expressed in feed units to allow aggregation of feed-grain crops and the feed-grain and soybean rotation into a single activity, to simplify use of the wheat-to-feed-grain activities and to allow aggregation of soybean oilmeal and cottonseed oilmeal into a homogeneous product.

Each of the 144 programming regions has a land restraint to reflect the total area available for use of the five crop activities. The models allow wheat, feed-grain or feed-grain and soybean activities to occupy all land available within a region. However, the soybean activity is restrained to not more than 50 percent of the land available; the cotton activity is restrained to the largest percentage of land used in the past for any one region.

Mathematical Structure

The objective function of cost minimization models used can be stated as:

$$\text{Minimize } f(c) = \sum_{i=1}^{144}\sum_{k=1}^{5} c_{ki}\, x'_{ki} + \sum_{m=1}^{31} d_m\, y_m + \sum_{g=1}^{3}\sum_{m=1}^{31} b_{gmm'}\, z_{gmm'} \quad (1)$$

in which,

c_{ki} = cost per acre of producing the kth activity in the ith programming region,

x'_{ki} = level of production of the kth activity in the ith programming region,

d_m = cost per unit of transferring wheat into feed grains in the mth consuming region,

y_m = quantity of wheat transferred into feed grains in the mth consuming region,

b_{gm} = cost of transporting a unit of the gth product from (to) the mth consuming region to (from) the m′th consuming region,

z_{gm} = quantity of the gth product transported from (to) the mth consuming region to (from) the mth consuming region.

Equation 1 is maximized subject to the linear restraints:

$$D_{1m} = \sum_{i=1}^{r} a_{1i}\, x'_{1i} - h_m y_m \pm \sum_{m'=1}^{31} t_{1mm'}\, z_{1mm'}\ ; \quad (2)$$

$$D_{2m} = \sum_{i=1}^{r} a_{2i}\, x'_{2i} + \sum_{i=1}^{r} a_{3i}\, x'_{3i} + h_m y_m \pm \sum_{m'=1}^{31} t_{2mm'}\, z_{2mm'} \quad (3)$$

$$D_{3m} = \sum_{i=1}^{r} a_{3i}\, x'_{3i} + \sum_{i=1}^{r} a_{4i}\, x'_{4i} \sum_{i=1}^{r} a_{5i}\, x'_{5i} \pm \sum_{m'=1}^{31} t_{3mm'}\, z_{3mm'}\ ; \text{ and} \quad (4)$$

$$D_c = \sum_{i=1}^{144} a_{5i}\, x'_{5i}\ , \quad (5)$$

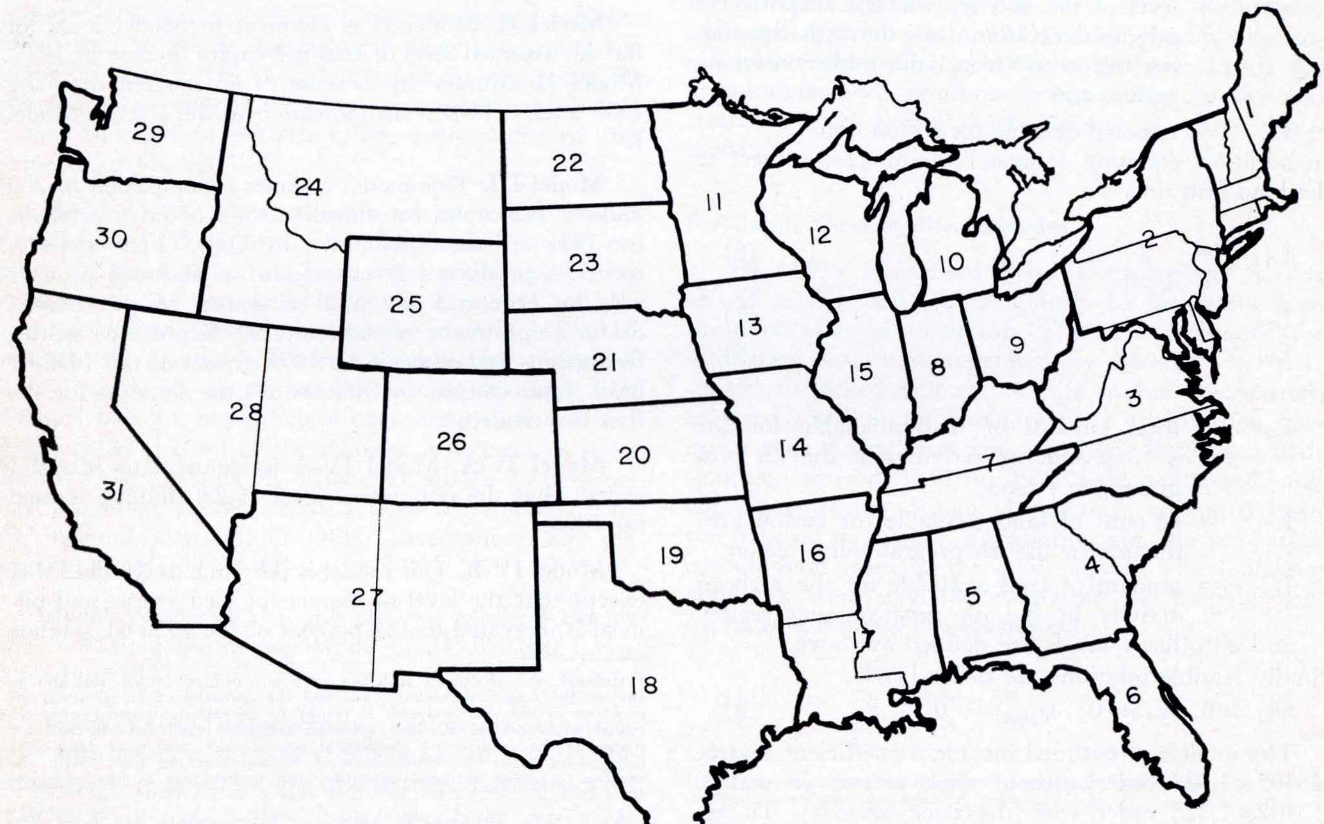

Fig. 2. Spatial location of consuming regions.

where

D_{gm} = demand for the gth product in the mth consuming region in which: g=1 refers to wheat demand; g=2 refers to feed-grain demand and g=3 refers to oilmeal demand,

a_{ki} = yield per acre of the kth producing activity in the ith programming region with k=1=wheat, k=2=feed grains, k=3=feed grains and soybeans, k=4=soybeans and k=5=cotton,

x'_{ki} = level of production (acres) of the kth activity in the ith programming region,

r = number of programming regions in the mth consuming region,

h_m = amount of wheat transferred into feed grains per unit of the wheat-to-feed-grain transfer activity in the mth consuming region,

y_m = level of the wheat-to-feed-grain transfer activity in the mth consuming region,

$t_{gmm'}$ = amount of the gth product transported from the mth consuming region to the m′th consuming region or the amount of the gth product transported to the mth consuming region from the m′th consuming region per unit of the 1mm′th transportation activity,

$z_{gmm'}$ = level of the activity which transports the gth product from (to) the mth consuming region to (from) the m′th consuming region, and

D_c = national demand for cotton lint.

In addition, equation 1 must be minimized subject to the land restraints:

$$L_{Ti} \geqq \sum_{k=1}^{5} x'_{ki} \quad , \qquad (6)$$

$$L_{Ci} \geqq x'_{5i} \quad , \qquad (7)$$

$$L_{Si} \geqq x'_{4i} \quad , \qquad (8)$$

where

L_{Ti} = total amount of land available for the k=5 producing activities in the ith programming region,

L_{Ci} = amount of land available for cotton production in the ith programming region,

L_{Si} = amount of land available for the soybean activity in the ith programming region,

and all other symbols are defined as above.

Finally feasible solutions are defined as:

$$x'_{ki} \geqq 0; \quad y_m \geqq 0; \quad z_{gmm'} \geqq 0 \quad . \qquad (9)$$

The models as outlined include a coefficient matrix of 402 x 1,923 order without slack vectors (a matrix of 402 x 2,325 order with the slack vectors). To assure against an infeasible solution in some of the empirical models with large demand restraints, 93 artificial activities were introduced (one for each of the three final demand categories in the 31 consuming regions) which enabled the demand in any consuming region to be met at a very high artificial cost if producing regions as defined were not able to satisfy the demand.[4]

Variations for Empirical Models

Several sets of assumptions were used in the various models relative to population, income, feed-livestock product conversion efficiency and per-acre yields and costs. These alternative assumptions (i.e., different levels at which demand restraints and technical coefficients are placed) allow examination of the effect of different levels of exports, varying rates of technological advance over the nation and similar developments in interregional competition. We now review the several empirical models used in the study. All models refer to restraints and variables for 1975.

Model I. A United States population of 222 million is assumed for 1975. Real per-capita consumption of farm products is projected to increase in accordance with the change in per-capita income outlined later. Trends in per-acre yields and in feed-livestock conversion rates are predicted as a continuation of the 1940-60 trend. The trend in production cost per unit of crop output is projected from the 1949-61 trend. Exports of wheat, feed grains and oilmeals approximate the 1956-61 average export levels.

Model II. Model II is identical to Model I except for the assumed level of real per-capita income in 1975. Model II assumes an increase of 65 percent over the 1955 level, a 15-percent increase over the level in Model I.

Model III. This model assumes a population of 230 million. Per-capita consumption rates of farm products for 1975 are those estimated by Daly.[5] Feed requirements to produce a given amount of livestock product are the economic potential estimates of the United States Department of Agriculture.[6] Exports of wheat, feed grains and oilmeals for 1975 are set at the 1956-61 level. Input-output coefficients are the same as for the first two models.

Model IV-A. Model IV-A is identical to Model I except that the population level of 230 million is used for 1975.

Model IV-B. This model is the same as Model IV-A except that the level of exports of feed grains and oilmeal is increased to 125 percent of the 1956-61 average

[4] Although the articificial activities were not utilized in the solutions to any of the empirical models, they had the potential of being useful for problems of the size analyzed. If results to an empirical model were obtained with the aid of these artificial activities, the least-cost real activities in the solution are meaningful economically, and some results are forthcoming from the expenditure of elapsed machine time. With the addition of these artificial activities, the matrix was of the order of 402 x 2,016 and 402 x 2,418, with and without slack vectors, respectively.

[5] Rex F. Daly. The long-run demand for farm products. Agr. Econ. Res. 8:1-19. 1956.

[6] Glen T. Barton, Economic Research Service, U. S. Department of Agriculture. Private communication. Sept. 1961.

export levels of these commodities. (Wheat exports remain as in previous models—100 percent of the 1956-61 level.)

Model IV-C. Wheat exports are increased to 125 percent of the 1956-61 level in Model IV-C. The 25-percent increase is allocated to regions bordering the St. Lawrence Seaway (consuming regions 9, 10, 11 and 12). Feed-grain and oilmeal exports are increased to 150 percent of the 1956-61 levels, the increase being distributed among consuming regions in the proportion of 1956-61 exports. Other assumptions are the same as for Model IV-A.

Model IV-D. Wheat exports are increased to 150 percent of the 1956-61 levels and are distributed among consuming regions in proportion to 1956-61 exports. Feed-grain and oilmeal exports are increased to 200 percent of their 1956-61 average levels and also are distributed among consuming regions in the 1956-61 pattern. Other assumptions are the same as for Model IV-A.

Model IV-E. Wheat exports are at 150 percent of the 1956-61 level and are distributed among regions in the same manner as in that period. Feed-grain exports are set at 200 percent of 1956-61 levels, with 50 percent allocated equally to consuming regions 9, 10, 11 and 12 and another 50 percent allocated to the remaining regions in the same proportion as in 1956-61. Oilmeal exports, also doubled, have 20 percent of the increase allocated to Pacific Coast consuming regions, 50 percent to the St. Lawrence Seaway consuming regions (regions 9, 10, 11 and 12) and the remaining 30 percent as a residual to other consuming regions following the 1956-61 pattern. Other assumptions are the same as for Model IV-A.

Model IV-F. Wheat exports are increased to 200 percent of 1956-61, with the distribution among regions the same as at that time. Feed-grain exports, increased to 200 percent of 1956-61, have half of the increase forced through consuming regions 9, 10, 11 and 12; 20 percent allocated to consuming regions 3 and 5; and the remaining 30 percent following the 1956-61 pattern. Southeastern consuming regions 3 and 5 absorb 20 percent of the increase in oilmeal exports; Pacific Coast regions 29, 30 and 31 absorb 20 percent; and the remaining 60 percent follows the original 1956-61 regional distribution. Other assumptions are the same as for Model IV-A.

Model V. Model V is the same as Model I except that a United States population of 243,880,000 is assumed for 1975.

Model VI-A. Differences in previous models dealt only with demand restraints, or right-hand sides of the equations. We now examine alternatives concerned with differences in the technical matrix. Model VI-A assumes the 1950-62 trend in crop yields to continue until 1975. Hence, the per-acre yield estimates are higher than the projections (based on the 1940-61 trend) used for models I through V. For demand restraints, the USDA **economic maximum** feed-livestock conversion rates are used.[7]

Model VII-A. This model also utilizes a different coefficient matrix than other models just outlined. This matrix is one of "advanced technology" since the coefficients reflect conditions where states of the South and Southeast would use techniques for feed grains and soybeans equivalent to counterparts in the North Central states. Also, the coefficients for cotton in the Southeast are equivalent in technology to those of the Southwest. Labor, power and machinery, and all other crop expenses except fertilizer costs are assumed equivalent for all regions producing feed grains and soybeans in the Corn Belt, southern and eastern states. Fertilizer costs differ among programming regions, however, because of geographical dispersion and varying responses to fertilizer and related inputs among regions. The model assumes an equal degree of mechanization (and, hence, comparable farm size) for different crops in the various regions. The wheat activity remains unchanged from that used in models I through V. Demand levels are the same as those used for Model IV-B.

Model VII-B. The model is identical to Model VII-A except that the export demand requirements assumed are the same as those in Model IV-F.

Various empirical models were created by changing the variables representing possible levels of demand for agricultural products in 1975 or by varying the coefficients representing technology. We now discuss the assumptions and conditions representing the demand restraints and technical coefficients of the various models.

Per-Capita Consumption Estimates

The 1955 Household Food Consumption Survey served as the basis for estimating the per-capita consumption rates of foods for 1975.[8] The technique for estimation was that suggested by Lavell[9] who personally furnished estimates of the income distribution of the United States population by urbanization category and geographical area for 1975. Per-capita consumption rates of food for 1975 were established, and consuming region demand levels were estimated from the data on population distribution and the per-capita consumption rates in the 1955 survey. The following equations were used for estimating the level of per-capita consumption of a given food:

$$c^{i,75}_{kh} = \sum_{j=1}^{m} c^{i,54}_{jkh} \; p^{75}_{jkh} \; ; \qquad (10)$$

[7] The conversion rates of economic potential are lower than those for the economic maximum rates assumed in Model VI-A.

[8] Food consumption of households in the U. S.; household food consumption survey, 1955. U. S. Dep. Agr., Washington, D. C. 1956.

[9] Robert Lavell. Economic Research Service, U. S. Department of Agriculture. Private communication. Oct. 1960.

$$c^{i,75}_{h} = \sum_{k=1}^{3} c^{i,75}_{kh} \; u^{75}_{kh} \; ; \qquad (11)$$

$$c^{i,75} = \sum_{h=1}^{4} c^{i,75}_{h} \; g^{75}_{h} \qquad (12)$$

where,

$c^{i,54}_{jkh}$ = the per-capita consumption of the ith food within the jth income class in the kth urbanization category and the hth geographical area in 1954,

p^{75}_{jkh} = the percentage of the population falling within the jth income class in the kth urbanization category and the hth geographical area in 1975,

$c^{i,75}_{kh}$ = the per-capita consumption of the ith food in the kth urbanization category and the hth geographical area in 1975,

u^{75}_{kh} = the percentage of the population living in the kth urbanization category in the hth geographical area in 1975,

$c^{i,75}_{h}$ = the per-capita consumption of the ith food in the hth geographical area in 1975,

g^{75}_{h} = the percentage of the population living within the hth geographical area in 1975, and

$c^{i,75}$ = the per-capita consumption of the ith food in 1975.

Food consumption in any group is influenced by many variables—such as income, sex and age distribution, occupation and degree of urbanization. Equations 10 through 12 consider only income and degree of urbanization. A different income distribution will, of course, be reflected for each income level assumed. The national income level assumed for all models but Model II and those specifically noted later reflects a real per-capita disposable income in 1975 that is 50 percent higher than in 1955. The income distributions used were generated from this level and the technique of Burk.[10] Models III-A and III-B and models VI-A and VI-B incorporate Daly's consumption estimates for 1975.[11]

Conversion of the weights of retail foods to farm weights yields the "farm level" requirements of each crop product. Multiplication of the per-capita "farm level" requirements by the appropriate population figure provides the aggregate requirement for a particular crop.

Population Assumptions

The Bureau of Census has published several sets of population projections for future years.[12] These projections incorporate varying assumptions about trends in migration, fertility and mortality. Series I of the Census projections was used for most of the population estimates in this study. The 1955-70 rate of change postulated by the Bureau of Census was assumed to continue until 1975. State estimates were aggregated into the geographical areas on which the per-capita consumption estimates are based. An estimate of the percentage of total population within a given geographical area, as in equation 12, was obtained by dividing the population of each geographical area by the total population.

Livestock Feeding Efficiency

The rates of converting feed into livestock products were estimated for some models by projecting 1940-60 trends. Other models employ the economic potential or economic maximum of Barton.[13] The **economic potential** and attainable estimates represent the coefficients expected by 1975 from adoption of presently known technology. The **economic maximum** estimates are based on assumption of complete and efficient economic application of presently known technology.

From estimates of (a) livestock products required by the 1975 population and (b) projected feed-livestock conversion rates, the amount of feed necessary to meet 1975 restraints can be estimated. In making the estimates, feed requirements were first calculated in total feed units. Allocation was then made to particular classes of feed, depending on projected consumption, conversion rates and historic trends. Equations 13 through 16 summarize the derivation of total feed units necessary to achieve the required output of livestock products.

$$Q^{i}_{r} = c^{i,75} n^{75} \qquad (13)$$

$$Q^{i}_{1} = Q^{i}_{r} / f_{i} \qquad (14)$$

$$FU^{i} = Q^{i}_{1} g^{i} \qquad (15)$$

$$FU = \sum_{i=1}^{m} FU^{i} \qquad (16)$$

$c^{1,75}$ has the same meaning as in equation 12 and,

n^{75} = population level assumed for 1975,

Q^{i}_{r} = quantity of the ith food demanded expressed in retail weights,

f_{i} = factor for converting the ith food from retail to farm level weights,

[10] Marguerite C. Burk. Measures and procedures for analysis of U. S. food consumption. U. S. Dep. Agr., Agr. Handbook No. 206. 1961.

[11] Daly, Op. cit.

[12] Current population reports, population estimates. U. S. Dep. Commerce. Bureau of the Census. Series P-25, No. 180. 1957.

Current population reports, population estimates. U. S. Dep. Commerce. Bureau of the Census. Series P-25, No. 187. 1958.

[13] Glen T. Barton. Economic Research Service, U. S. Department of Agriculture. Private correspondence. Sept. 1962.

g^i = feed units required to produce a unit of the ith food product,

FU^i = feed units required to produce the required amounts of the ith food product, and

FU = feed units required to produce the required amounts of all relevant food products; m being the number of different food products.

Human Consumption

In addition to livestock feed requirements, grains of various types also are used directly as human food. These cereal food requirements, based on population and income projections and the relevant demand elasticities of the products, were estimated for other grains as well as for wheat. The consumption requirements were converted to grain equivalents, with the feed grains expressed in feed units for purposes of aggregation. They were added to the feed grains required as livestock feed. Grain requirements for human food were expressed in feed units to enable the wheat-to-feed-grain transfer activity to be handled more easily in the programming matrix. Oil and other nonfeed products of soybeans and cottonseed are considered by-products of the meal demand.

Cotton lint. The projection of per-capita requirements for cotton lint was derived in a manner somewhat different from that for other consumption items. Changes in per-capita consumption of cotton between the periods 1944-46 and 1959-61 were projected to 1975, for a national lint requirement of 18.1 pounds per person.

Exports. In initial models, we assume that 1975 exports of agricultural products will be at 1956-61 average levels. To allow increased agricultural exports and to examine their effects on the regional location of agricultural production, alternative assumptions then are posed in models IV-A through IV-F.

Regional Demand Requirements

Tables 1, 2 and 3 show the 1975 demand restraints in the 31 consuming regions for wheat, feed grains and oilmeals, respectively. The demand restraint for cotton lint is on a national basis.

Transfer Activities

Each consuming region has the possibility of transferring wheat into feed grains to help meet feed-grain requirements. This transfer occurs only if wheat is the cheapest source of feed in terms of per-unit production and transportation costs. Positive transfer costs are involved in converting wheat to feed grains in some models. For the programming models I through VI, zero transfer costs are assumed. In Model VII, the advanced technology model, a national average price of $1.80 for wheat and $1.07 for corn was assumed in deriving the cost elements (i.e., the difference between the two prices) for the wheat-to-feed-grain transfer activity.

SOLUTIONS TO COST-MINIMIZATION MODELS

Models I through VII determine the optimal pattern of land use, agricultural production and product shipments to meet regional demands at the least possible cost. The production and shipment patterns differ among the various models. Hence, the several models imply both (a) the extent of surplus capacity in American agriculture in 1975 and (b) the extent of interregional change and competition in prospect should certain conditions be realized with respect to demand and technology.

Model I

The regional land-use and crop-production patterns prescribed by Model I are shown in fig. 3. This model is relatively conservative in its projection of potential yields. It, as do all other models, implies a growing surplus capacity in American agriculture. In terms of comparative advantage and interregional competition projected for 1975, the model shows the amount and location of land not needed for wheat, cotton, feed grains and soybeans. This land is located primarily in the Southeast and Great Plains and in fringe regions of the Corn Belt. Under the conditions of the model, 74,118,600 acres of land devoted to crops in the base period, 1953, are not needed for these uses in 1975. This amount is 45 million acres greater than the acreage included in the Soil Bank by 1960.

The land retirement or withdrawal indicated follows largely the pattern expected from previous knowledge. The surplus land indicated in regions of the South Atlantic, Delta and Appalachian states reflects the less efficient technology and structure of agriculture in these regions. With projections of per-acre production costs and yields to 1975, these regions still would be tied to their present structure of small farms and high costs. The projections, based upon the period 1940-60, lead to an extension of relative disadvantage in crop production in these states.

Even with no change in relative yields (i.e., all regions increasing yields by the same percentage between 1960 and 1975), some regions would have surplus land by 1975, since productivity is projected to increase by a greater absolute amount than demand. Regions with lowest initial advantage and trends in technology would then have surplus land indicated.

The regional pattern of crop production conforms to the comparative advantage of the different regions under the technology and demand conditions projected to 1975. Feed-grain production is even more heavily concentrated in the Corn Belt. Soybean production is

Table 1. Demand restraints (millions of bushels) for wheat by consuming region and models, 1975.[a]

Region	Model I	Model II	Models III and VI-A and B	Models IV-A and VII-A	Model IV-B	Model IV-C	Model IV-D	Model IV-E	Models IV-F and VII-B	Model V
1	9,633	9,633	9,633	9,633	9,633	9,633	14,450	9,633	19,269	9,633
2	138,810	138,633	147,684	141,640	141,640	141,640	179,562	141,640	217,477	145,957
3	18,453	18,427	19,745	18,865	18,865	18,865	21,471	18,865	36,078	19,494
4	1,530	1,526	1,737	1,596	1,596	1,596	1,596	1,596	1,596	1,697
5	6,553	6,553	6,553	6,553	6,553	6,553	9,829	6,553	13,105	6,553
6	−43	−43	−43	−43	−43	−43	−43	−43	−43	−43
7	12,596	12,012	13,979	12,665	12,665	12,665	12,665	12,665	12,665	13,603
8	8,005	7,986	8,970	8,313	8,313	8,313	8,313	8,313	8,313	8,782
9	30,984	30,847	33,893	31,859	31,859	58,528	34,915	58,528	37,971	33,312
10	11,547	11,515	13,127	12,051	12,051	19,091	12,858	19,091	13,665	12,820
11	67,739	67,585	75,481	70,208	70,208	86,843	72,115	86,843	74,022	73,974
12	21,073	21,062	21,635	21,252	21,252	93,133	29,491	93,133	37,732	21,526
13	10,006	9,982	11,212	10,391	10,391	10,391	10,391	10,391	10,391	10,977
14	46,102	46,020	51,847	47,956	47,956	47,956	47,956	47,956	47,956	50,735
15	35,280	35,196	39,513	36,630	36,630	36,630	36,704	36,630	36,777	38,689
16	−152	−152	−152	−152	−152	−152	−152	−152	−152	−152
17	57,049	57,048	57,082	57,060	57,060	57,060	85,446	57,060	113,832	57,076
18	187,369	187,287	191,461	188,674	188,674	188,674	265,985	188,674	343,295	190,665
19	21,988	21,933	24,761	22,873	22,873	22,873	22,873	22,873	22,873	24,221
20	79,495	79,304	89,072	82,550	82,550	82,550	82,550	82,550	82,550	87,208
21	15,223	15,186	17,071	15,812	15,812	15,812	15,812	15,812	15,812	16,711
22	7,171	7,154	8,035	7,447	7,447	7,447	7,447	7,447	7,447	7,867
23	1,055	1,052	1,189	1,098	1,098	1,098	1,098	1,098	1,098	1,163
24	−7,728	−7,755	−6,389	−7,301	−7,301	−7,301	−7,301	−7,301	−7,301	−6,649
25	−552	−553	−485	−531	−531	−531	−531	−531	−531	−498
26	5,697	5,673	6,889	6,077	6,077	6,077	6,077	6,077	6,077	6,657
27	−549	−550	−482	−527	−527	−527	−527	−527	−527	−495
28	9,912	9,883	11,372	10,378	10,378	10,378	10,378	10,378	10,378	11,088
29	105,434	105,379	108,186	106,312	106,312	106,312	148,219	179,427	190,126	107,651
30	59,329	59,473	61,344	60,094	60,094	60,094	85,254	103,998	110,413	60,987
31	12,315	12,282	13,962	12,840	12,840	12,840	15,823	18,047	18,806	13,642
U.S.	971,357	969,576	1,037,883	992,271	992,271	1,114,497	1,236,722	1,236,722	1,481,172	1,024,849

[a] Negative entries indicate a "white-area" production greater than the demand requirements within a given region and allow small out-shipments.

Table 2. Demand restraints (thousands of tons) for feed grains by consuming region and model, 1975 (in feed units).[a]

Region	Model I	Model II	Models III and VI-B	Models IV-A and VII-A	Model IV-B	Model IV-C	Model IV-D	Model IV-E	Model IV-F	Model V	Model VI-A
1	4,013	4,065	3,814	4,129	4,264	4,399	4,668	4,444	4,347	4,339	3,279
2	11,147	11,346	10,573	11,503	11,874	12,246	12,989	12,372	12,103	12,174	8,967
3	6,625	6,727	5,751	6,855	7,089	7,323	7,791	7,402	8,532	7,285	5,174
4	5,992	6,077	5,033	6,189	6,189	6,189	6,189	6,189	6,189	6,554	4,561
5	3,212	3,252	2,756	3,306	3,382	3,459	3,612	3,485	3,854	3,479	2,529
6	1,152	1,168	965	1,191	1,191	1,191	1,191	1,191	1,191	1,261	872
7	3,440	3,520	2,870	3,602	3,602	3,602	3,602	3,602	3,602	3,922	2,479
8	8,456	8,599	7,976	8,729	8,729	8,729	8,729	8,729	8,729	9,258	7,055
9	5,360	5,447	5,088	5,524	5,608	5,692	5,861	6,683	6,683	5,827	4,524
10	2,408	2,471	2,656	2,491	2,501	2,511	2,531	2,629	2,629	2,692	2,215
11	8,946	9,037	9,606	9,212	9,337	9,462	9,712	10,933	10,933	9,732	7,895
12	8,102	8,203	8,599	8,303	8,488	8,674	9,044	10,850	10,850	8,799	7,329
13	21,891	22,217	20,557	22,599	22,599	22,599	22,599	22,599	22,599	23,938	18,107
14	6,751	6,865	6,385	6,973	6,973	6,973	6,973	6,973	6,973	7,428	5,646
15	14,372	14,629	13,709	14,801	14,973	15,146	15,492	15,205	15,080	15,713	12,320
16	1,864	1,893	1,916	1,929	1,929	1,929	1,929	1,929	1,929	2,049	1,777
17	4,608	4,648	4,677	4,695	5,220	5,745	6,794	5,923	5,542	4,859	4,492
18	4,812	4,921	7,718	4,901	5,472	6,044	7,187	6,238	5,824	5,069	7,231
19	119	125	446	129	129	129	129	129	129	149	392
20	953	972	1,226	984	984	984	984	984	984	1,042	1,090
21	4,762	4,829	6,204	4,920	4,920	4,920	4,920	4,920	4,920	5,209	5,481
22	666	675	856	687	687	687	687	687	687	727	759
23	3,019	3,060	3,920	3,117	3,117	3,117	3,117	3,117	3,117	3,296	3,470
24	531	541	1,032	556	556	556	556	556	556	602	887
25	34	36	119	38	38	38	38	38	38	46	95
26	476	485	893	498	498	498	498	498	498	537	772
27	329	335	580	342	342	342	342	342	342	365	507
28	447	455	779	464	464	464	464	464	464	495	683
29	1,287	1,301	1,254	1,310	1,553	1,611	1,913	1,663	1,553	1,358	1,196
30	744	759	697	771	892	921	1,070	946	892	821	629
31	5,226	5,358	4,880	5,417	5,484	5,551	5,684	5,573	5,525	5,781	4,377
U.S.	141,744	144,014	143,534	146,162	148,945	151,728	157,293	157,293	157,293	154,806	126,789

[a] A ton of feed units is a corn-equivalent ton where 1 ton of corn equals 1 ton of feed units, 1 ton of oats equals 1,800 pounds of feed units, 1 ton of barley equals 1,800 pounds of feed units, 1 ton of grain sorghum equals 1,900 pounds of feed units and 1 ton of wheat equals 2,100 pounds of feed units.

Table 3. Demand restraints (thousands of tons) for oilmeals by consuming region and model, 1975 (in feed units).[a]

Region	Model I	Model II	Models III and VI-B	Models IV-A and VII-A	Model IV-B	Model IV-C	Model IV-D	Model IV-E	Model IV-F	Model V	Model VI-A
1	892	905	514	922	922	922	922	922	922	975	446
2	3,390	3,436	2,217	3,499	3,626	3,753	4,008	3,674	3,870	3,661	1,985
3	1,241	1,256	1,123	1,430	1,521	1,613	1,796	1,556	1,841	1,331	1,049
4	795	808	826	838	838	838	838	838	838	870	765
5	1,017	1,023	942	1,029	1,191	1,354	1,678	1,253	1,758	1,051	922
6	270	275	255	280	280	280	280	280	280	296	237
7	742	754	645	786	786	786	786	786	786	812	587
8	1,026	1,042	998	1,061	1,061	1,061	1,061	1,061	1,061	1,122	883
9	1,177	1,189	1,204	1,203	1,304	1,404	1,605	2,736	1,496	1,250	1,113
10	411	417	597	424	434	443	462	568	452	446	494
11	657	666	1,073	678	701	724	771	1,035	746	710	892
12	715	723	713	735	789	842	949	1,554	891	762	623
13	1,324	1,345	1,469	1,369	1,369	1,369	1,369	1,369	1,369	1,448	1,305
14	1,012	1,029	1,427	1,059	1,059	1,059	1,059	1,059	1,059	1,108	1,274
15	1,635	1,653	1,724	1,672	1,810	1,948	2,224	1,863	2,075	1,737	1,592
16	427	434	326	453	453	453	453	453	453	467	313
17	3,535	3,546	3,278	3,619	4,338	5,057	6,495	4,612	5,719	3,599	3,263
18	1,516	1,543	758	1,596	1,597	1,598	1,601	1,580	1,599	1,660	709
19	452	460	291	505	505	505	505	505	505	494	269
20	507	515	816	524	524	524	524	524	524	554	730
21	478	486	715	494	494	494	494	494	494	523	635
22	26	26	37	27	27	27	27	27	27	28	33
23	102	103	151	105	105	105	105	105	105	111	133
24	125	127	162	129	129	129	129	129	129	136	147
25	55	56	47	57	57	57	57	57	57	61	43
26	233	237	228	241	241	241	241	241	241	255	208
27	415	422	228	428	428	428	428	428	428	454	210
28	194	198	152	201	201	201	201	201	201	213	140
29	264	269	326	273	273	273	273	730	730	289	307
30	182	185	216	188	188	188	188	644	644	199	206
31	617	628	674	669	669	669	669	897	897	677	656
U.S.	25,429	25,755	24,129	26,493	27,918	29,344	32,196	32,196	32,196	27,301	22,168
Cotton Lint[b]	13,478	13,478	13,768	13,768	13,768	13,768	13,768	13,768	13,768	14,271	13,768

[a] A ton of feed units is a corn-equivalent ton where 1 ton of soybean oilmeal equals 3,300 pounds of feed units and 1 ton of cottonseed oilmeal equals 2,700 pounds of feed units.
[b] 500-pound bales.

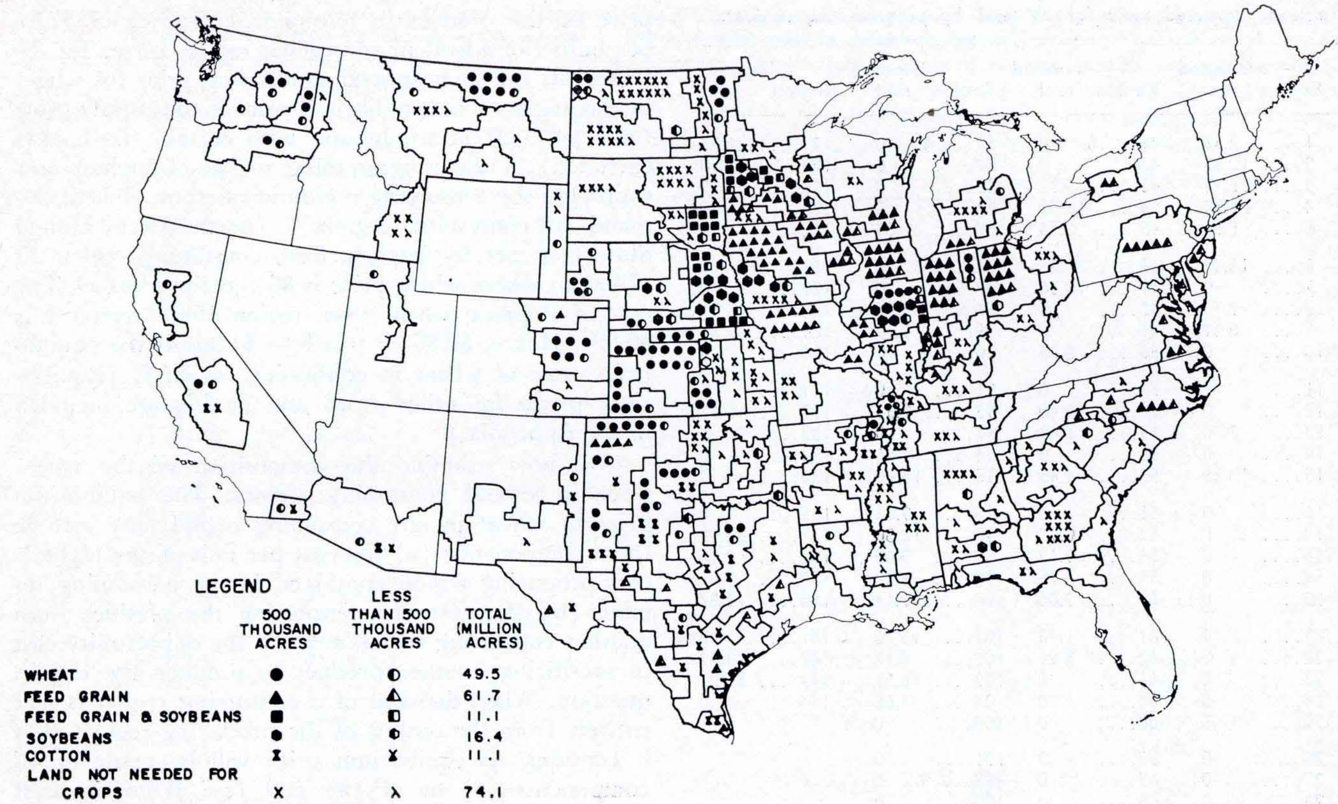

Fig. 3. Regional production pattern for Model I.

indicated in the South and in the fringes of the Corn Belt. Cotton production is allocated to the Delta states, Texas, Arizona and California. Wheat is produced mainly in the southern and central Plains, northern Montana and the Pacific Northwest. However, some wheat is indicated for regions in California and Arizona, while some regions in the northern Plains produce none. Similarly, some feed grains are indicated for southern Texas, with none indicated for parts of eastern Ohio and Indiana where traditionally they have been grown. When transportation costs are included in the model, more products tend to be produced, if land is available, nearer their point of consumption. In some studies of comparative advantage and interregional competition that have ignored this special aspect, greater centralization of crop production within specialized areas has been indicated—as compared with the current study.[14]

Table 4 includes the imputed equilibrium rents or shadow prices for all land in the 144 programming regions. The shadow prices are opportunity costs indicating the amount by which total costs could be reduced if one more acre of land were available in the specified region. For example, if region 1 had another acre of land, the national required grain production could be attained at a savings of $2.38. (Similar shadow prices also are available for restraints of cotton land and soybean land but are not presented.)

The composition of these equilibrium rents can be illustrated as follows: the corn-equivalent yield of feed grains in programming region 1 in New York is 53.253 bushels per acre. The price per corn-equivalent bushel in consuming region 2 (the consuming region made up of New York and Pennsylvania and which includes programming region 1) is $1.055 (the shadow price on the feed-grain demand restraint for consuming region 2). Multiplying yield times price, 53.253×1.055, a revenue of $56.18 is indicated for region 1 in New York. Subtracting the cost per acre of the feed-grain activity in programming region 1 from this revenue, $56.18 − 53.80, the land rent is $2.38 in programming region 1. In a similar manner, the equilibrium rent for land in programming region 39 (northeastern Indiana) is due to the wheat activity. The wheat yield in this region is 51.4 bushels per acre, and the equilibrium price on wheat in consuming region 8 (Indiana) is 98.2 cents per bushel. Multiplying $51.4 \times 0.982 =$ $50.47 and subtracting $36.47, the cost per acre of wheat, the land rent in region 39 is $14.00. In the multiple-product programming region 47 of east-central Illinois, the land rent is due to the wheat activity.[15] The wheat yield in region 47 is 48.7 bushels, and the equilibrium price in consuming region 15 (Illinois) is 86.3 cents per bushel. Then, $48.7 \times 0.863 =$ $42.03, less the per-acre cost of

[14] For example, see: Earl O. Heady and Alvin C. Egbert. Spatial programming models to specify surplus grain production areas. In: A. S. Manne and H. M. Markowitz, editors. Studies in process analysis. Monograph 18. Wiley & Sons, New York. 1962. pp. 161-214.

[15] The feed-grains with soybeans activity was not restricted by the amount of land available in region 47. An equilibrium rent on soybean land also exists in region 47, since soybeans occupy all land available for this crop. The soybean activity uses both soybean land and total land. Hence, for every acre increase in soybean production in region 47, wheat production must decrease by 1 acre. Therefore, the equilibrium rent on soybean land is the difference in net returns (the value of production less cost) between soybeans and wheat.

Table 4. Imputed rents for all land by programming regions.

Region	Imputed rent	Region	Imputed rent	Region	Imputed rent	Region	Imputed rent
1	$ 2.38	41	$ 0	81	$ 0	121	$21.77
2	10.58	42	0	82	0	121	0
3	26.72	43	6.62	83	0	123	0
4	22.33	44	18.02	84	0	124	0
5	5.69	45	5.74	85	2.09	125	0
6	16.44	46	3.05	86	0	126	0
7	0	47	10.36	87	0	127	0
8	2.73	48	0	88	8.18	128	0
9	8.49	49	0	89	9.38	129	2.36
10	0	50	8.32	90	0	130	0
11	0	51	0	91	0	131	0
12	0	52	10.40	92	2.33	132	1.92
13	2.70	53	7.92	93	0	133	0
14	0	54	0	94	1.56	134	0
15	10.36	55	4.45	95	16.80	135	0
16	0	56	0	96	9.83	136	0
17	0	57	0.98	97	12.50	137	12.78
18	0	58	9.12	98	5.09	138	7.16
19	0	59	6.76	99	8.00	139	5.17
20	0	60	2.06	100	12.14	140	12.87
21	0	61	1.43	101	13.70	141	0
22	0	62	5.91	102	8.72	142	19.92
23	0	63	0	103	16.59	143	35.83
24	0	64	0	104	1.65	144	0
25	1.05	65	0	105	0		
26	0	66	0	106	0		
27	0	67	0	107	0		
28	0	68	0	108	0		
29	0.78	69	0	109	5.59		
30	0	70	0	110	0		
31	0	71	0	111	5.76		
32	0	72	0	112	1.29		
33	3.89	73	0	113	0		
34	0	74	0.53	114	0.67		
35	24.00	75	6.31	115	0		
36	1.63	76	7.96	116	24.74		
37	16.56	77	5.81	117	12.72		
38	13.05	78	0	118	17.23		
39	14.00	79	7.14	119	10.57		
40	0	80	0.19	120	33.01		

growing wheat of $31.67, and the rent is $10.36.

The equilibrium rents, thus, are opportunity costs in the economic sense that they indicate the advantage of one alternative over the next best alternative. For a marginal producing region (such as region 40 in southern Michigan) where some of the land is used but not all is required, the rent is zero. (Equilibrium land rents are provided in Appendix table A-1 for other models.)

The demand requirements within any given consuming region can be met either by production within that region or by imports from other regions. Also, wheat from one region may be transferred into feed grains to help meet the feed-grain requirements at a lower cost either within the region or for other consuming regions. Table 5 indicates the sources by which demands for food wheat are satisfied in the 31 consuming regions. Tables 6 and 7 provide parallel data for feed grains and oilmeals. Similar data underly all other crops and models of this study but will not be repeated in later sections.

The last column of table 5 gives the equilibrium price of the product in question. The price of $1.37 per bushel of wheat in consuming region 1 (see fig. 2) represents the programmed equilibrium price for wheat in this region. The equilibrium price is the supply price (cost per unit of production with certain fixed costs excluded) in the programming region of highest cost supplying the consuming region in question. Wheat demand in consuming region 1 (northeastern United States) is met by imports from consuming region 15 (Illinois) where wheat price is 86 cents per bushel. The cost of shipping wheat from region 15 to region 1 is $0.504. Hence, $0.86 + 0.504 = $1.364 is the equilibrium price of wheat in consuming region 1. (Equilibrium prices for other crops and models are included in the Appendix.)

We now examine the composition of the wheat price in several consuming regions. The equilibrium price of wheat in any consuming region may include three components: (a) the cost per unit of the highest-cost producing region contained in the consuming region, (b) the cost of transporting the product from another consuming region and (c) the opportunity cost in sacrificing another product to produce the one in question. When demand of a consuming region is met entirely from the output of the producing regions that it contains, its equilibrium price will be made up of components (a) or of (a) and (c). When it must import wheat, the equilibrium price will include component (b). The equilibrium price of wheat in consuming region 20 (Kansas) is 65 cents per bushel. Figure 3 shows that producing regions 85, 87, 88 and 89, all within consuming region 20 (Kansas), produce wheat. The cost per bushel of producing wheat in these four regions is 58 cents, 65 cents, 37 cents and 28 cents, respectively. The high-cost producing region is 87 in south-central Kansas, and it provides the equilibrium price of 65 cents in consuming region 20 (Kansas). Region 87 is the only one of the four producing regions with any idle land. Hence, it is the "marginal" region in terms of supplying the wheat demand in Kansas. Since the Kansas demand is filled before all land in producing region 87 within the state is used, the land in the latter producing region has a zero opportunity cost. Thus, the equilibrium price of wheat in Kansas is composed only of the "real cost" of producing wheat in producing region 87.

Consuming region 5 (Mississippi) imports all its wheat from consuming region 20 (Kansas). The equilibrium price in Mississippi is $1.40—the cost of producing wheat in producing region 87 of Kansas (or the equilibrium price of wheat in Kansas) plus the cost per bushel of transporting wheat (75 cents) from Kansas to Mississippi. Consuming region 15 (Illinois) has an equilibrium price that contains two elements of supply cost: the real cost of production and a per-bushel opportunity cost. Region 47 is the only producing region within Illinois that supplies wheat to Illinois. The cost per bushel in producing region 47 is $\$31.67 \div 48.7 = \$0.65$. As fig. 3 indicates, there is no

Table 5. Consuming region food-wheat demand restraints, production within consuming regions, imports and exports among consuming regions, transfers and equilibrium prices, Model I. (All quantities refer to consuming regions.)

Consuming region (see fig. 2)	Demand requirement (mil. bu.)	Production within region (mil. bu.)	Imports		Exports		Wheat-feed-grain transfer (mil. bu.)	Equilibrium price ($/bu.)
			Quantity (mil. bu.)	From region	Quantity (mil. bu.)	To region		
1........	9,633.3	..	9,633.3	15	..	..	..	1.37
2........	138,810.4	..	138,810.4	8,15,21	..	..	..	1.31
3........	18,452.7	1,529.6	15,293.1	15	..	..	..	1.34
4........	1,529.6	..	1,529.6	15	..	..	..	1.28
5........	6,552.6	..	6,552.6	20	..	..	..	1.40
6........	−43.0	..	..	..	..	..	43.0	1.29
7........	12,596.4	12,596.4	..	..	..	..	..	1.23
8........	8,005.2	62,199.1	..	..	54,193.9	2	..	0.98
9........	30,983.5	..	30,983.5	11,20	..	..	..	1.12
10........	11,546.7	11,546.7	..	..	..	..	..	1.12
11........	67,739.0	69,344.9	..	..	1,605.9	9	..	0.88
12........	21,072.8	..	21,072.8	21	..	..	..	1.02
13........	10,006.4	..	10,006.4	21	..	..	..	1.01
14........	46,134.0	46,134.0	..	..	..	..	..	0.83
15........	35,280.3	100,295.6	..	..	65,012.1	1,2,3,4	..	0.86
16........	−152.4	36,392.5	..	..	36,544.9	17	..	1.07
17........	57,048.9	4,285.6	52,763.3	16,19	..	..	..	1.28
18........	187,369.1	127,882.4	59,486.7	19	..	..	..	1.14
19........	21,988.4	101,486.8	..		75,707.8	17,18	3,790.7	0.71
20........	79,495.2	351,161.5	..	..	35,930.1	5,9	235,727.4	0.65
21........	15,222.8	104,605.7	..	..	78,769.6	2,12,13	10,612.8	0.64
22........	7,171.3	28,301.9	..	..	..	..	21,130.7	0.82
23........	1,055.0	1,055.1	..	..	..	..	..	0.88
24........	−7,728.0	85,968.3	..	..	76,847.6	28,29,30	16,842.6	0.53
25........	−552.0	552.7	..	..	..	..	1,074.6	0.77
26........	5,697.2	72,432.2	..	..	..	..	66,735.0	0.62
27........	−548.5	24,098.2	..	..	14,197.7	31	10,448.5	0.85
28........	9,912.1	5,135.4	4,777.2	24	..	..	..	1.05
29........	105,433.8	111,730.0	34,551.7	24	..	..	40,845.1	0.89
30........	59,329.2	45,433.5	37,518.8	24	..	..	23,621.5	0.98
31........	12,314.7	46,367.8	14,197.7	27	..	..	48,248.7	1.19

idle land, and the imputed land rent (table 4) in programming region 47 is $10.36 per acre. In other words, if there were an additional acre of land in producing region 47, it could be used to lower the total cost of producing the total product mix by $10.36. This per-acre opportunity cost results in a per-bushel opportunity cost of 21 cents ($10.36 ÷ 48.7). Thus, the equilibrium price of wheat in consuming region 15 (Illinois) is the 65-cent real cost of producing a bushel of wheat in region 47 within the state, plus the opportunity cost per bushel of 21 cents, or 86 cents. The equilibrium price of wheat in consuming region 1 (the northeastern states) contains all three elements of supply cost: the 65-cent real cost of producing wheat in producing region 47 (within Illinois), the 21-cent opportunity cost for wheat in producing region 47, and the 50-cent cost of transporting a bushel of wheat from Illinois to consuming region 1. Hence, the sum is $\$0.65 + 0.21 + 0.50 = \$1.36$, the approximate equilibrium price of wheat in consuming region 1.

Although examples are not provided here, equilibrium prices of other crops are composed similarly from real production costs, opportunity costs and transportation costs. In some cases, there is a "feed back" among wheat and feed grains in their opportunity and conversion costs. There also are price interdependencies among cotton, wheat for food, wheat for feed, feed grains and soybeans. For example, the feed-grain demand in consuming region 24 (Montana and Idaho) is met by the wheat-to-feed-grain transfer activity, and the feed-grain equilibrium price is a function of the cost of producing wheat in producing region 105 of central Montana.

Interregional flows. The flows or trade among consuming regions are indicated in fig. 4 for wheat, fig. 5 for feed grains and fig. 6 for oilmeals. These figures parallel the import-export quantities indicated in tables 5, 6 and 7. Wheat flows to eastern regions from producing and consuming regions in Colorado, Nebraska and Kansas; and to Pacific states from Montana and Oklahoma. Feed grains flow eastward from Corn Belt states and Kansas; they flow westward from Nebraska and Colorado. Oilmeals show a fairly diverse set of flows from the Corn Belt, but western regions are supplied largely by producing regions within Nebraska.

Model II

Model II differs from Model I in only one respect:

Table 6. Consuming region feed-grain demand restraints, production within consuming region, imports and exports among consuming regions, wheat-to-feed-grain transfers, and equilibrium prices within consuming regions, Model I; in feed units.[a]

Consuming region (see fig. 2)	Demand requirement (mil.bu.)	Production within region (mil.bu.)	Imports		Exports		Wheat-feed-grain transfer (mil.bu.)	Equilibrium price[b] ($/bu.)
			Quantity (mil.bu.)	From region	Quantity (mil.bu.)	To region		
1	4,013.4	..	4,013.4	9	..	..	..	1.11
2	11,146.7	6,350.4	4,796.4	8,9,15	..	..	..	1.06
3	6,624.6	5,879.6	744.9	9	..	..	..	1.08
4	5,991.4	267.4	5,724.0	8	..	..	..	1.13
5	3,211.5	..	3,211.5	8,14	..	..	..	1.12
6	1,152.0	..	1,150.6	13	..	..	1.4	1.15
7	3,440.4	1,178.0	2,262.4	15	..	..	..	0.97
8	8,456.3	15,674.7	..	..	7,218.7	2,4,5	..	0.74
9	5,360.9	11,985.5	..	..	6,624.7	1,2,3	..	0.78
10	2,408.1	2,408.1	..	..	..	..	..	0.81
11	8,945.9	8,946.0	..	..	..	..	..	0.67
12	8,102.4	5,963.1	2,139.3	13,15	..	..	..	0.83
13	21,890.6	24,494.6	..	..	2,604.3	6,12	..	0.63
14	6,750.8	9,079.7	..	..	2,328.9	5	..	0.74
15	14,372.3	19,638.3	..	..	5,265.9	2,7,12	..	0.63
16	1,864.3	..	1,864.3	20	..	..	..	0.83
17	4,608.1	..	4,608.1	20	..	..	..	1.02
18	4,812.0	4,812.1	..	..	..	..	..	0.80
19	119.4	..	..	..	..	..	119.4	0.63
20	953.1	..	..	..	6,472.4	16,17	7,425.4	0.58
21	4,762.0	6,418.4	..	..	1,990.7	31	334.3	0.57
22	665.6	..	..	..	..	..	665.6	0.73
23	3,018.5	3,018.3	..	..	..	..	..	0.69
24	530.5	..	..	..	..	..	530.5	0.47
25	33.9	..	..	..	..	..	33.9	0.69
26	476.4	536.9	..	..	2,162.6	28,31	2,102.2	0.55
27	329.1	..	..	..	..	..	329.1	0.76
28	447.4	..	447.4	26	..	..	..	0.83
29	1,286.6	..	..	..	..	..	1,286.6	0.79
30	744.1	..	..	..	..	..	744.1	0.87
31	5,225.7	..	3,705.8	21,26	..	..	1,519.8	1.06

[a] A ton of feed units is a corn-equivalent ton.

[b] Price given is the price of a corn-equivalent bushel.

by assuming a level of consumer income 10 percent higher than in Model I. The aggregate quantity of wheat required is slightly less in Model II because of the negative income elasticity for wheat products. However, the demand for feed grains and oilmeals is somewhat higher in Model II because of positive income elasticities for livestock products. Figure 7 indicates the pattern of production derived under Model II.

Wheat production is brought into northern South Carolina (producing region 14) and eastern Arkansas (producing region 127) under Model II, but is discontinued in producing regions 13 (southern North Carolina) and 77 (northeastern Colorado). Adjustments in wheat acreages also take place in producing regions that are the programs of both models I and II. In terms of interregional transportation, consuming region 4 (Georgia and South Carolina) becomes only self-sufficient in wheat and no longer exports this product.

An increase in income also has a small impact on the location of feed-grain production. Producing regions 30 (southeastern Ohio) and 77 (northeastern Colorado) provide most of the nation's additional requirements. Region 30 was not in feed-grain production under Model I, and region 77 shifts land from wheat, as compared with Model I, to feed grains. Aside from a few marginal areas, no important change occurs in the location of the feed-grains and soybean activity. The same is true for the soybean activity, acreage adjustments occuring only in the "marginal" producing regions as compared with Model I.

While Model II has requirements for the same amount of cotton lint, it has larger requirements for oilmeals than Model I. The additional oilmeal requirements are met by increases in the acreages of the feed-grains with soybeans and soybean activities, with no increase in the acreages of cotton.

Surplus producing capacity still is indicated for Model II. Its 10-percent greater per-capita income, indicating a greater consumption of livestock products and feed grains, reduces surplus land by about a million acres under that of Model I. Total land not needed for the crops specified is 72,838,400 acres under Model II, as compared with 74,118,600 under Model I.

A comparison of the equilibrium prices for wheat in models I and II indicates that regional price differences between them are almost negligible. Also, the changes in the imputed land rents under Model II are unimpor-

Table 7. Consuming region oilmeal demand restraints, production with consuming region, imports and exports among consuming regions and equilibrium prices within consuming regions, Model I; in feed units.[a]

Consuming region (see fig. 2)	Demand requirement (thou. T)	Soybean production within region (thou. T)	Cottonseed production in region (thou. T)	Imports		Exports		Soybean price ($/bu.)	Cottonseed price ($/T)
				Quantity (thou. T)	From region	Quantity (thou. T)	To region		
1	892.1	..	..	892.1	21	..	..	1.25	..
2	3,389.5	..	..	3,389.5	11,15,21	..	..	1.27	..
3	1,240.9	..	..	1,240.9	15	..	..	1.28	32.54
4	794.8	319.4	..	475.5	13	..	..	1.16	29.20
5	1,016.8	1,016.8	..	..	..	..	..	1.04	28.03
6	270.4	..	13.6	256.8	19,21	..	..	1.11	28.00
7	741.8	..	219.4	522.4	15	1,240.9	3	1.06	27.92
8	1,026.0	..	..	1,026.0	11,13	..	..	1.05	..
9	1,176.7	76.6	..	1,100.1	11	..	..	1.13	..
10	411.0	..	..	411.0	15	..	..	1.14	..
11	656.5	3,225.7	..	..	..	2,569.2	2,8,9,12	0.83	..
12	715.2	..	..	715.2	11	..	..	0.98	..
13	1,323.5	2,767.2	..	..	..	1,443.8	4,8	0.87	..
14	1,012.0	..	7.5	1,004.5	21	..	..	0.95	23.15
15	1,635.3	5,153.5	..	..	..	3,518.1	2,3,7,10	0.92	..
16	426.7	..	355.9	70.8	18	..	..	0.99	25.60
17	3,534.6	..	..	3,534.6	18,21	..	..	1.02	25 91
18	1,516.1	259.0	1,847.1	..	..	590.0	16,17	0.79	20.61
19	452.2	311.2	158.9	..	..	18.0	6	0.75	20.83
20	506.6	506.6	..	..	..	..	..	0.95	..
21	478.1	8,202.5	..	..	..	7,724.3	b	0.77	..
22	25.8	150.5	..	..	..	124.7	24	0.97	..
23	101.7	102.2	..	..	..	..	..	1.02	..
24	124.7	..	..	124.7	22	..	..	1.27	..
25	55.4	..	..	55.4	21	..	..	0.99	..
26	232.7	..	..	232.7	21	..	..	0.91	..
27	414.6	..	336.1	78.5	21	..	..	1.29	33.33
28	194.4	..	1	194.4	21	..	..	1.29	..
29	264.3	..	..	264.3	21	..	..	1.29	..
30	181.6	..	..	181.6	21	..	..	1.29	..
31	616.3	..	400.0	217.3	21	..	..	1.29	34.40

[a] A ton of feed units is a corn–equivalent ton.

[b] Ships to regions 1,2,6,14,17,25,26,27,28,29,30 and 31.

tant. Similarly, for feed grains and oilmeals, the equilibrium prices change only very slightly under Model II. The 10-percent increase in consumer income would have little aggregate effect on the nation's agriculture or the prices of its products. The income elasticity of demand for farm products is too low to cause any major change. However, the changes specified for such specific producing regions would be important for them individually.

Figures 8, 9 and 10 indicate the quantities and flows of interregional commodity trade under Model II. While the pattern of flows remains generally the same, the quantities of wheat-to-feed-grain transfers and the movements between specific regions change in all cases.

Model III

The one-step difference between models I and II does not extend to Model III. Several major variables are altered in Model III: The per-capita consumption rates are the 1975 estimates by Daly,[16] rather than those based on the 1955 consumer's survey. The USDA estimate of the economic potential in livestock feeding efficiency is substituted for the feed-livestock conversion rates based on 1940-60 trends.

In combination, the feed-conversion rates and the per-capita consumption figures upon which Model III is based reduce the amount of unused land to 70,737,600 acres; an amount about 2.1 million lower than for Model II and 3.4 million lower than for Model I. The unused land indicated for Model III would still be much greater than the amount existing in 1965, however. Hence, either major interregional shifts in land use or large production-control programs are indicated for 1975.

The land-use and production patterns for Model III are indicated in fig. 11. Compared with Model I and Model II, producing regions 50 in eastern Missouri, 56 in southwestern Minnesota and 91 in north-central Oklahoma are activated for wheat production, while region 95 in northern Texas is dropped.

Feed-grain production retains the same general regional distribution as under Model I and Model II. Some feed-grain production shifts to the West, how-

(text continued on page 530)

[16] Daly, Op. cit.

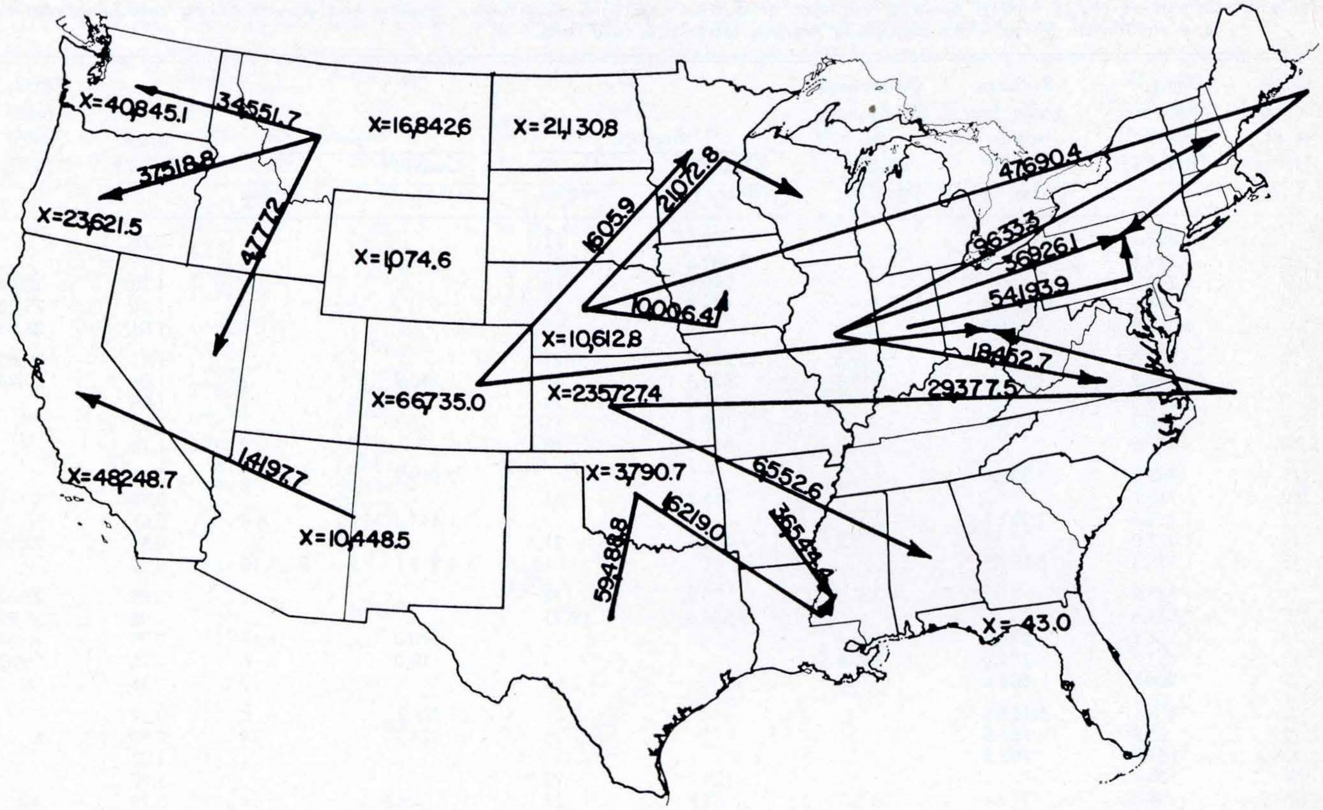

Fig. 4. Interregional flows (indicated by arrows and quantities) and intraregional transfers (magnitudes of x) of wheat to feed grains (thousands of bushels), Model I.

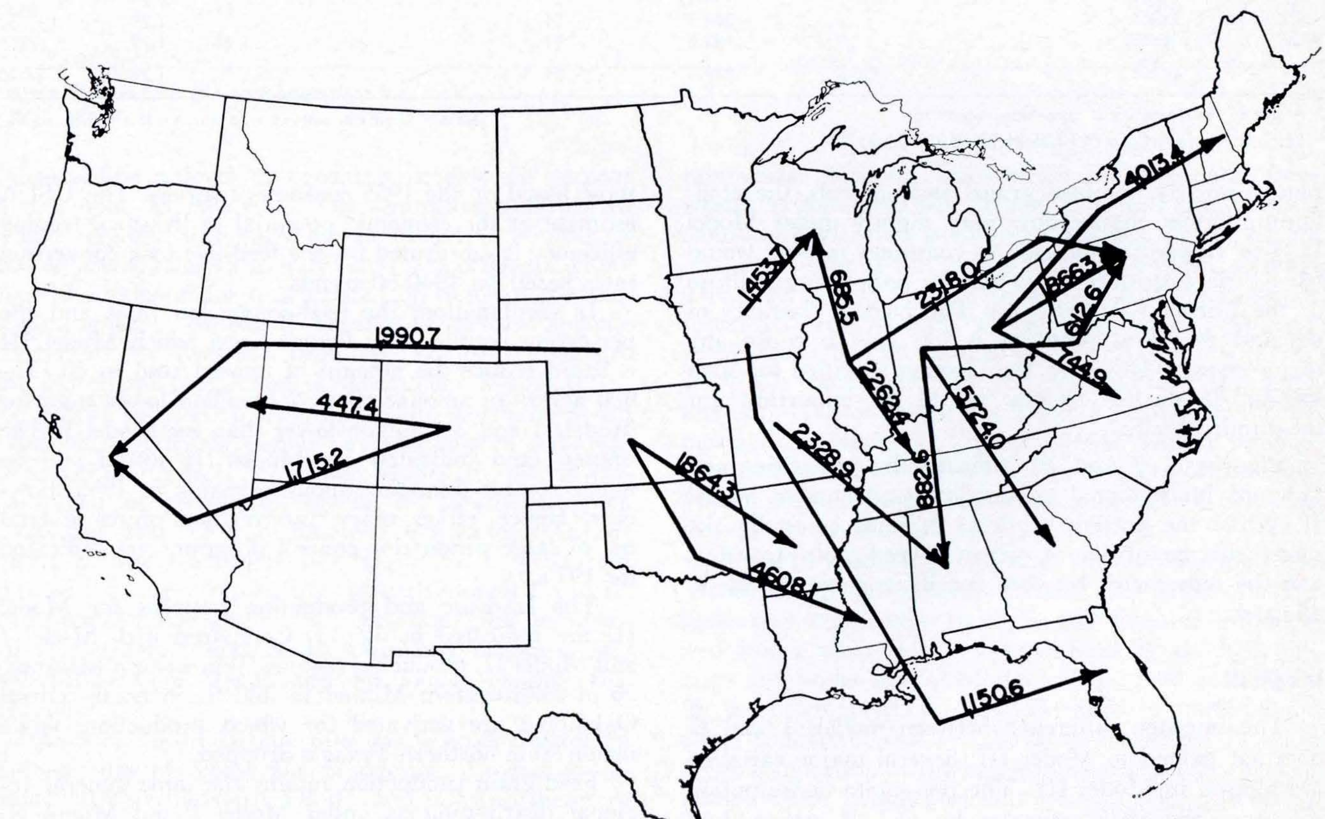

Fig. 5. Interregional flows (indicated by arrows and quantities) of feed grains (thousands of tons of feed units), Model I.

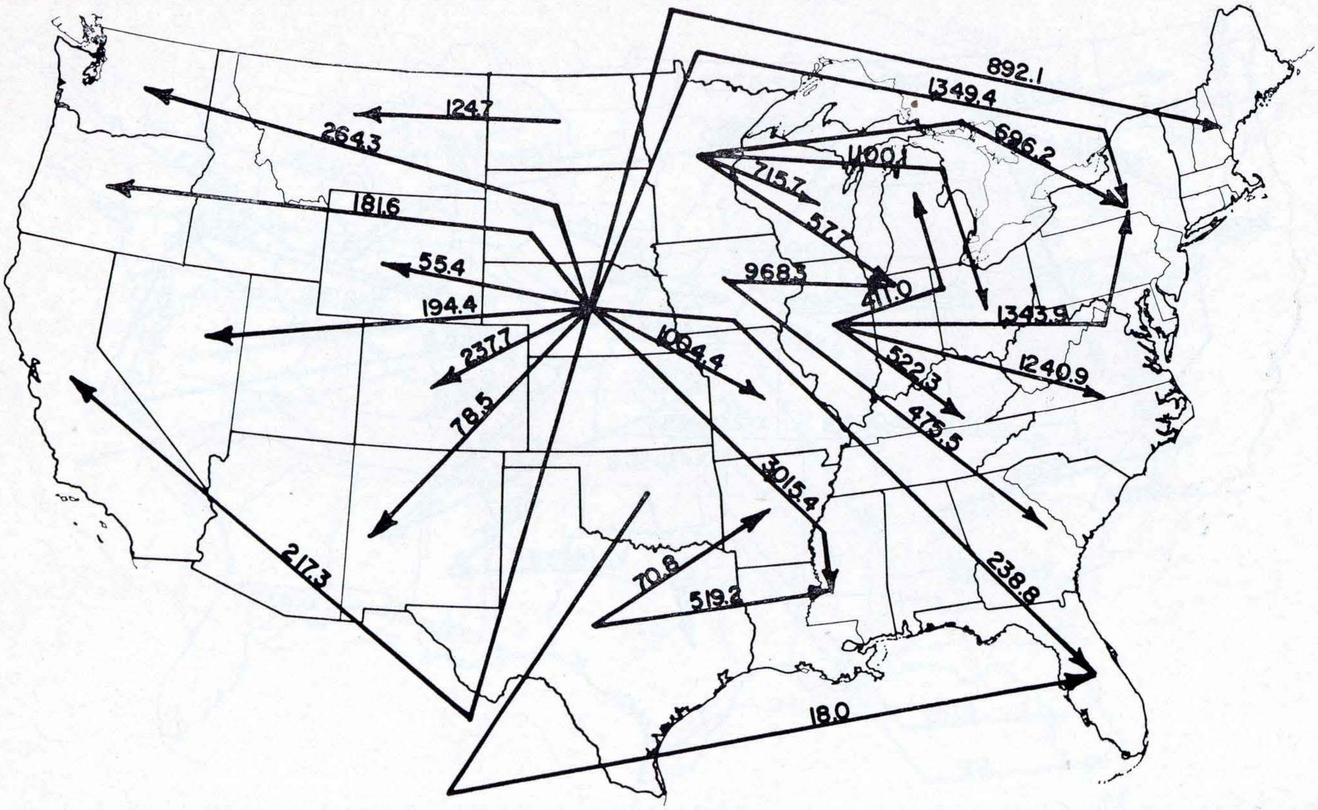

Fig. 6. Interregional flows (indicated by arrows and quantities) of oilmeals (thousands of tons of feed units), Model I.

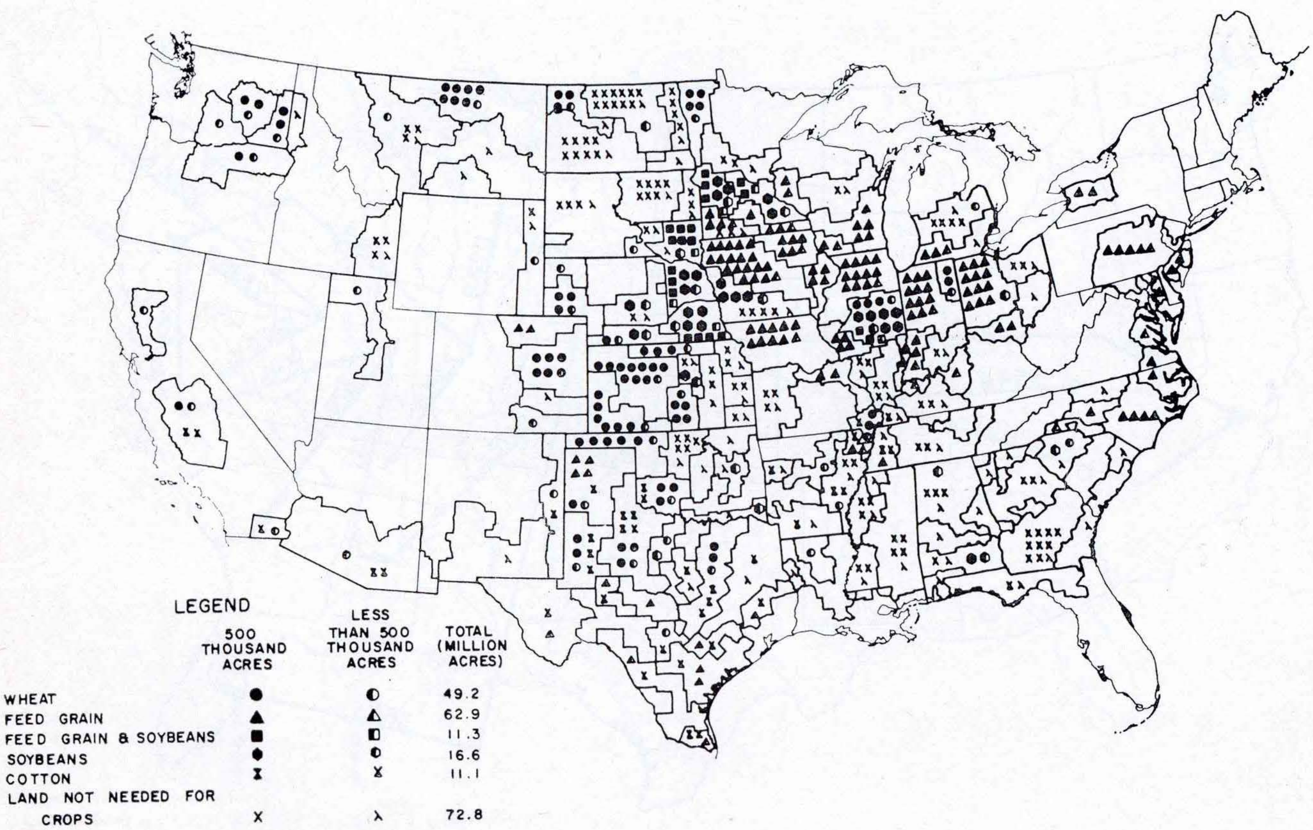

Fig. 7. Regional production pattern for Model II.

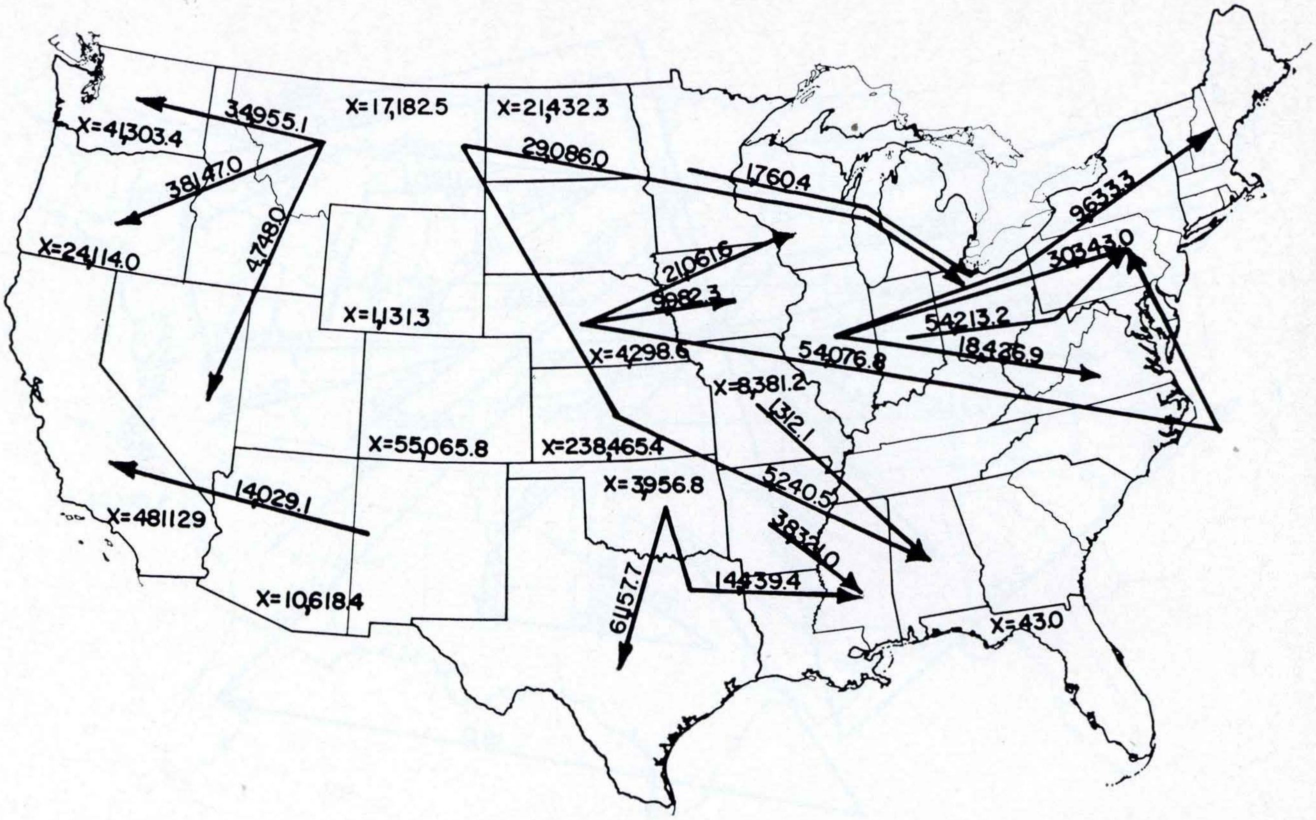

Fig. 8. Interreginal flows (indicated by arrows and quantities) and intraregional transfers (magnitudes of x) of wheat to feed grains (thousands of bushels), Model II.

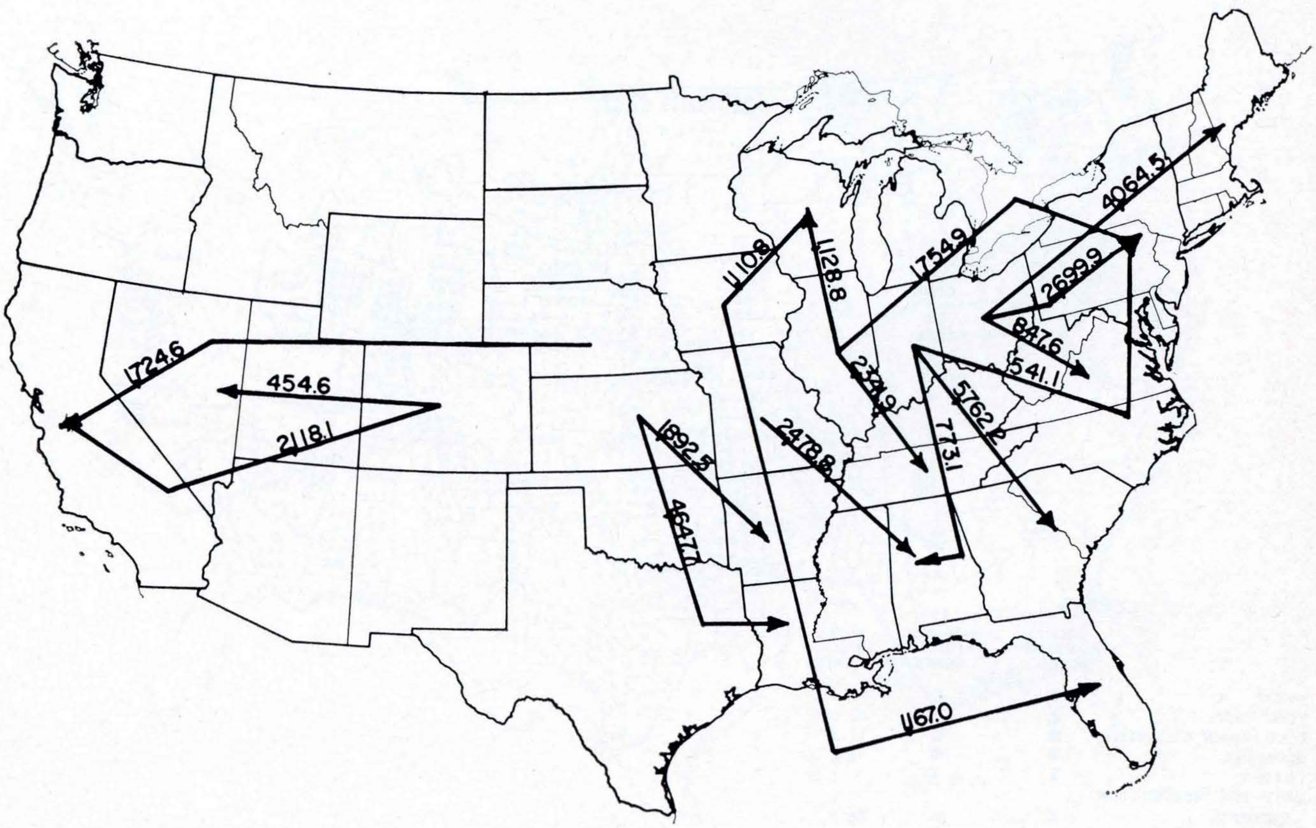

Fig. 9. Interregional flows (indicated by arrows and quantities) of feed grains (thousands of tons of feed units), Model II.

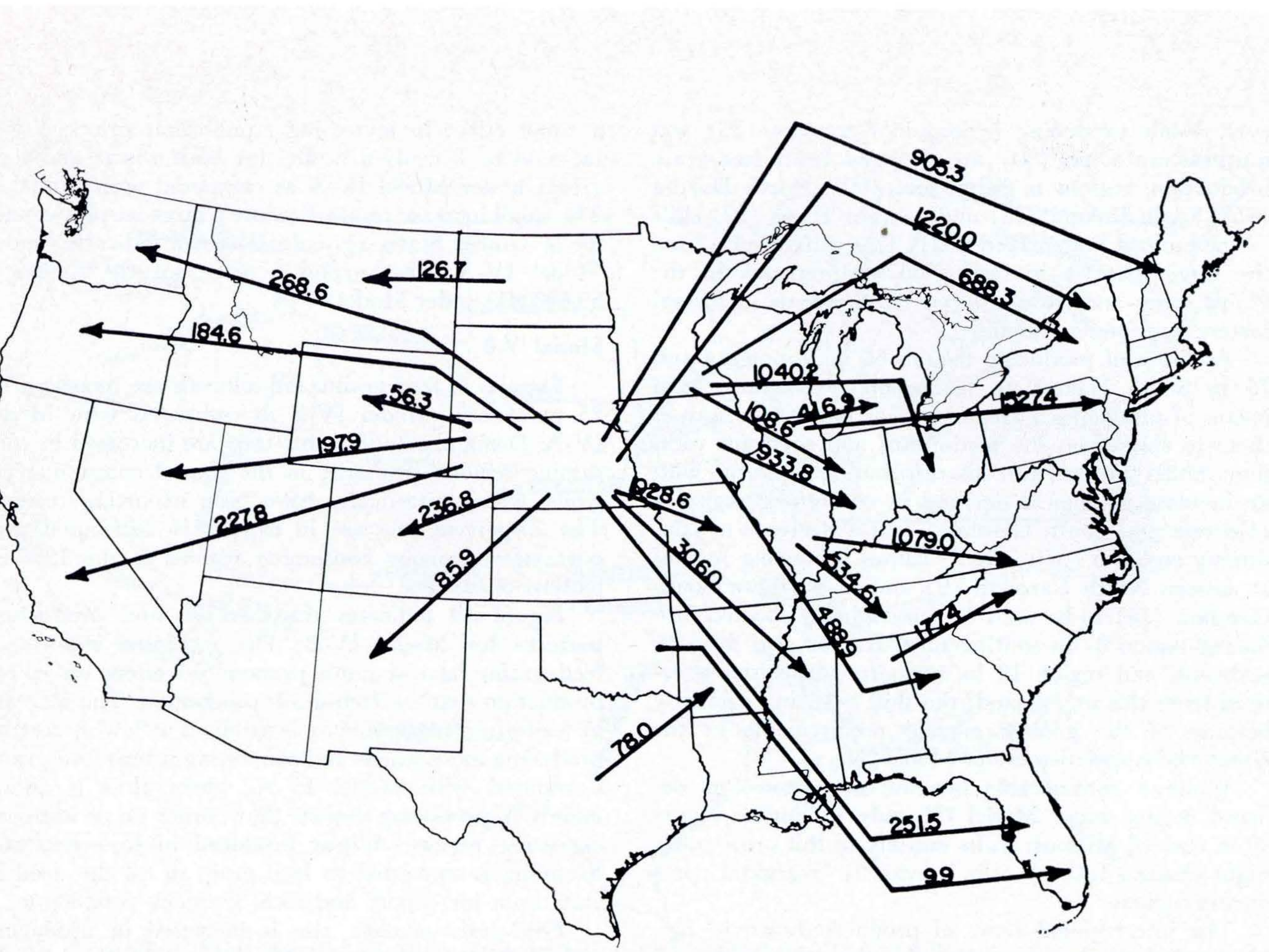

Fig. 10. Interregional flows (indicated by arrows and quantities) of oilmeals (thousands of tons of feed units), Model II.

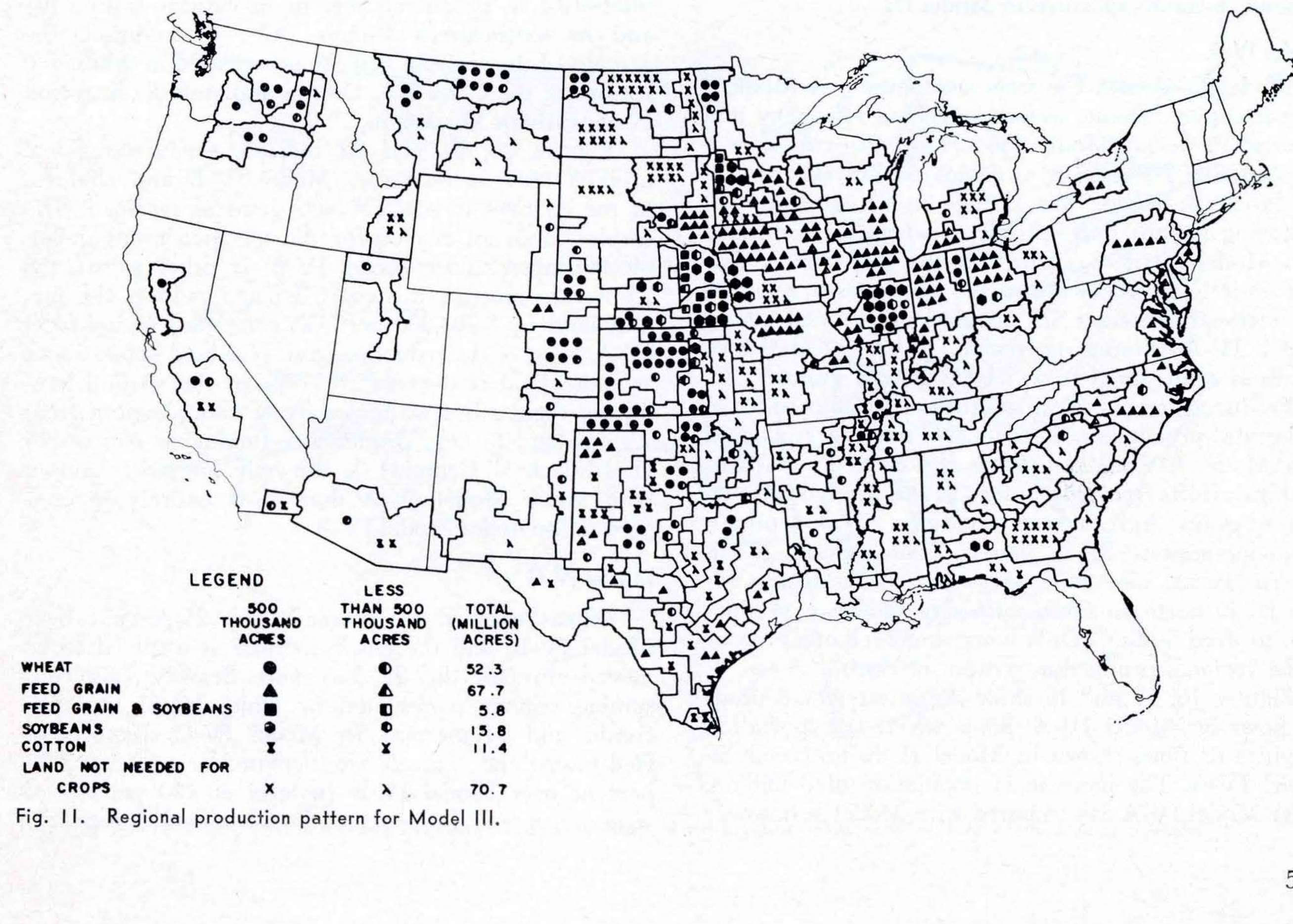

Fig. 11. Regional production pattern for Model III.

ever. While producing regions in Kentucky (29) and southeastern Ohio (30) are dropped from feed-grain production, regions in Minnesota (60), North Dakota (65), South Dakota (73) and western Texas (97) shift to these crops under Model III. This shift results from the large increase in feed-grain requirements in the Plains states and from reduced requirements in several eastern consuming regions.

Addition of producing regions 60 in Minnesota and 73 in South Dakota to feed-grain production, as a means of producing a greater proportion of feed, causes them to shift from the feed-grains and soybeans rotation. Shifts in the over-all distribution pattern, with an increase in oilmeal demand in consuming region 4 (Georgia and South Carolina) and a decrease in consuming region 5 (Mississippi) causes producing regions in eastern North Carolina (9) and in northern South Carolina (14) to be used for producing soybeans. Producing region 87 in south-central Kansas also shifts to soybeans, and region 19 in northern Mississippi is retired from this use of land; the shift occuring evidently because of the greater oilmeal requirements in the Great Plains specified under Model III.

While a considerable increase in cotton lint demand occurs under Model III, only producing region 50 in eastern Missouri shifts entirely to this crop; other slight changes take place in previously "marginal" producing regions.

The interregional flows of products shown in figs. 12, 13 and 14 are consistent with the production and land-use pattern of fig. 11 and the consuming region demand restraints specified in Model III.

Model IV-A

Model IV-A uses the same assumption as Model I for per-capita income, livestock feeding efficiency and exports. However, Model IV-A (fig. 15) considers a population of 230 million, as compared with 222 million for Model I. Under this change in demand, several producing regions shift entirely to wheat, as compared with Model I (fig. 3). Three of the five regions that shift entirely to wheat are in the South, as a result of the regional increases in population assumed under Model IV-A. Producing region 77 in northeastern Colorado again shifts from wheat to feed grains.

Producing region 30 in southeastern Ohio shifts to feed-grain production, in Model IV-A as compared with Model I, while producing region 40 in southern Michigan shifts from purely feed grains to soybeans and to feed-grain and soybean rotations. Two southern producing regions, 126 in western Louisiana and 133 in eastern Texas, also shift to soybeans. Producing region 33 in northern Ohio shifts from soybean production to feed grains. Only very small changes occur in the regional production pattern of cotton.

Figures 16, 17 and 18 show the interregional product flows for Model IV-A. Some wheat transportation activities or flows shown in Model II do not occur in Model IV-A. The increase in population of 8 million, under Model IV-A as compared with Model I, has only a small effect in increasing equilibrium prices. Prices increase by 3 cents a bushel for both wheat and feed grains under Model IV-A as compared with Model I. The small increase results because a large surplus capacity of United States agriculture is still indicated under Model IV-A. The surplus acreage for the nation is 69,878,000 under Model IV-A.

Model IV-B

Exports of feed grains and oilmeals are increased by 25 percent in Model IV-B as compared with Model IV-A. Demand requirements thus are increased in consuming regions, primarily in the coastal consuming regions, which historically have been exporting regions. The 25-percent increase in exports is distributed proportionately among consuming regions in the 1956-61 pattern of exports.

Figure 19 indicates the land-use and production patterns for Model IV-B. The increased exports of feed grains have a more pronounced effect on wheat production than on feed-grain production. The increase in feed-grain requirements is attained at lowest cost by producing more wheat and converting it into feed grain. Compared with Model IV-A, wheat thus is added mainly in producing regions that border on or are near exporting regions. Wheat produced in Colorado and Montana is converted to feed grain to fill the need in California for export and local livestock production.

Feed-grain acreage also is increased in producing regions 56 of southwestern Minnesota and 95 of northern Texas, and the feed-grain and soybean acreage is intensified in producing regions in eastern Iowa (40) and in southeastern Illinois (47). In addition, the acreage of the soybean activity is increased in producing regions of the Corn Belt. Cotton also emerges in region 17 of southern Mississippi.

Figures 20, 21 and 22 indicate the interregional product movements under Model IV-B and conform to the changes in production regions as outlined. The surplus land not needed for the specified crops is 66,094,000 acres under Model IV-B. In other words, the 25-percent increase in export demand reduces the surplus land by 3,784,000 acres as compared with Model IV-A. Most of the reduction in surplus land comes about as more land is devoted to crops in the various producing regions but without shifting entire regions from surplus land to crop production. Producing region 123 (north-central Georgia) is the only one with unused land under Model IV-A that shifts entirely to crop production under Model IV-B.

Model IV-C

Wheat exports are increased by 25-percent over Model IV-B, and the entire increase is assumed to be moved through the St. Lawrence Seaway (via consuming regions represented by Ohio, Michigan, Wisconsin and Minnesota) in Model IV-C. Exports of feed grains and oilmeals are increased an additional 25 percent over Model IV-B (a level of 150 percent of

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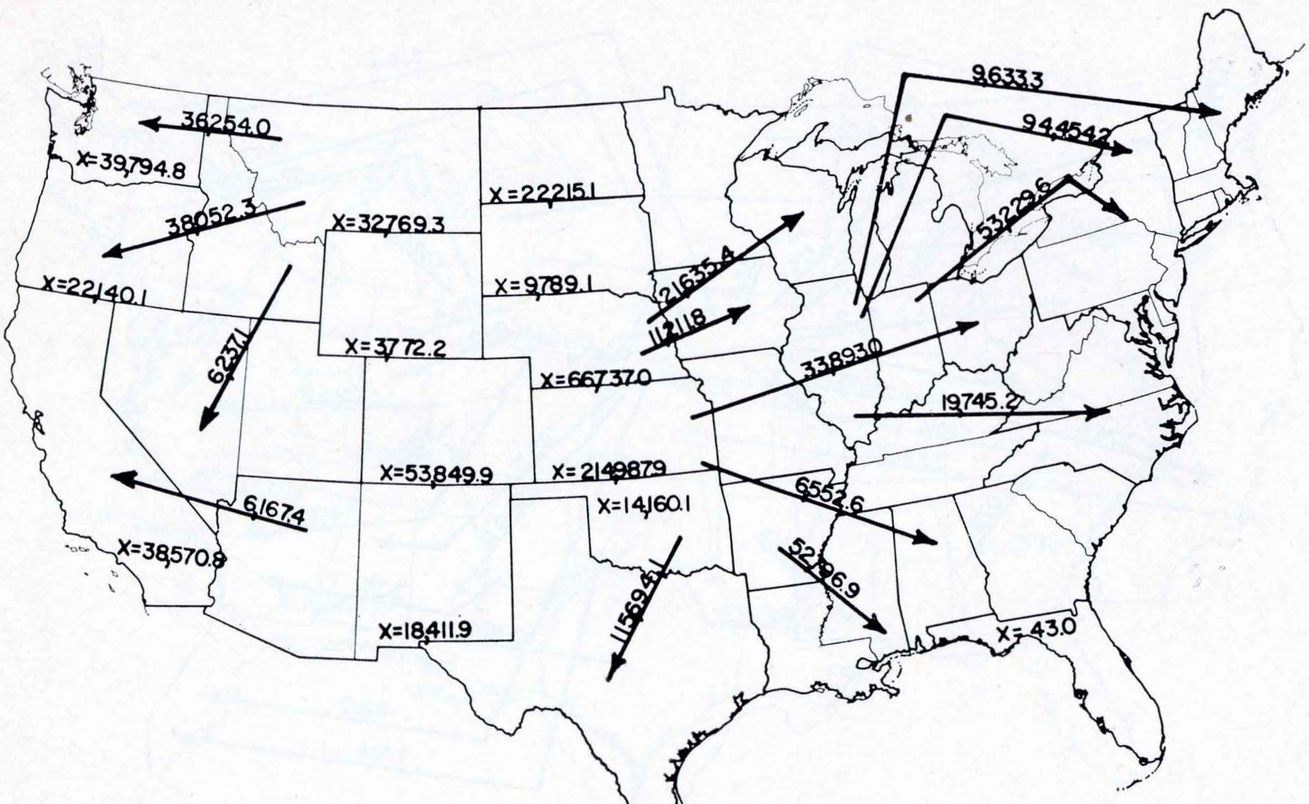

Fig. 12. Interregional flows (indicated by arrows and quantities) and intraregional transfers (magnitudes of x) of wheat to feed grains (thousands of bushels), Model III.

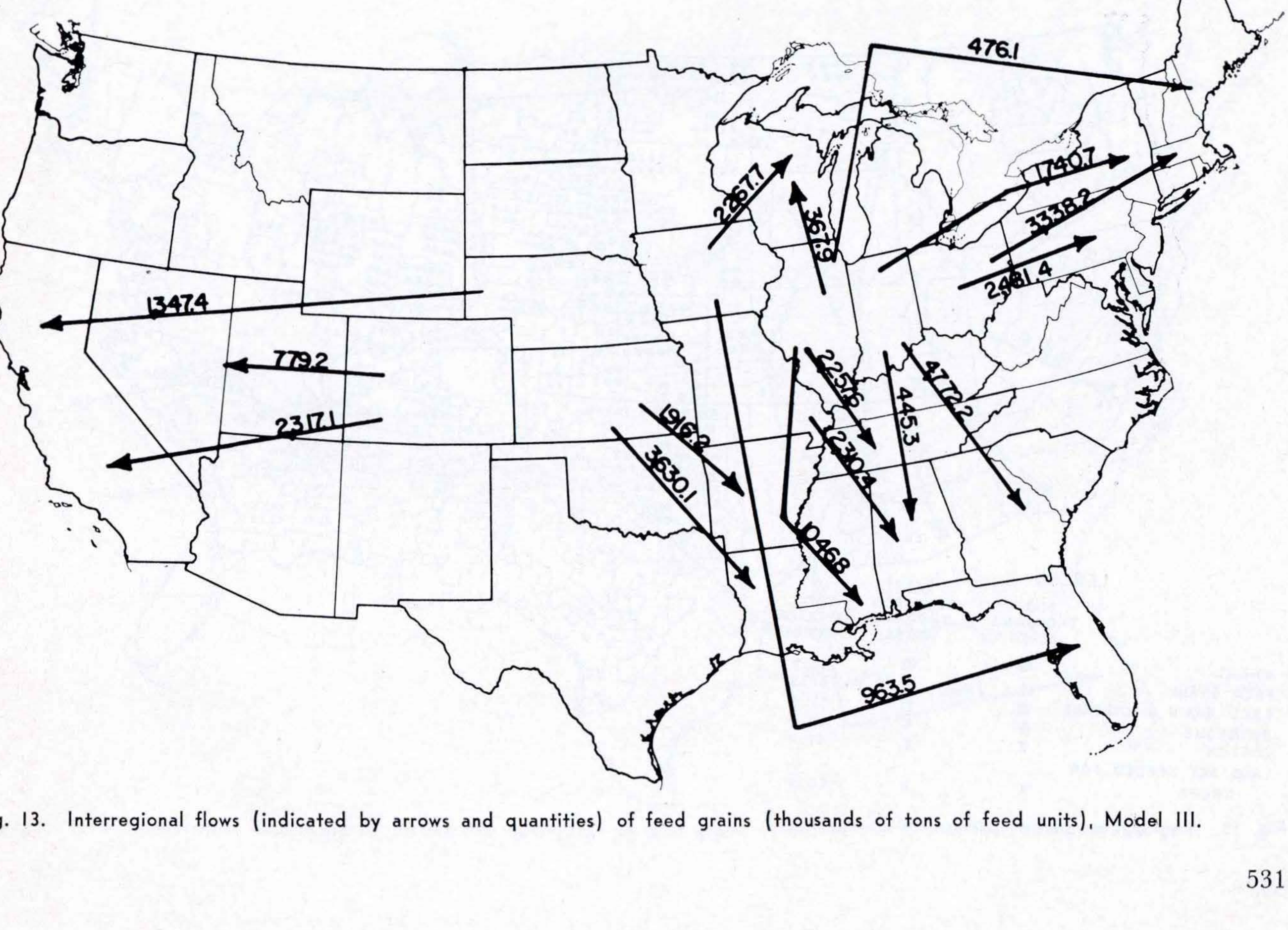

Fig. 13. Interregional flows (indicated by arrows and quantities) of feed grains (thousands of tons of feed units), Model III.

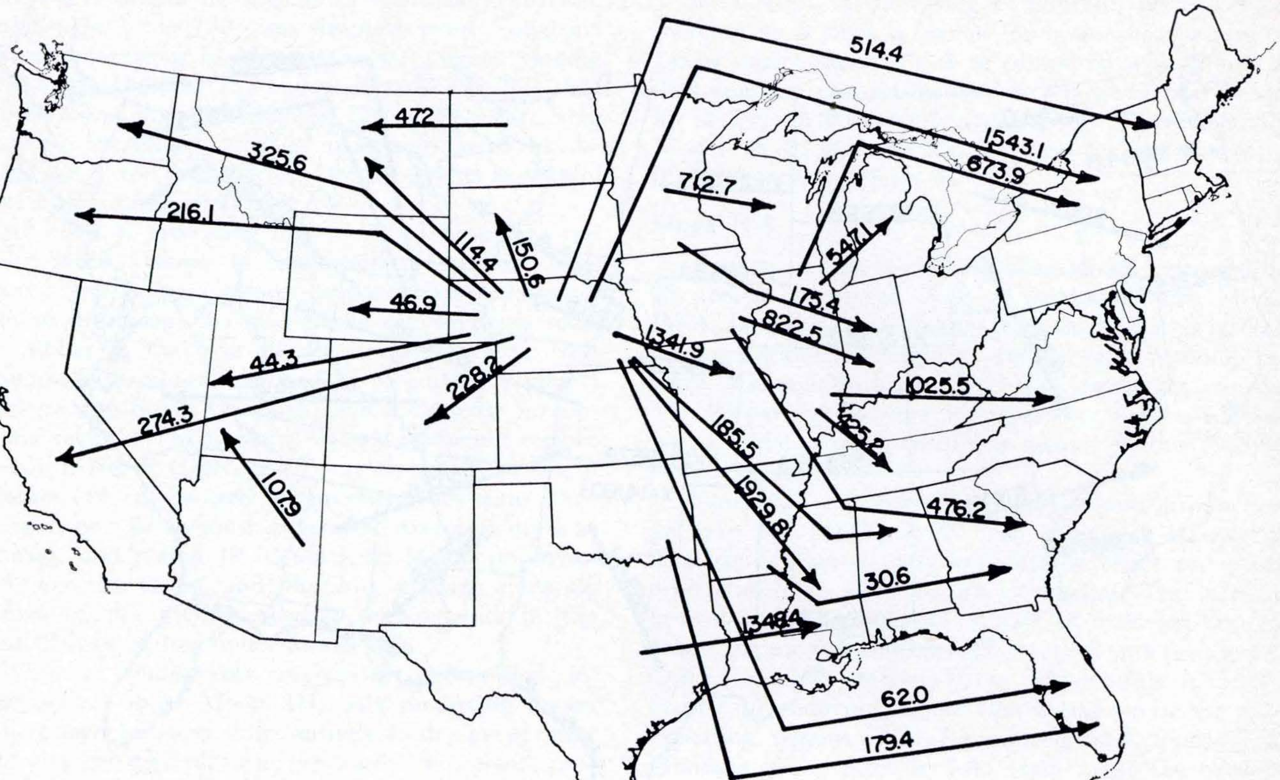

Fig. 14. Interregional flows (indicated by arrows and quantities) of oilmeals (thousands of tons of feed units), Model III.

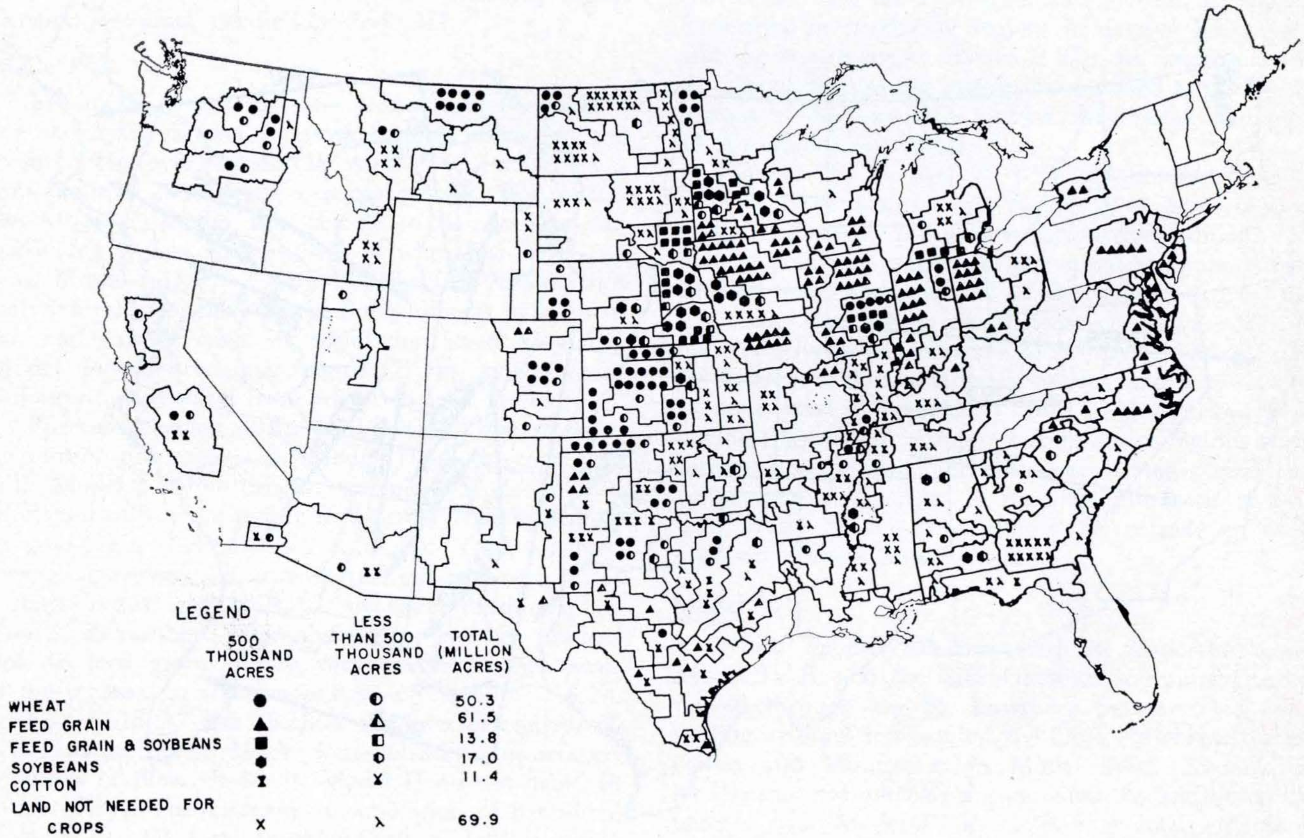

Fig. 15. Regional production pattern for Model IV-A.

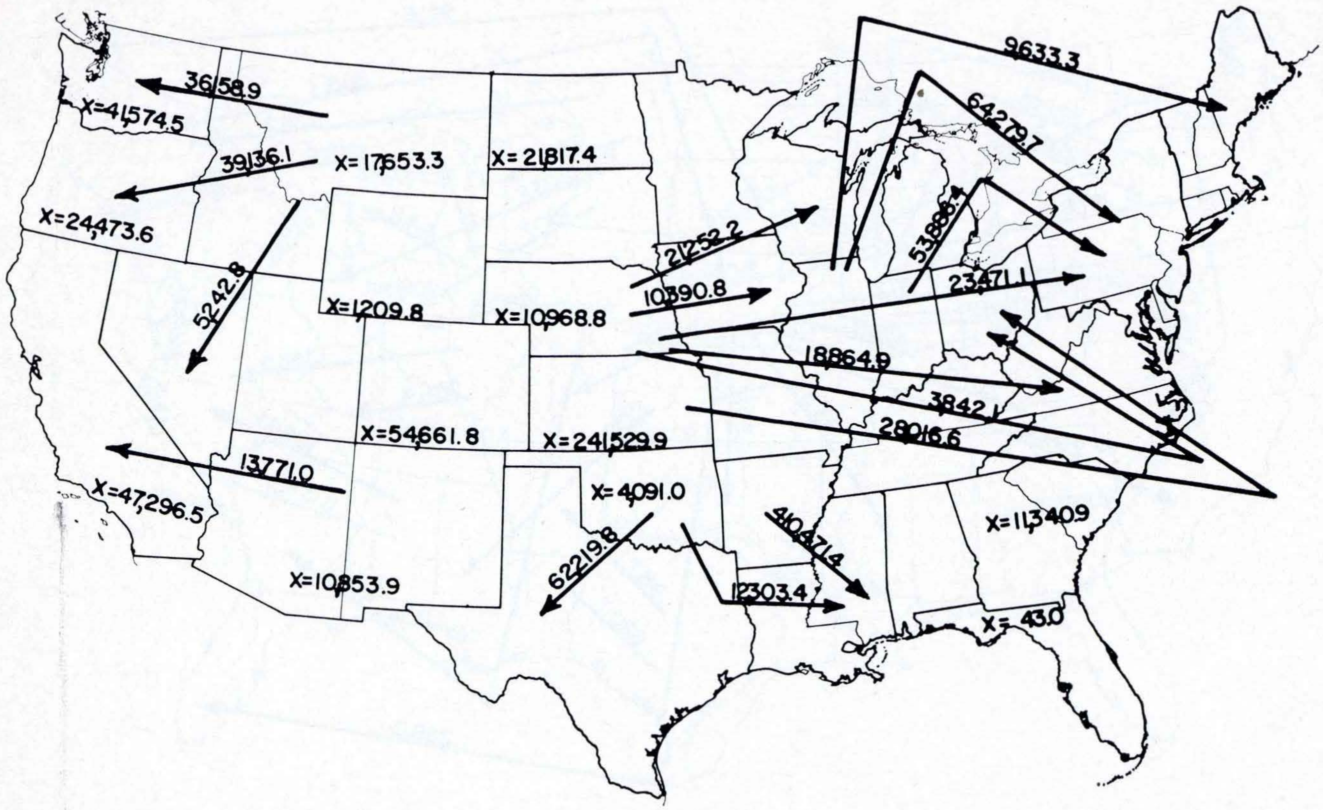

Fig. 16. Interregional flows (indicated by arrows and quantities) and intraregional transfers (magnitudes of x) of wheat to feed grains (thousands of bushels), Model IV-A.

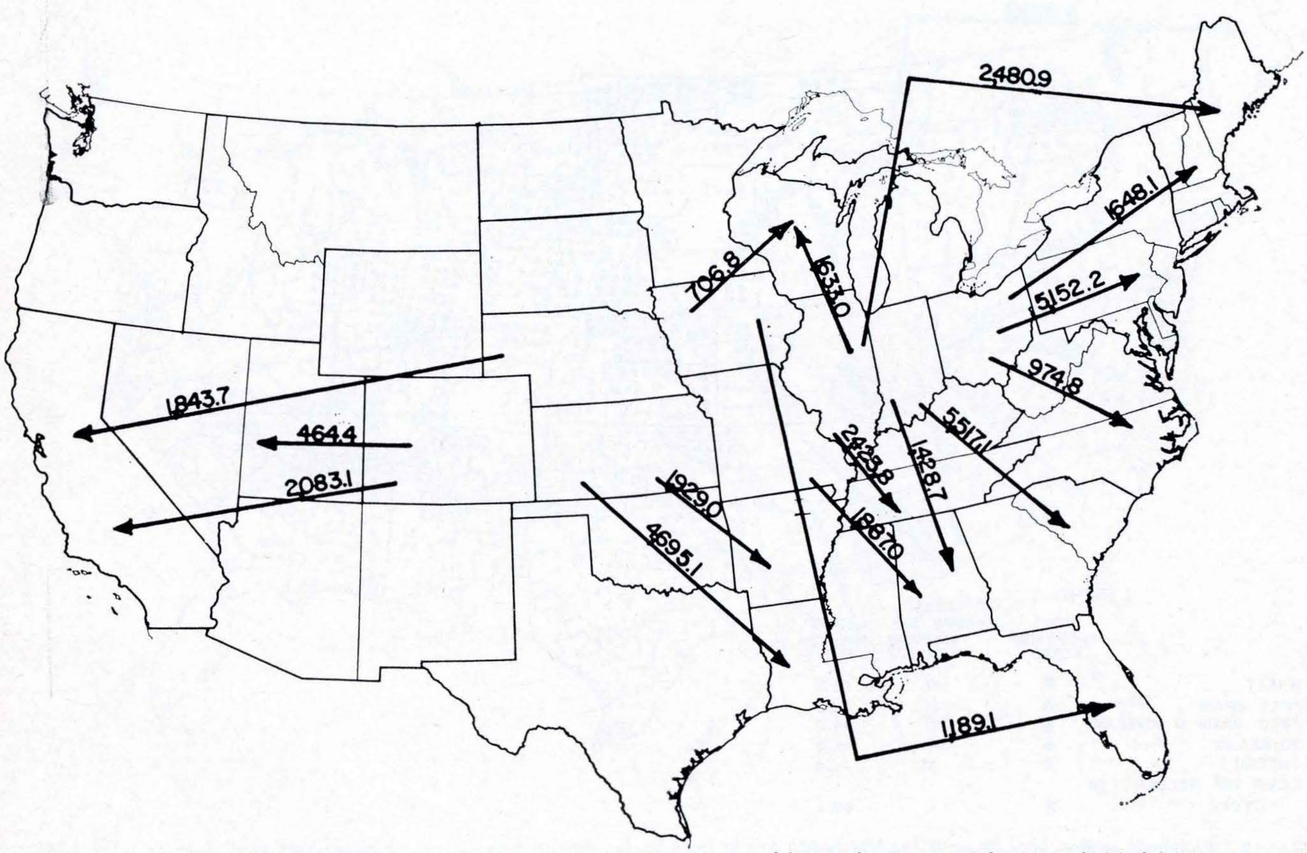

Fig. 17. Interregional flows (indicated by arrows and quantities) of feed grains (thousands of tons of feed units), Model IV-A.

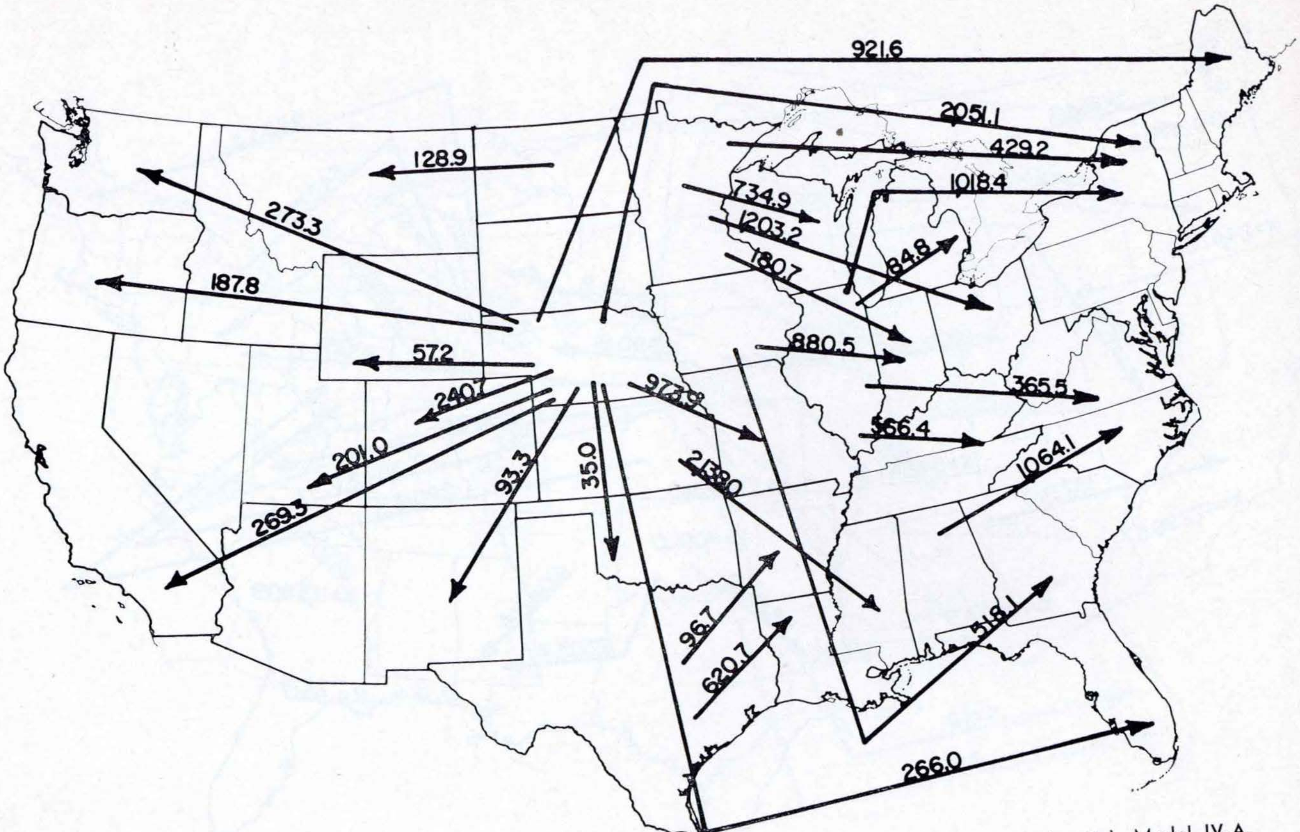

Fig. 18. Interregional flows (indicated by arrows and quantities) of oilmeals (thousands of tons of feed units), Model IV-A.

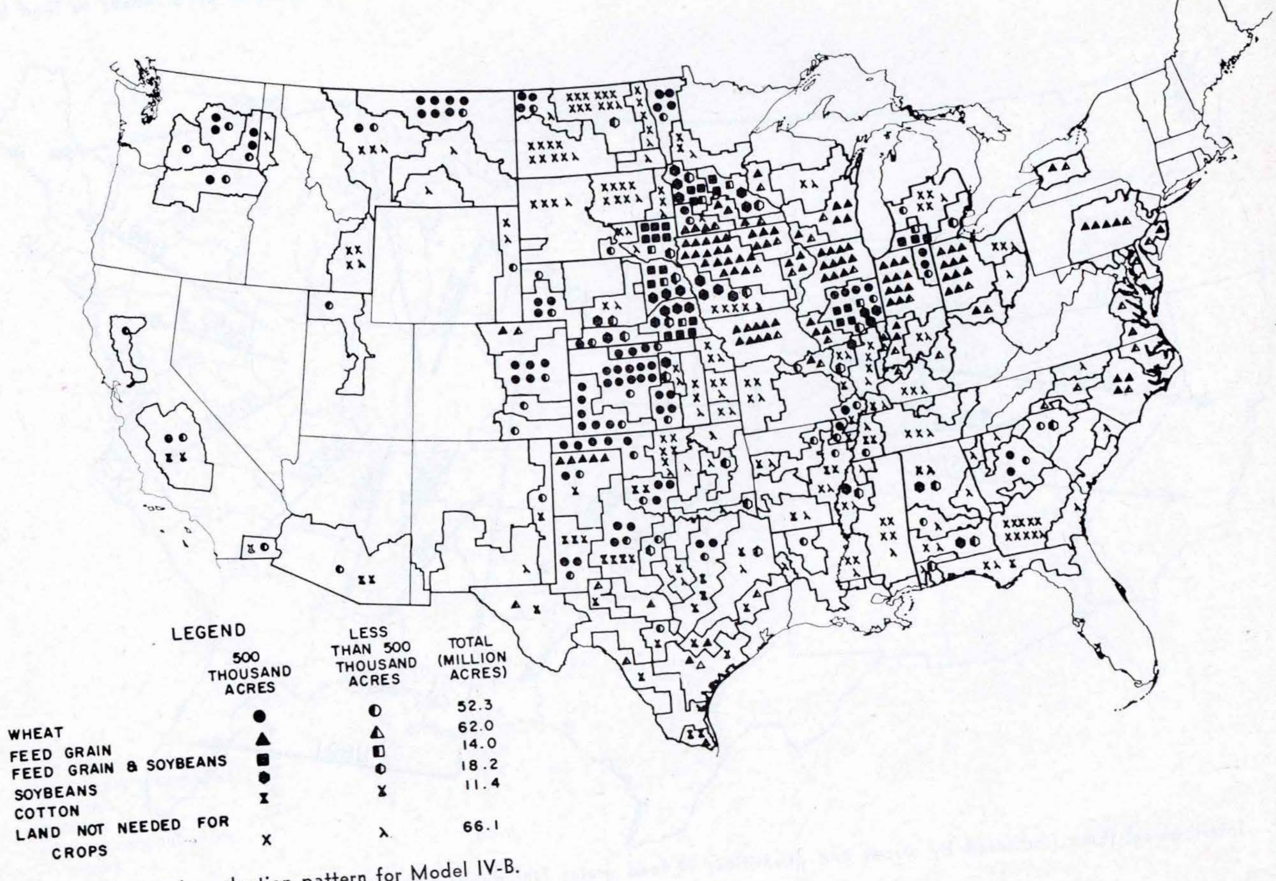

Fig. 19. Regional production pattern for Model IV-B.

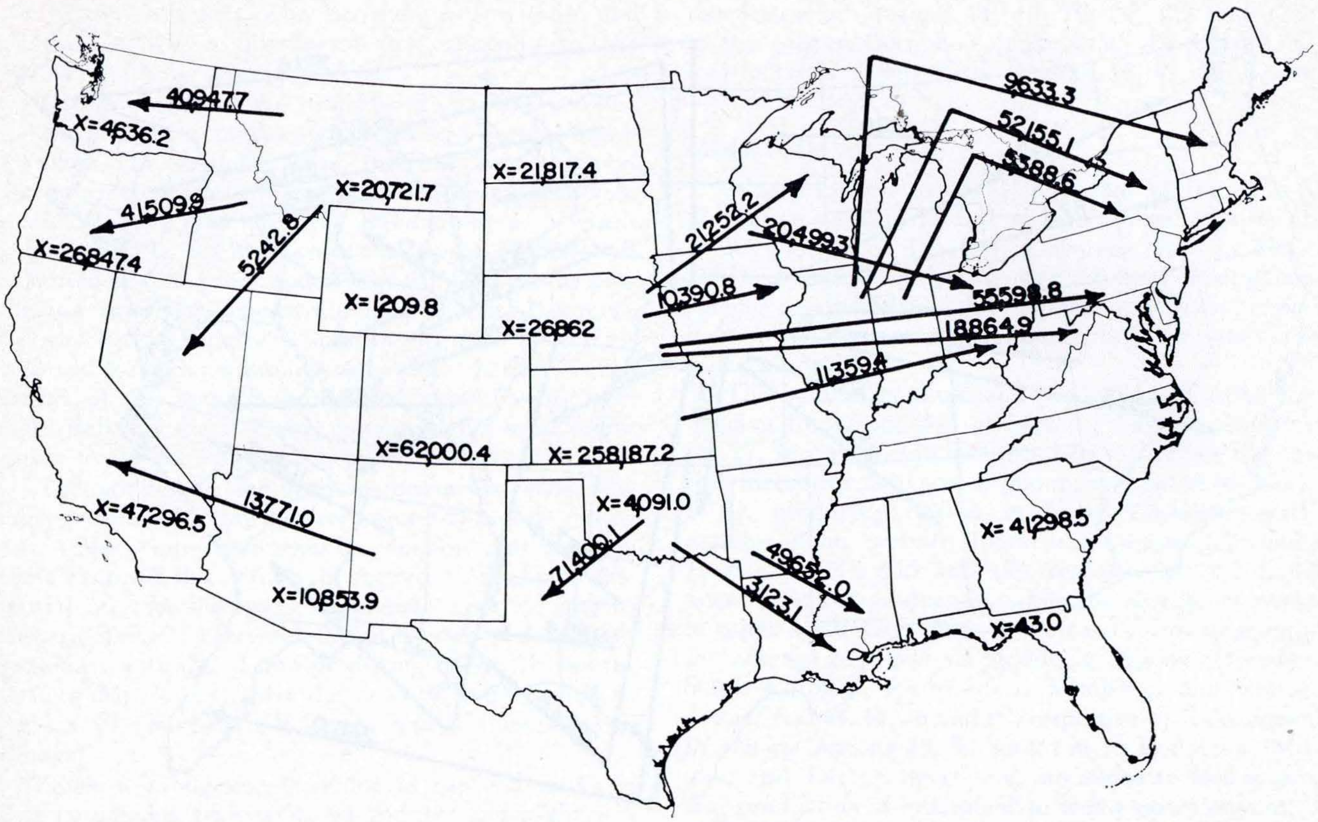

Fig. 20. Interregional flows (indicated by arrows and quantities) and intraregional transfers (magnitudes of x) of wheat to feed grains (thousands of bushels), Model IV-B.

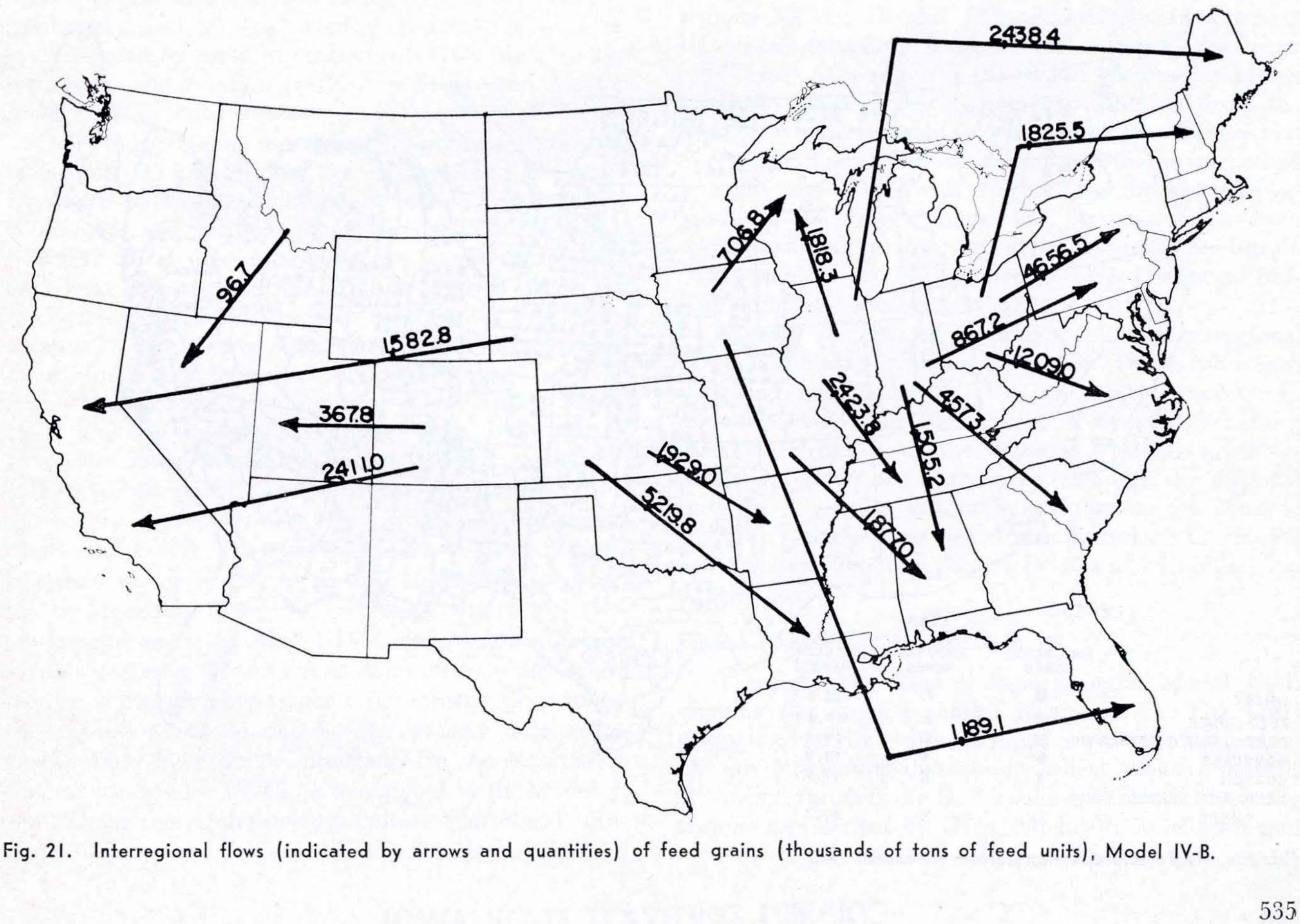

Fig. 21. Interregional flows (indicated by arrows and quantities) of feed grains (thousands of tons of feed units), Model IV-B.

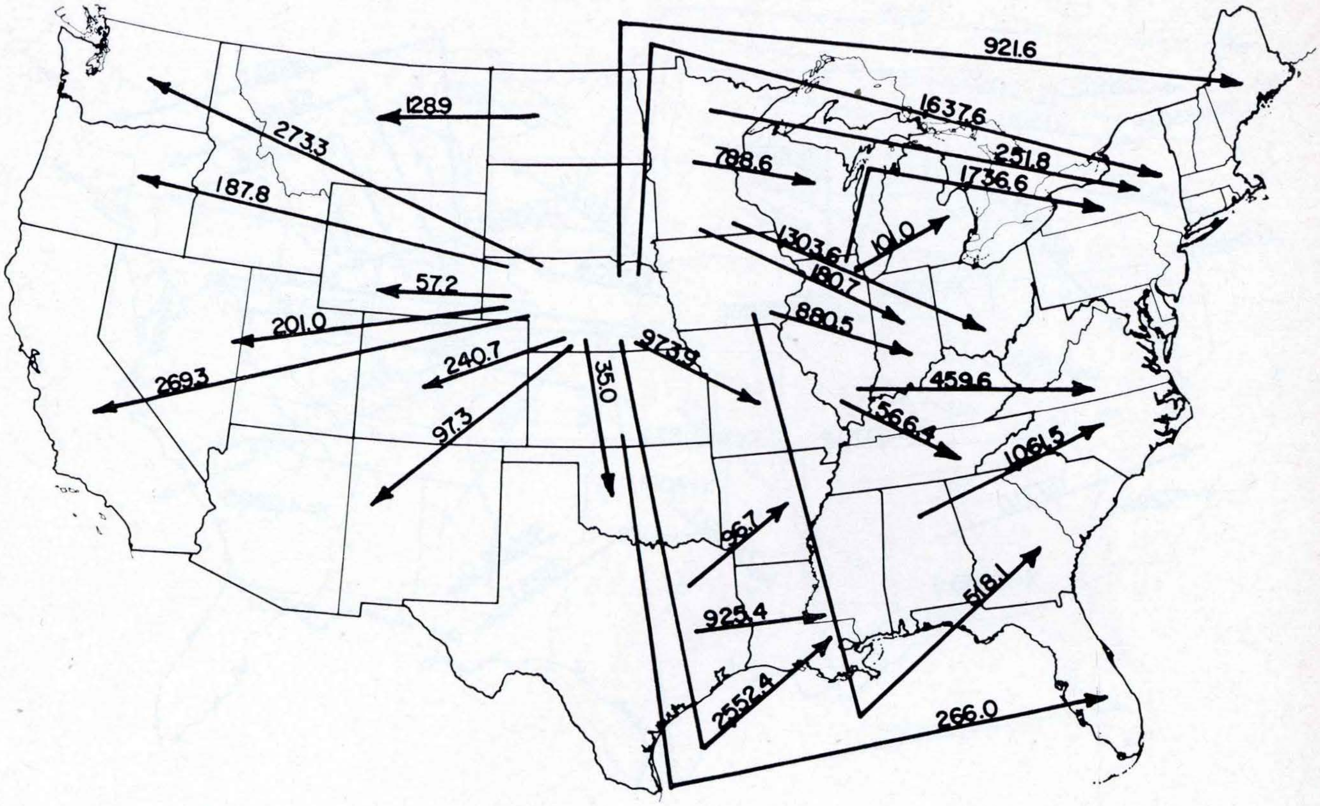

Fig. 22. Interregional flows (indicated by arrows and quantities) of oilmeals (thousands of tons of feed units), Model IV-B.

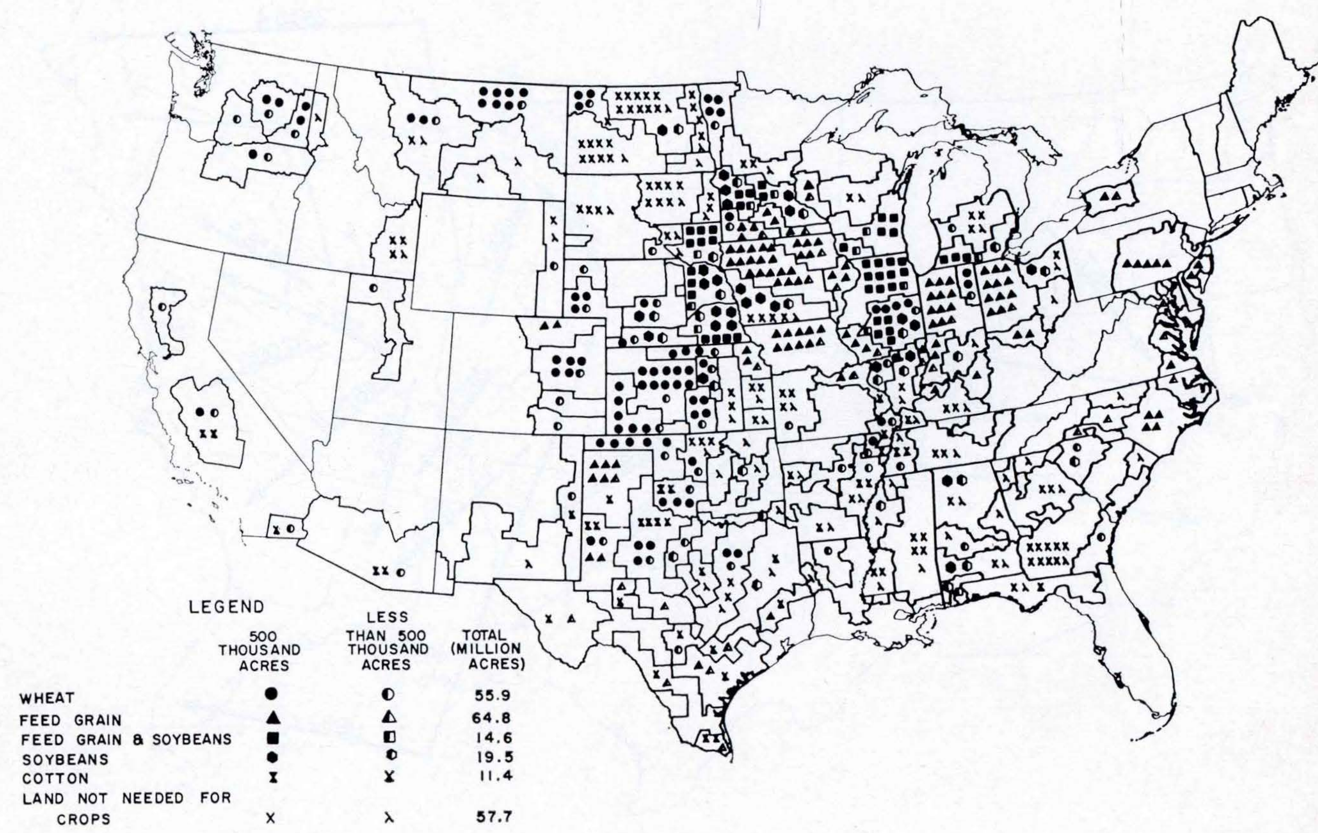

Fig. 23. Regional production pattern for Model IV-C.

the 1956-61 average). The increment in feed-grain and oilmeal exports is distributed proportionally to the 1956-61 patterns among regions.

Conforming with the projected 25-percent increase in wheat exports, producing regions in Georgia, South Carolina, the southern Corn Belt and central Great Plains are brought into or increase wheat production under Model IV-C (fig. 23). Land devoted to wheat in region 95 of northwestern Texas under Model IV-B is shifted to feed grain under Model IV-C. Wheat production does not concentrate near the St. Lawrence Seaway even when the 25-percent increase in exports is forced through consuming regions that border it. The effects of the increase are spread about evenly over Corn Belt and Great Plains regions having some orientation to the St. Lawrence Seaway, however.

The additional feed-grain requirements bring producing regions 81 (northeastern Kansas) and 97 (western Texas) into feed-grain production and increase the acreage of this activity in regions 50 (eastern Missouri), 56 (southwestern Minnesota) and 95 (northwestern Texas). Likewise, the feed-grain and soybean rotation is introduced into producing region 17 (southwestern Mississippi), and the activity is intensified in regions 40 (southern Michigan) and 47 (east-central Illinois).

Soybean production is added in the eastern Corn Belt (producing regions 32, 34 and 48) and slightly in North Dakota (region 65) as the result of the increased oilmeal export demands. Producing regions 40 (southern Michigan) and 47 (east-central Illinois) decrease in soybean acreage as a consequence of the shift to the feed-grain and rotation activity in this region. Cotton production remains the same as in Model IV-B.

The interregional movement of products indicated by figs. 24, 25 and 26 does not show marked departure from the patterns established by earlier models. The volumes of interregional movements and intraregional transfers do change, however. The equilibrium prices of wheat are changed slightly more than those for feed grains or oilmeals between model IV-B to IV-C—a result to be expected since the increase in export demand for wheat is relatively greater than for feed grains and oilmeals. Equilibrium prices under Model IV-C also are only slightly greater than under Model IV-B (or under Model I), because surplus capacity is still indicated under the former model. Land not required for wheat, cotton, feed grains and soybeans totals 57,709,600 acres under Model IV-C; 8,384,400 less than under Model IV-B and 16,409,000 less than under Model I. Thus, the increased exports and demand represented by Model IV-C would not eliminate surplus capacity in American agriculture, but would require a considerably larger crop acreage than under the conditions of Model I. The greater acreage in crops would have great importance to the local areas concerned. Model IV-C, as compared with Model I, would have more intensive agriculture (i.e., could eliminate surplus land for crops) in producing regions of the Southeast (regions 11, 13, 17, 26, 123 and 128), in the eastern Corn Belt (regions 30, 40, 47 and 56) and in Great Plains states (regions 78, 81, 86, 87 and 110).

Model IV-D

Wheat exports are at 150 percent of the 1956-61 average levels, and feed-grain and oilmeal exports are at 200 percent of the 1956-61 average levels in Model IV-D. The distribution of each product among consuming regions follows the original, or 1956-61, export distribution pattern. Other assumptions are the same as for Model IV-A.

The optimal land-use and production patterns conforming to the solution of Model IV-D are shown in fig. 27. In comparison with Model IV-C, given the further increment in export demand represented by Model IV-D, producing regions in North Carolina, southeastern Idaho, western Idaho and eastern Oklahoma (regions 7, 113, 115 and 134, respectively) are added anew to wheat production, while the acreage of wheat in other scattered regions is increased. Simultaneously, the acreage of wheat in producing regions of western South Carolina, southwestern Minnesota and western Texas (regions 41, 56 and 97, respectively) is decreased. Producing regions 28, 51 and 136 in Kentucky, Missouri and Texas, respectively, are added to feed grains, and production is intensified in a few other regions.

Some feed grains are also produced with the feed-grain and soybean rotation introduced into producing regions 34, 54, 78 and 133, respectively, in southern Illinois, southwestern Iowa, central Nebraska and eastern Texas. As a result of the export increase of Model IV-D over Model IV-C, some land is shifted from the feed-grain and soybean rotation to soybean production in central Illinois. Soybean production also is intensified in a few regions and is introduced for the first time in northern Michigan (region 41). Acreage shifts from soybeans to feed grains with soybeans and to feed-grain production, respectively, in regions 34 (southern Indiana) and 40 (southern Michigan).

Figures 28, 29 and 30 indicate the interregional flows of the three product categories. The surplus land indicated for Model IV-D is 48,416,200 acres, an amount greater than the acreage in diversion programs in 1963. Hence, even the demand levels assumed for Model IV-D do not promise to eliminate the national problem of surplus production. However, the demand conditions under this model specify about 22 million less surplus acres than Model IV-A and 26 million less than Model I.

Model IV-E

The aggregate level of exports under Model IV-E remains the same as under Model IV-D. The ports through which the products move are changed, however. Of the 50-percent increase in wheat exports, half is channeled through the St. Lawrence Seaway consuming regions represented by Ohio, Michigan, Wisconsin and

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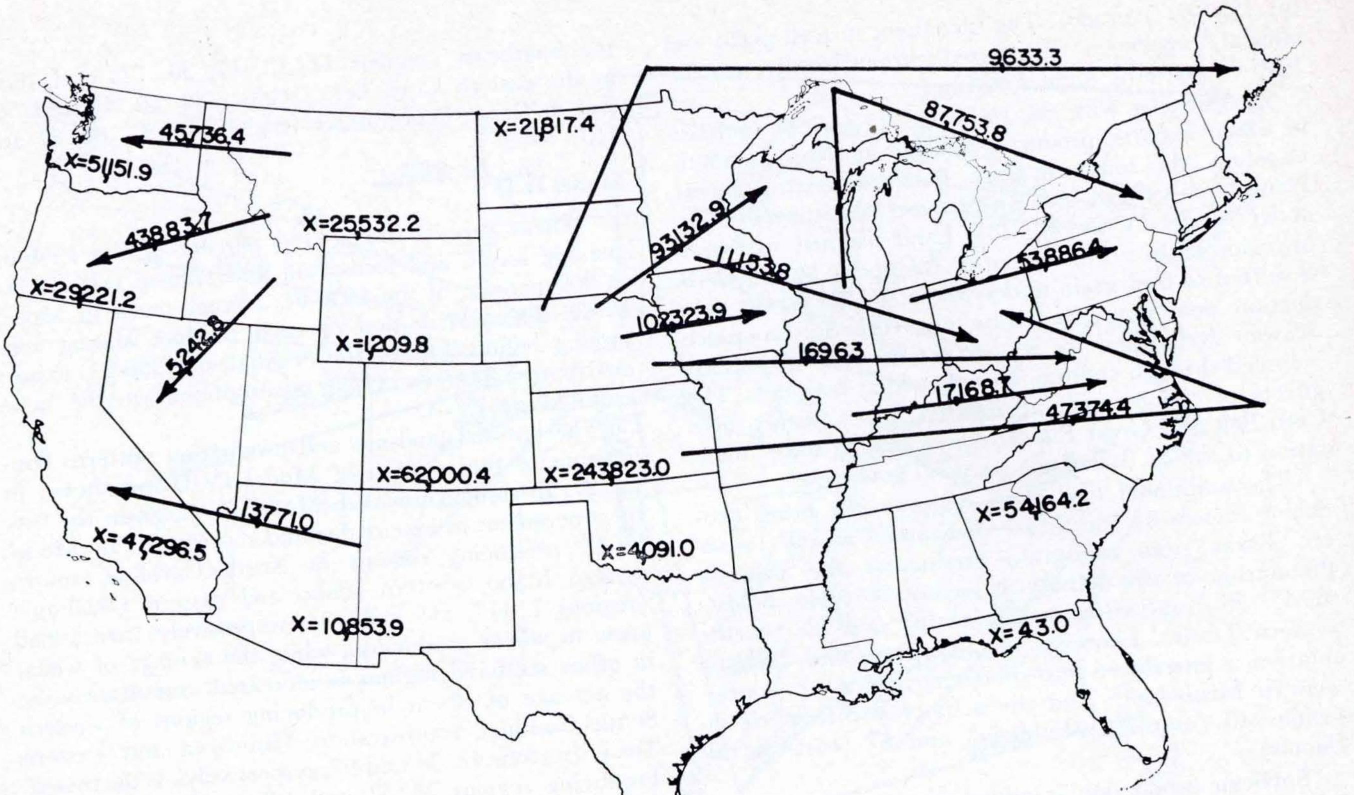

Fig. 24. Interregional flows (indicated by arrows and quantities) and intraregional transfers (magnitudes of x) of wheat to feed grains (thousands of bushels), Model IV-C.

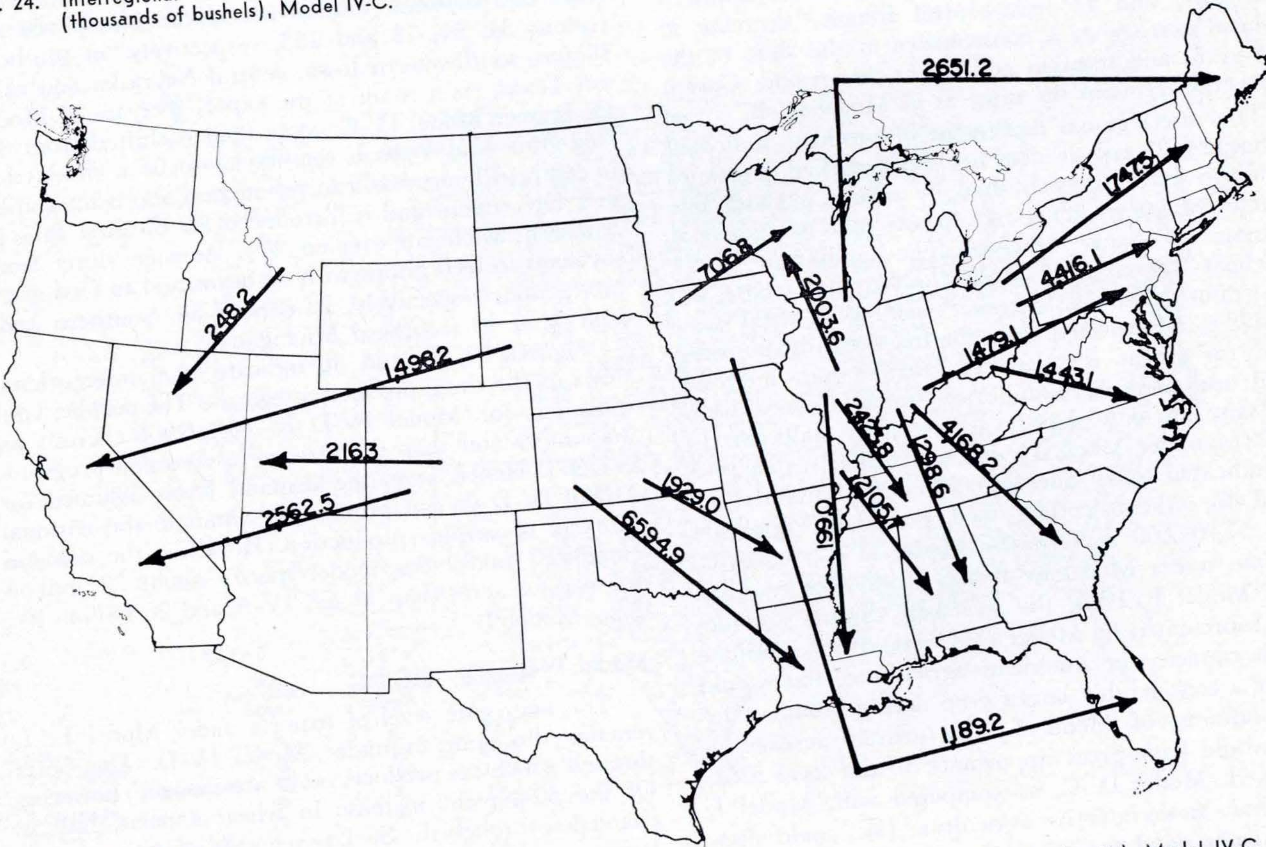

Fig. 25. Interregional flows (indicated by arrows and quantities) of feed grains (thousands of tons of feed units), Model IV-C.

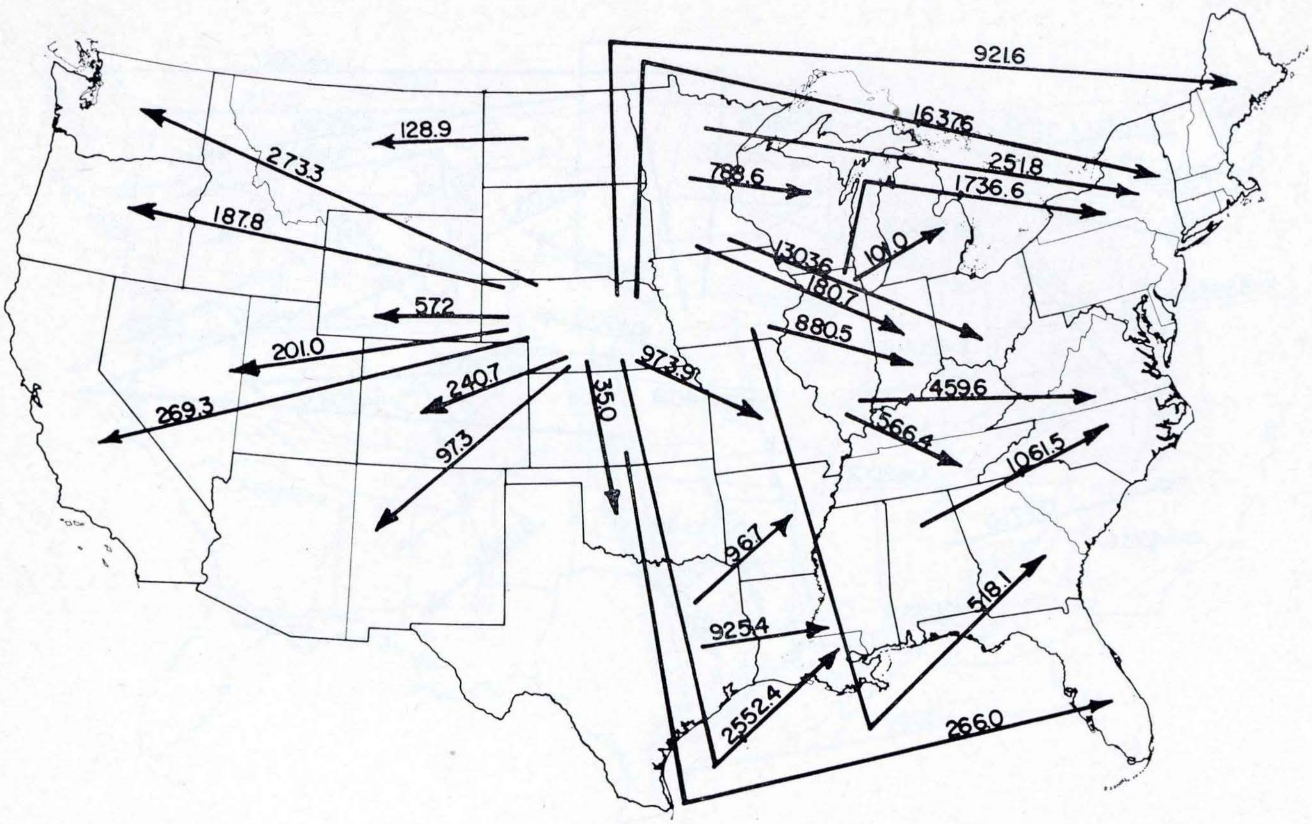

Fig. 26. Interregional flows (indicated by arrows and quantities) of oilmeals (thousands of tons of feed units), Model IV-C.

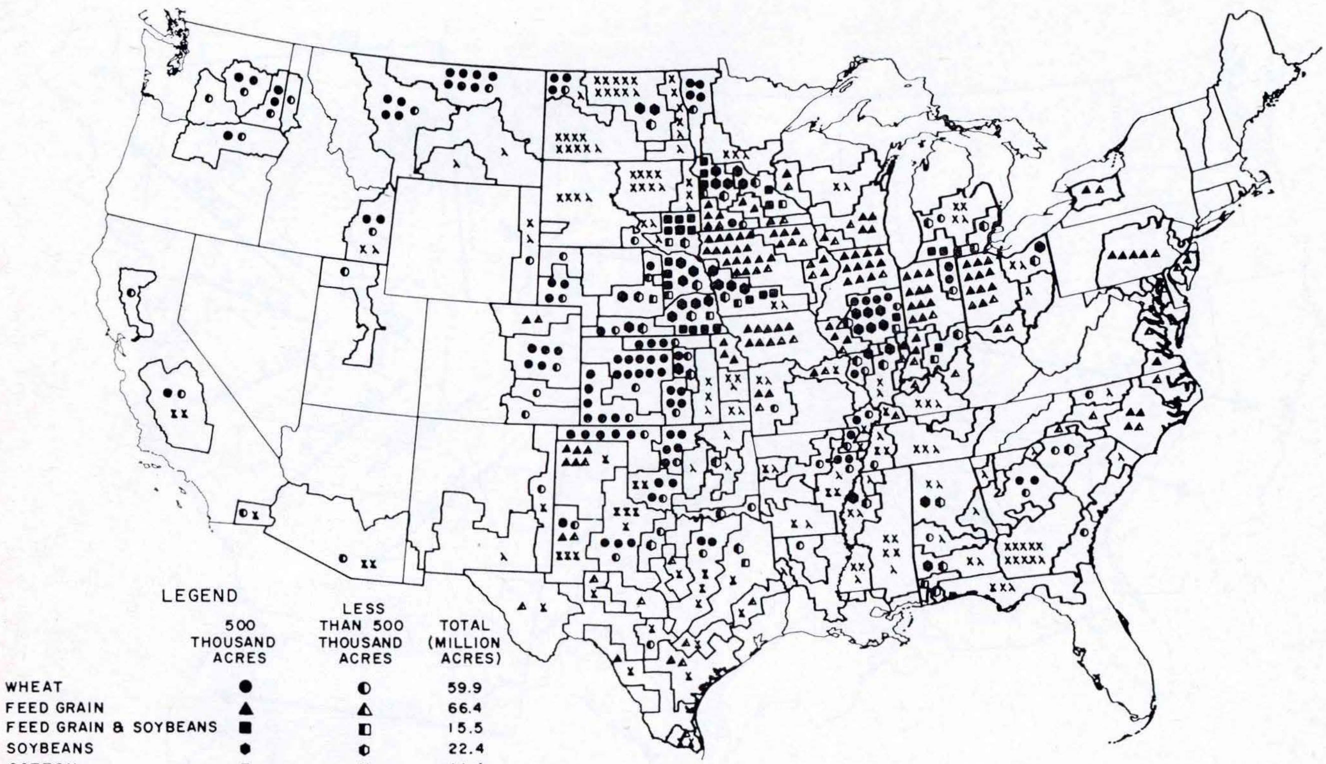

Fig. 27. Regional production pattern for Model IV-D.

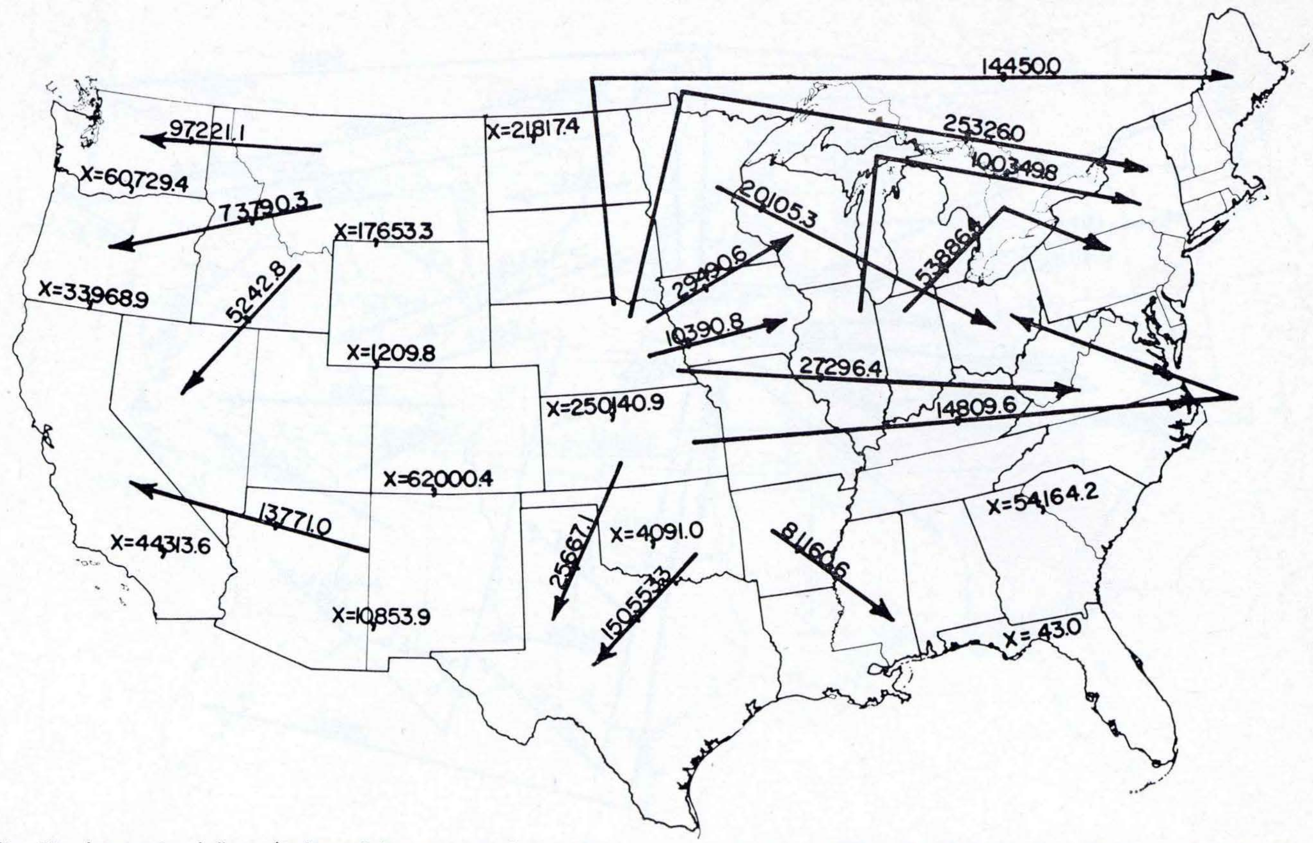

Fig. 28. Interregional flows (indicated by arrows and quantities) and intraregional transfers (magnitudes of x) of wheat to feed grains (thousands of bushels), Model IV-D.

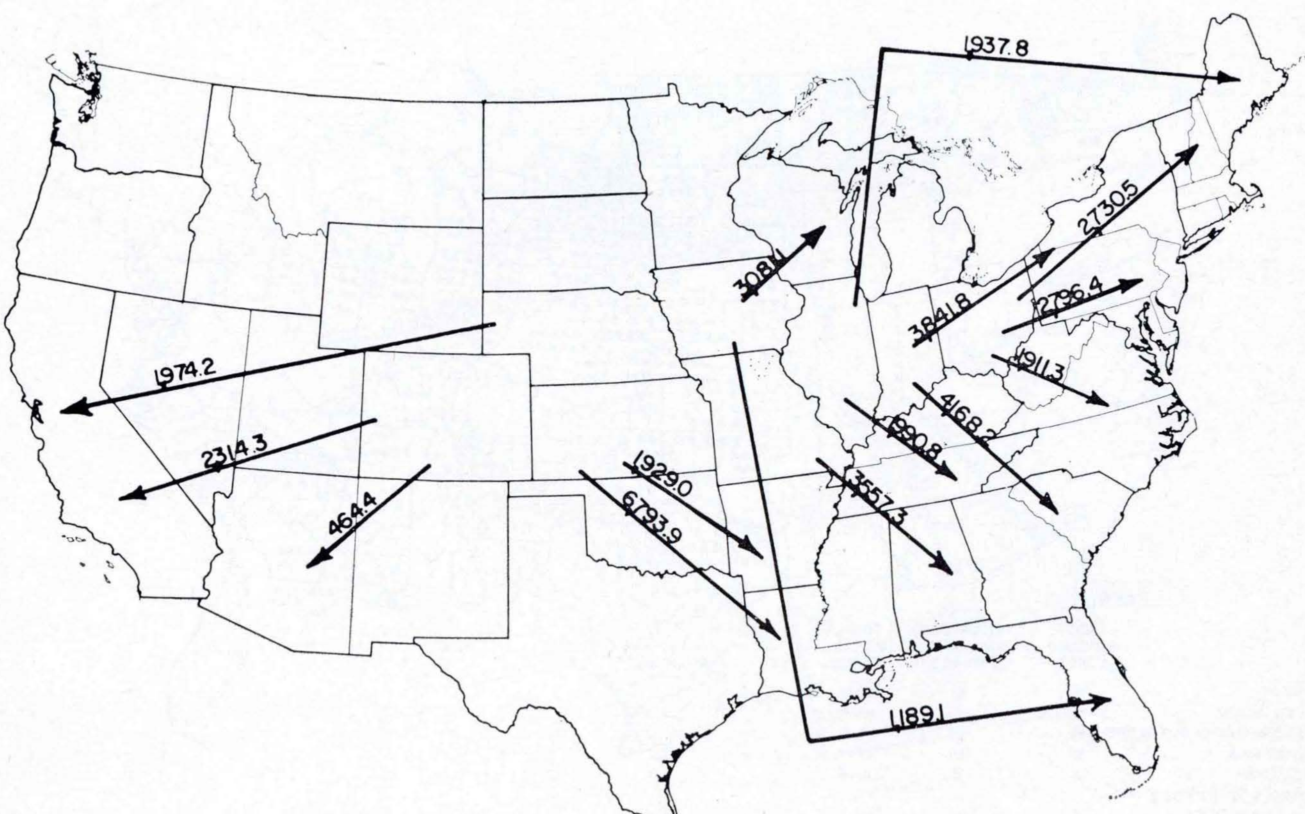

Fig. 29. Interregional flows (indicated by arrows and quantities) of feed grains (thousands of tons of feed units), Model IV-D.

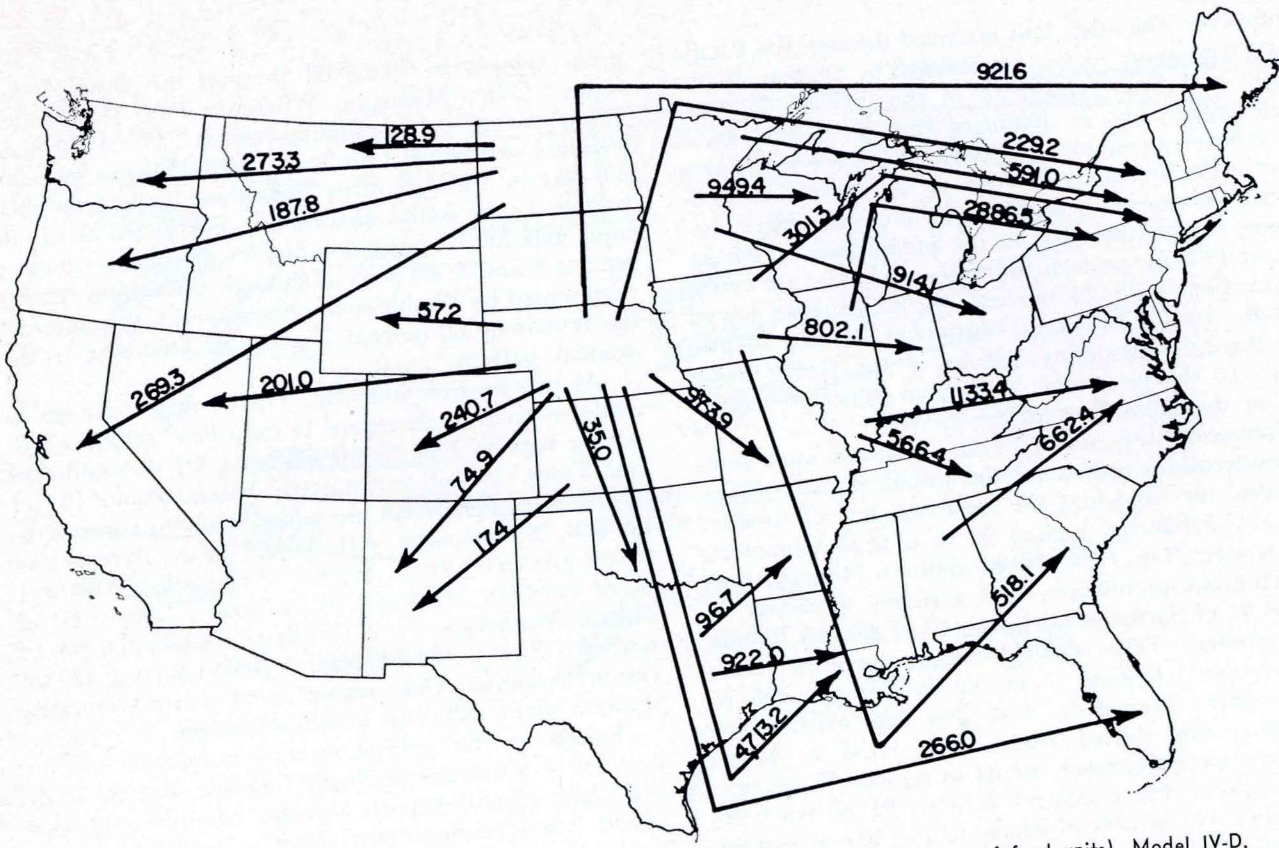

Fig. 30. Interregional flows (indicated by arrows and quantities) of oilmeals (thousands of tons of feed units), Model IV-D.

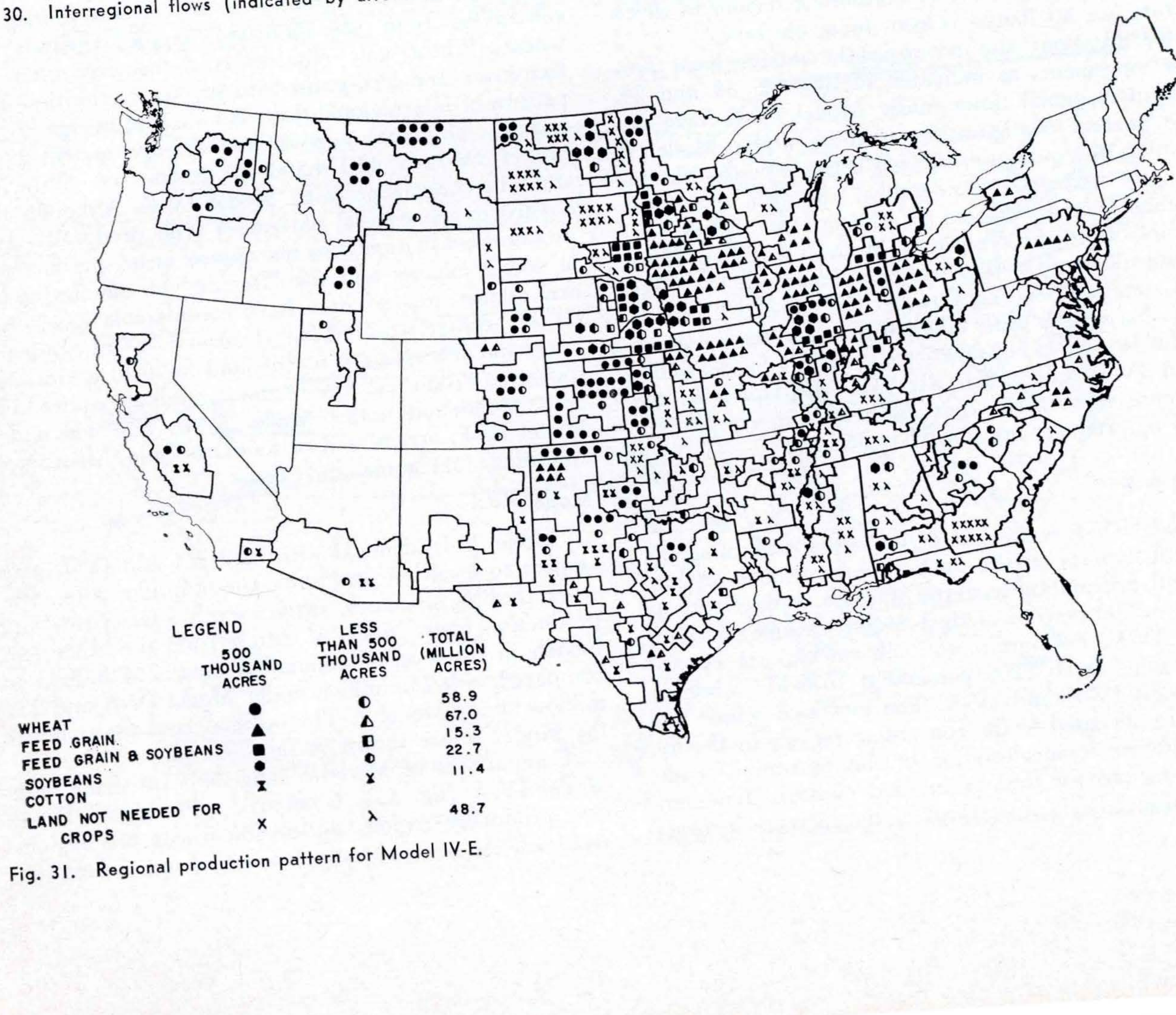

Fig. 31. Regional production pattern for Model IV-E.

Minnesota. The other half is moved through the Pacific Coast consuming regions represented by Oregon, Washington and California. Half of the increase in feed-grain exports also is channeled through the St. Lawrence Seaway consuming regions (i.e., the Great Lakes states). The remaining portion of the increase in feed-grain requirements is distributed among the other consuming regions following in the proportions of the initial, or 1956-61, pattern. Oilmeal exports also are varied in direction, with 20 percent of the increase forced through the Pacific Coast consuming regions, 50 percent through consuming regions of the Great Lakes states and the remaining 30 percent allocated on the basis of the initial pattern.

Compared with Model IV-D, wheat has some acreage reallocations because of the specification of different ports for exporting the same amount of product (fig. 31). Producing regions 62 in central Minnesota, 95 in western Texas and 107 in southern Montana shift to feed-grain production, and acreages of wheat in regions 41 of northern Michigan, 47 of eastern Illinois, 97 of western Texas and 113 of southeastern Idaho are increased. Regions 7 in North Carolina, 56 in southwestern Minnesota and 134 in southeastern Oklahoma are shifted from wheat, and a downward acreage adjustment occurs in regions 78 of central Nebraska, 86 of central Kansas, 91 of northern Oklahoma, 124 of central Alabama and 127 of eastern Arkansas. The shift in feed-grain and feed-grain with soybean acreage toward the consuming regions to which exports are attributed is even more obvious.

Reallocations also occur in the interregional product movements as indicated in figs. 32, 33 and 34. The interregional flows under Model IV-E have the same general configuration as those under Model I. However, the quantities moving between consuming regions are changed considerably. Also, the movement of oilmeals under Model IV-E (fig. 34) differs considerably from the pattern of Model I (fig. 6). South Dakota fills more of the meal requirements of the West. Iowa supplies New York rather than South Carolina. Somewhat similar shifts take place among other regions. Surplus land of 48,689,200 acres is slightly higher under Model IV-E than under Model IV-D. However, the difference is so slight that differences in equilibrium prices of products are hardly noticeable.

Model IV-F

Model IV-F is the last of the series examining the effect of exports on the optimal interregional production and distribution patterns of crops. Wheat exports are set at 200 percent of their 1956-61 average level in Model IV-F. Feed-grain and oilmeal exports remain at the same levels (200 percent of 1956-61) assumed for models IV-D and IV-E. The increased wheat exports are allocated to the consuming regions in the initial pattern. Some alteration of this pattern is made among regions for feed grains and oilmeals, however. As in Model IV-E, 50-percent of the increase in feed-grain exports is channeled through the Great Lakes states (Ohio, Michigan, Wisconsin and Minnesota), 20 percent through consuming regions 3 (West Virginia, Virginia and North Carolina) and 5 (Mississippi) and 30 percent through other consuming regions in proportion to the initial distribution. For increases in oilmeal exports, 20 percent is forced through consuming regions 3 and 5, 20 percent through consuming regions represented by Washington, Oregon and California and the remaining 60 percent is allocated according to the original pattern.

As can be seen from fig. 35, the major change in land use occurs with regard to the wheat activity. Producing regions 7 of North Carolina, 99 of south-central Texas, 106 of southeastern Montana and 134 of southeastern Oklahoma are added anew to wheat production, as compared with Model IV-E. Acreages of wheat are increased in regions 23 of eastern Arkansas, 41 of northern Michigan, 47 of eastern Illinois, 62 of central Minnesota, 91 of northern Oklahoma, 95 of northern Texas, 124 of central Alabama and 127 of eastern Arkansas. Only region 78 of central Nebraska shows a slight reduction in wheat acreage.

Except for the soybean activity introduced into region 10 of southeastern North Carolina, forcing feed-grain and oilmeal exports through consuming regions 3 and 5 has no important effect in reallocating production among regions. Most of the relocation of the feed-grain and feed-grain with soybeans activities result alone from the increased export demands for wheat. Wheat now requires land formerly used for feed-grain and feed-grain with soybeans activities. The pattern of interregional flows is indicated in figs. 36, 37 and 38. The total surplus land acreage indicated for Model IV-F is 42,174,500—a decline of 6,514,700 acres in comparison with Model IV-E. Although the change in the general pattern of crop production and product distribution does not appear great, the increase in wheat exports and the "forcing" of the feed-grain and oilmeal exports does have considerable effect (a) on the acreage required for wheat and (b) in causing a somewhat less efficient use of land for feed grains and soybeans. Producing regions that would be required for crop production under Model IV-E, but not under Model IV-F, are located in southern Ohio, Mississippi, Arkansas, Oklahoma and Texas.

Model V

Model V is identical with models I and IV-A with respect to levels of per-capita consumption rates, livestock feeding efficiency, export levels, crop yields and production costs. Model V differs from the other two models in the level of population used: 244 million as compared with 230 million under Model IV-A and 222 million under Model I. The optimal land-use patterns for Model V are shown in fig. 39.

Comparisons of Model V (fig. 39) are made with Model IV-A (fig. 15). Compared with Model IV-A, new producing regions added for wheat are regions

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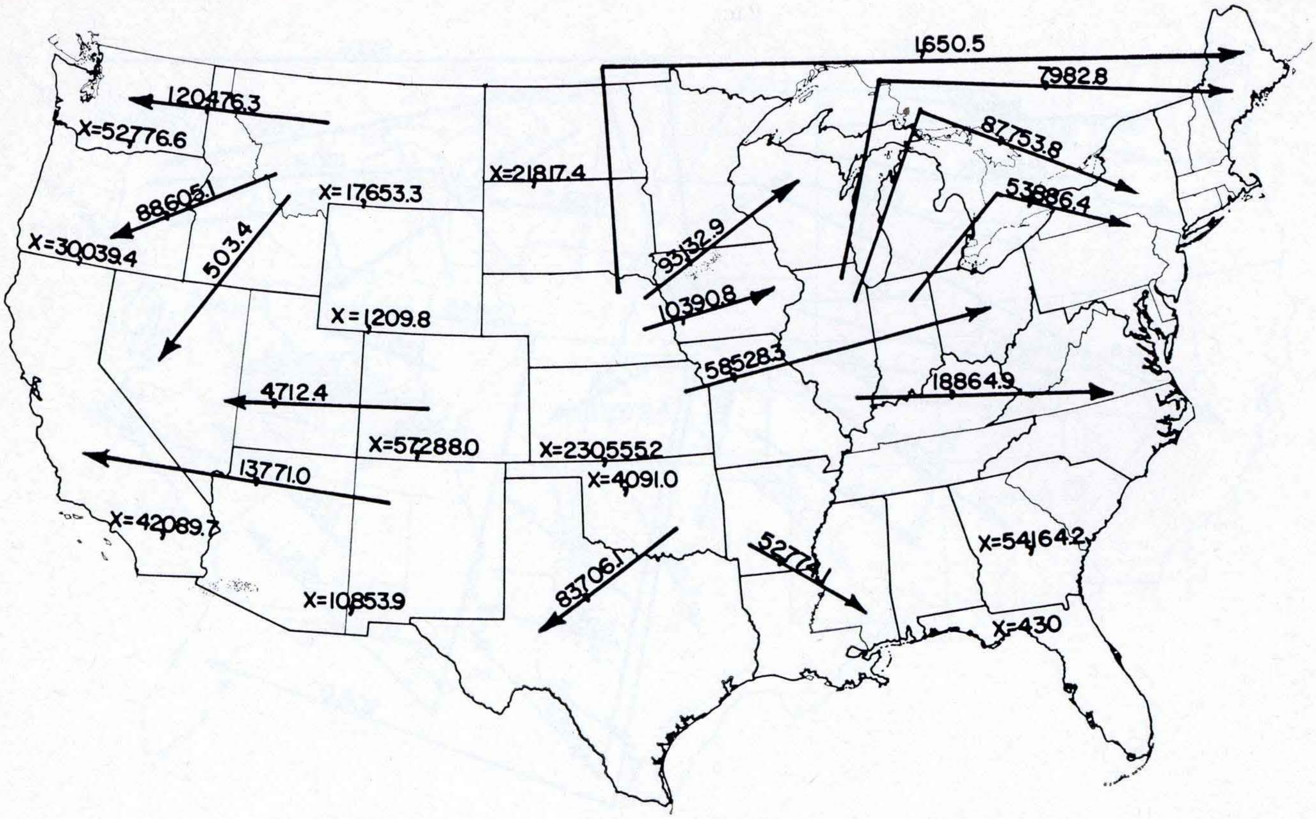

Fig. 32. Interregional flows (indicated by arrows and quantities) and intraregional transfers (magnitudes of x) of wheat to feed grains (thousands of bushels), Model IV-E.

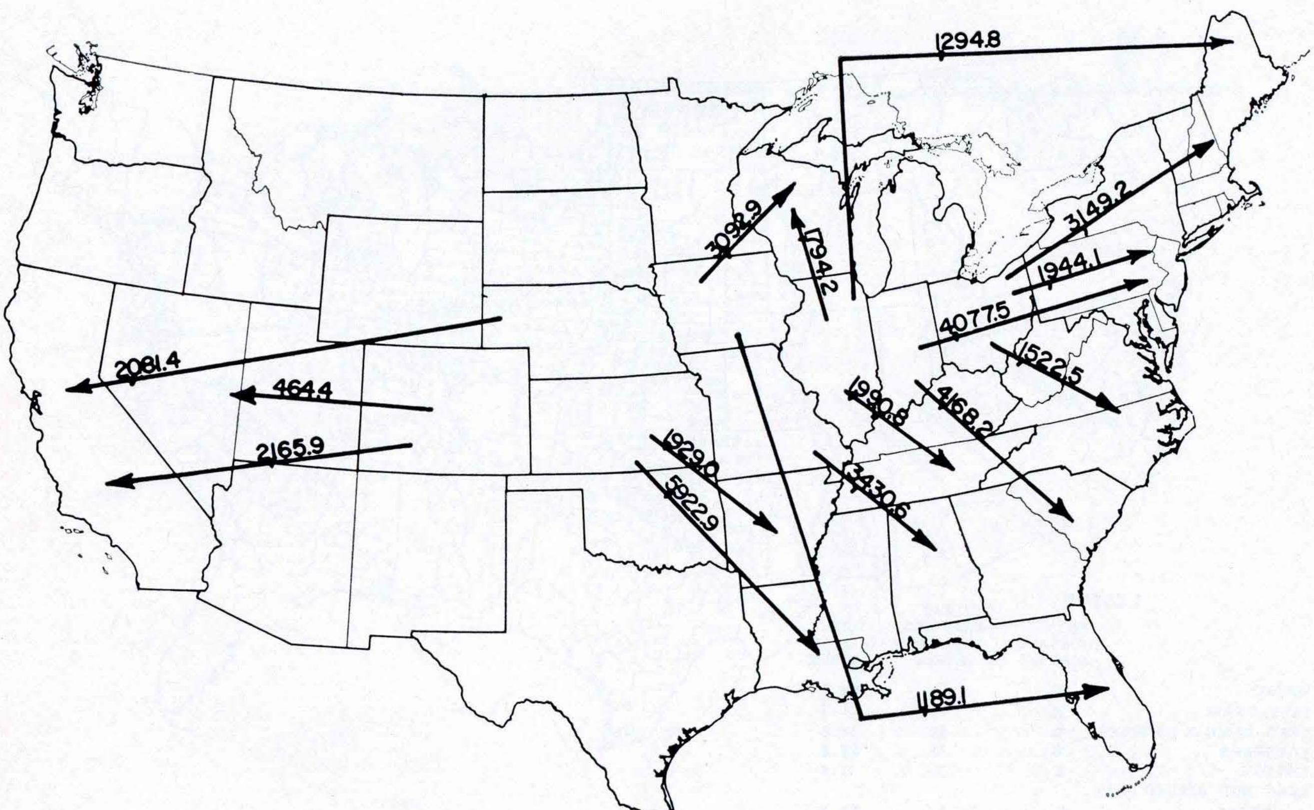

Fig. 33. Interregional flows (indicated by arrows and quantities) of feed grains (thousands of tons of feed units), Model IV-E.

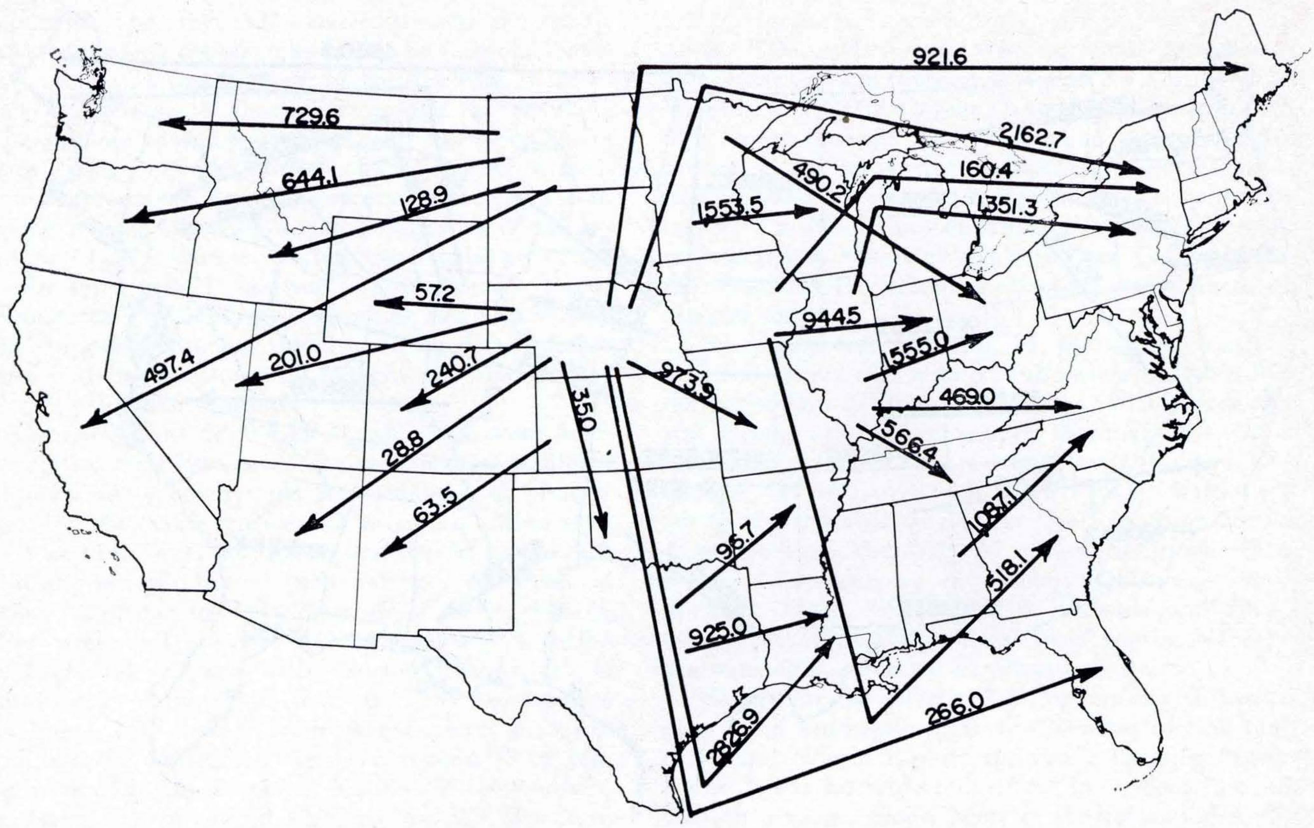

Fig. 34. Interregional flows (indicated by arrows and quantities) of oilmeals (thousands of tons of feed units), Model IV-E.

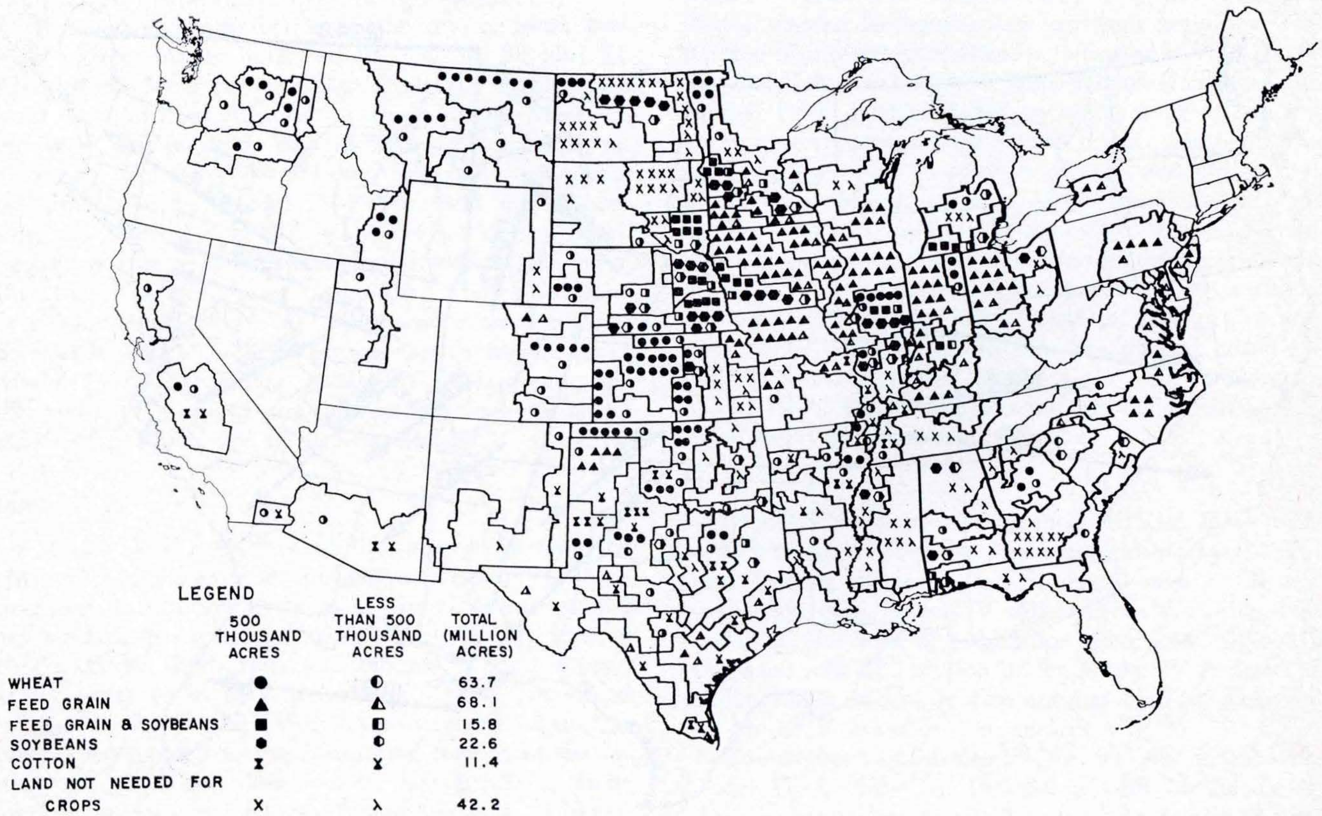

Fig. 35. Regional production pattern for Model IV-F.

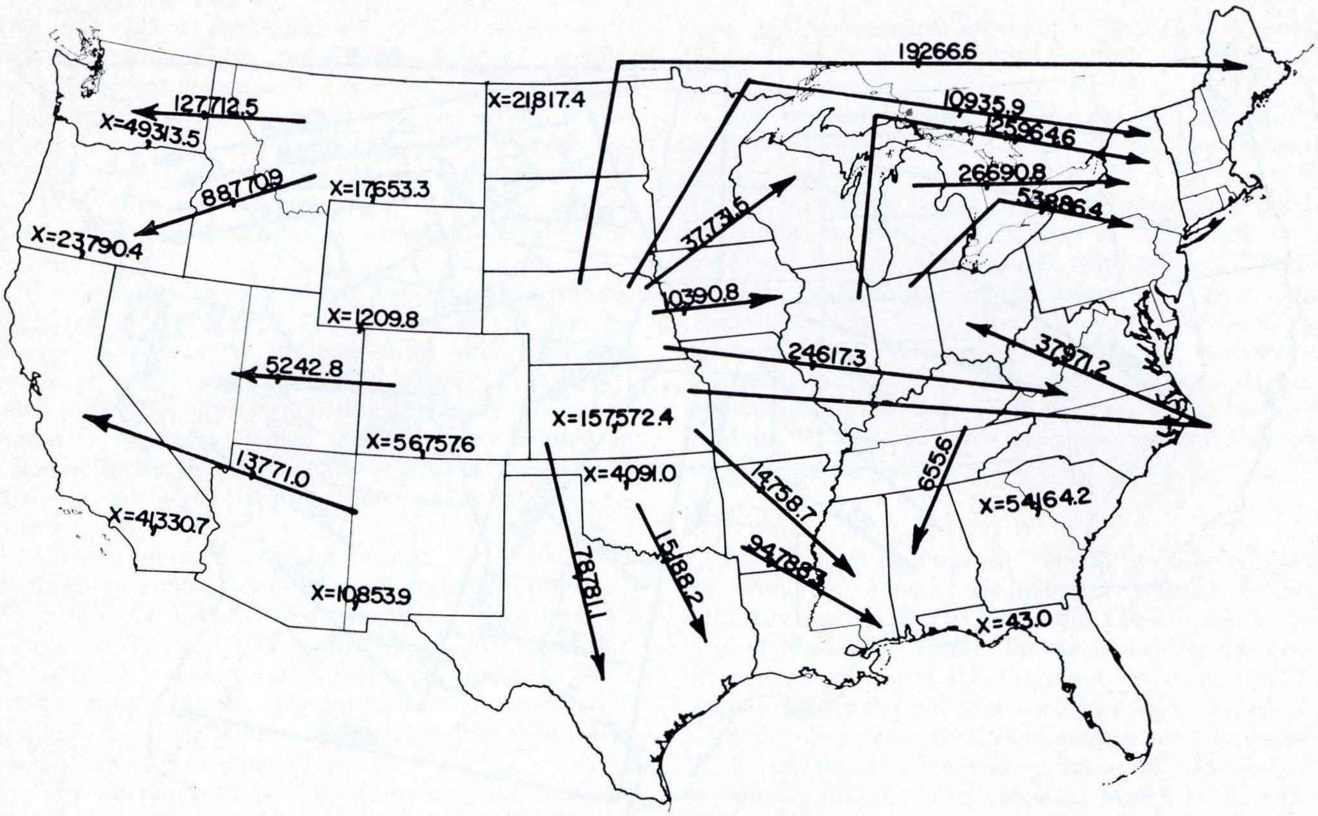

Fig. 36. Interregional flows (indicated by arrows and quantities) and intraregional transfers (magnitudes of x) of wheat to feed grains (thousands of bushels), Model IV-F.

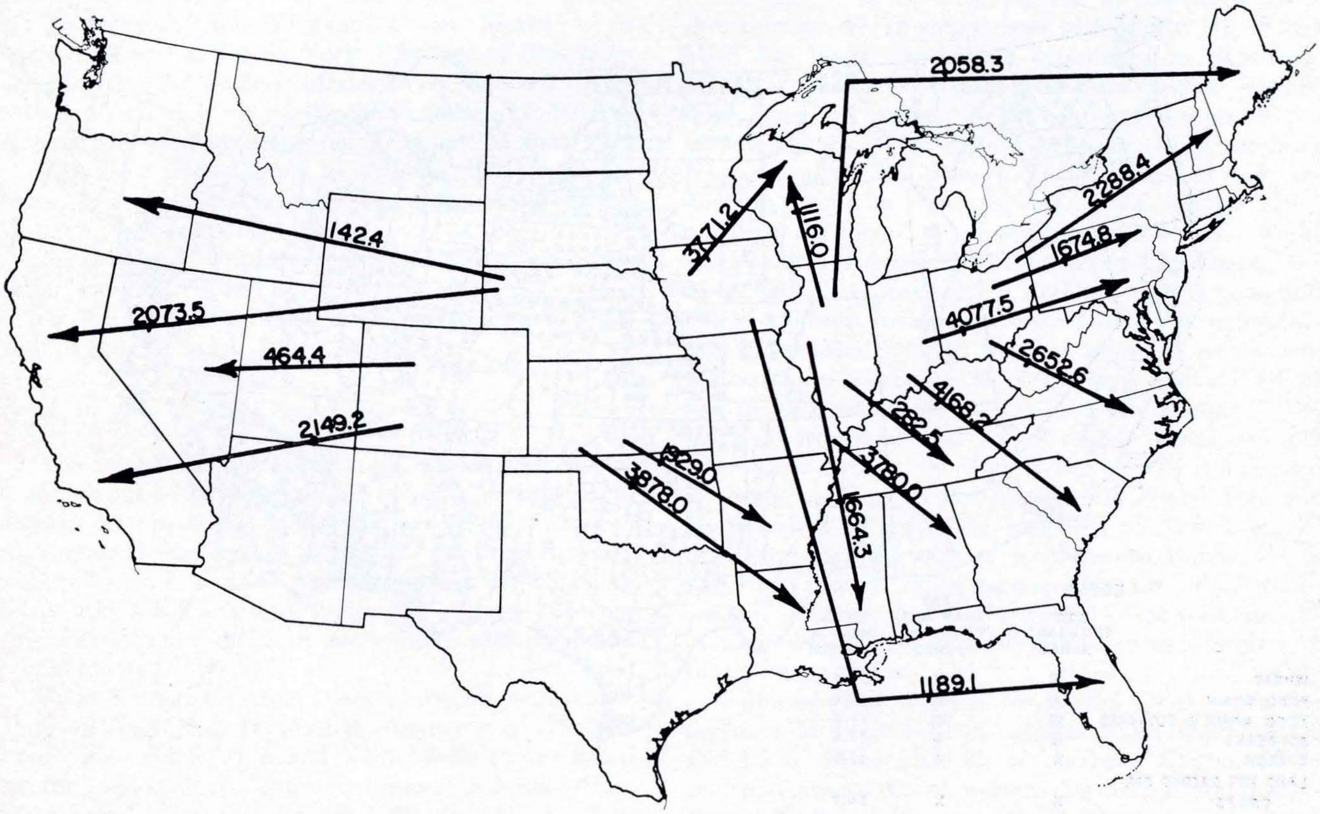

Fig. 37. Interregional flows (indicated by arrows and quantities) of feed grains (thousands of tons of feed units), Model IV-F.

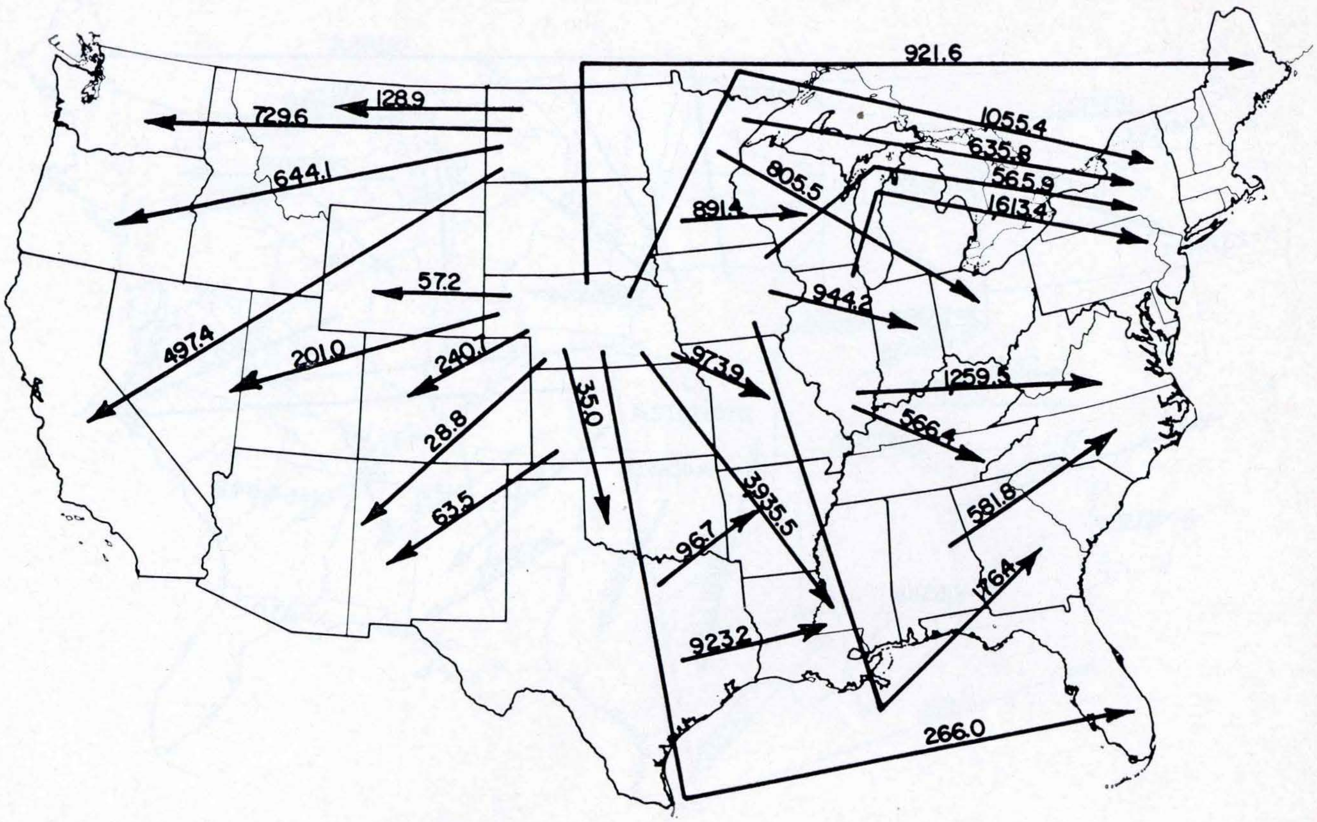

Fig. 38. Interregional flows (indicated by arrows and quantities) of oilmeals (thousands of tons of feed units), Model IV-F.

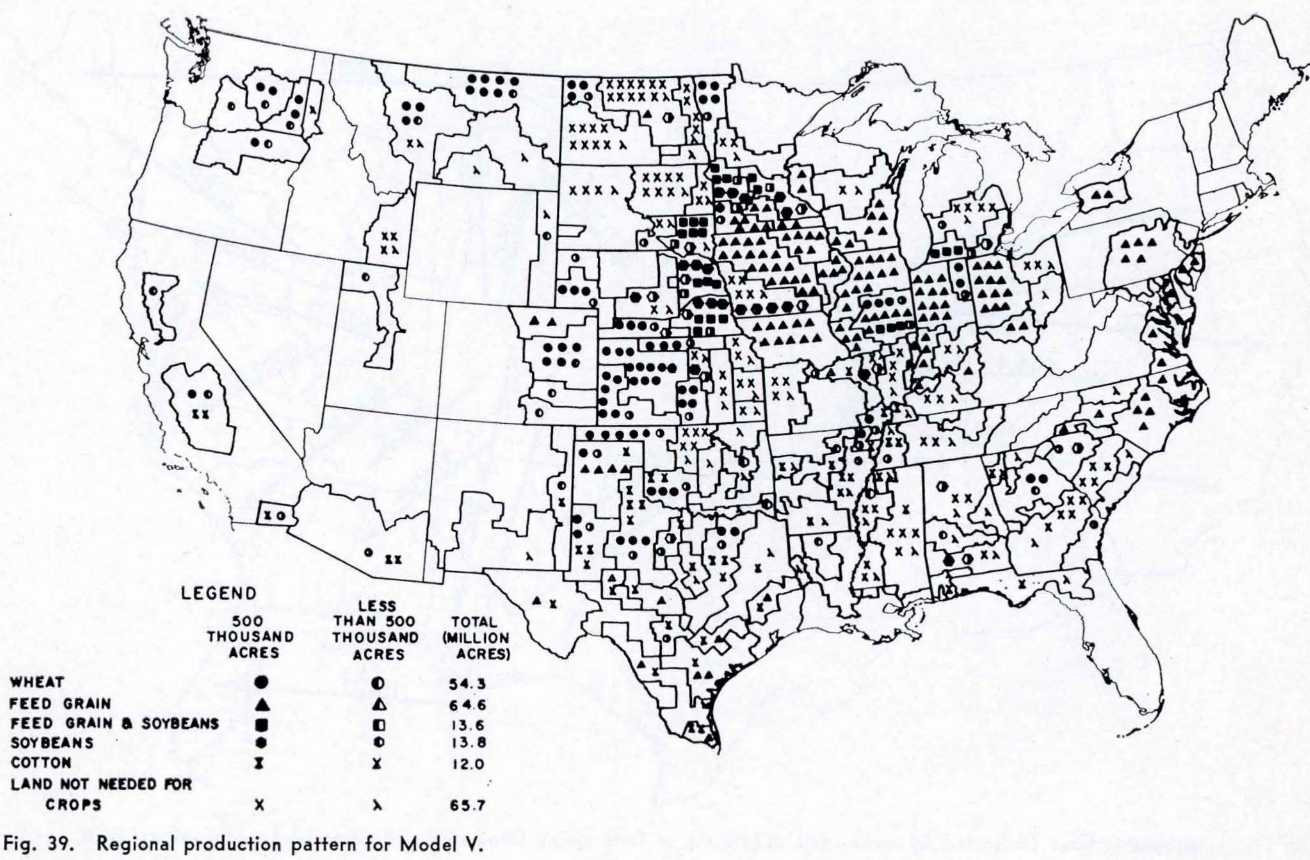

Fig. 39. Regional production pattern for Model V.

11 of the southeastern Atlantic Coast and 110 of southeastern Colorado; the remaining additional requirements of wheat being met by increased acreages in marginal regions scattered over most of the nation. Wheat acreage declines in a few regions as a result of the decline in need for land for other crops. Regions 26 of southern Missouri, 98 of central Texas and 128 of northern Arkansas shift land retired from wheat to cotton.

Feed grain is introduced into two producing regions, increased in two regions and reduced in two regions. Region 50 of eastern Missouri shifts land from feed grains to wheat, and region 99 of central Texas shifts land from feed grains to cotton. Soybeans are introduced in producing region 49 of southern Illinois in response to the increased oilmeal demands and acreage reallocations accompanying these additional requirements.

Cotton production is introduced into regions 17 of southern Alabama, 20 of northwestern Georgia, 21 of eastern Mississippi, 24 of northern Mississippi, 98 of central Texas, 99 of south-central Texas and 128 of northern Arkansas. It is increased in region 26 of south-central Missouri. The addition of cotton to these producing regions requires a corresponding adjustment in the acreages of other crops.

The interregional product flows and intraregional transfers for Model V are indicated in figs. 40, 41 and 42. As compared with Model IV-A, some of the more important interregional changes in product flows are these: Under Model IV-A, wheat flows from Nebraska to Pennsylvania and Virginia. Under Model V, it flows to Maine and New York. Feed grains flow from Colorado to Utah under Model IV-A, but not under Model V; from Iowa to Wisconsin under Model IV-A, but to Florida under Model V. Under Model IV-A, oilmeals flow from Illinois to Virginia, but not under Model V; and from Iowa to Tennessee under Model V, but not under Model IV-A.

Total surplus land area jumps to 65,707,900 acres under Model V as compared with Model IV-F, but it is less than the 69,878,000 acres under Model IV-A and 74,118,600 acres under Model I.

Model VI-A

The models discussed previously used the same matrix of input-output coefficients for crop activities and differed only in respect to national and regional demand requirements (differences in livestock feeding efficiency were reflected in demand levels for feed grains). Models VI-A and VI-B use a different set of crop-yield coefficients and two different assumptions about demand requirements.

Yield estimates in the previous models were based upon 1940-62 yield trends but are based on 1950-62 trends for models VI-A and VI-B. Yield trends based on the period 1950-62 are considerably higher than those based on the period 1940-62. In Model VI-A, the level of livestock feeding efficiency used for 1975 is the USDA economic maximum discussed previously. Hence, both crop yields and livestock efficiency are set at high levels.

The optimal land-use pattern obtained for Model VI-A is presented in fig. 43. The resultant interregional product flows and intraregional transfers are given in figs. 44, 45 and 46. Land not needed for crop production jumps to the very high level of 98,946,300 acres under this model. As compared with Model I, additional acreage would be shifted from crops in producing regions of New York, New Jersey, North Carolina, Arkansas, Ohio, Wisconsin, Illinois, Iowa, Minnesota, Nebraska, Kansas, Colorado and Oklahoma. Hence, technological improvement of the rate and level used in Model VI-A would mean important regional resource adjustments over the entire United States.

Model VI-B

Model VI-B employs the 1950-62 yield trends and the economic potential estimates of livestock feeding efficiency used in Model IV-A, but has demand at the level of Model III. Hence, the model utilizes the same demand requirements, but the input-output matrix for crops is different from that used in Model III. Model VI-B uses the same coefficient matrix used in Model IV-A but uses feed conversion rates and demand requirements that are different from Model IV-A. (The USDA economic maximum feed conversion rates are used in Model IV-A, while the economic potential rates are used in Model IV-B).

The optimal land-use pattern for Model VI-B is shown in fig. 47. In comparison with Model III, Model VI-B has wheat production introduced in producing regions 23 and 25 of eastern Arkansas, while acreage is increased in regions 26 of central Arkansas, 47 of eastern Illinois, 50 of eastern Missouri, 79 of southern Nebraska and 97 of western Texas. Wheat acreage reductions occur in some regions, while regions 41 of northern Michigan, 87 of south-central Kansas, 89 of southwestern Kansas, 91 of northern Oklahoma, 112 of eastern New Mexico, 127 and 128 of Arkansas and 142 of southern Arizona are retired from wheat production under Model IV-B. Regions added to feed grains under Model IV-B are 34 of southern Indiana, 61 of western Minnesota, 89 of southwestern Kansas, 94 of southwestern Oklahoma, 136 of central Texas and 142 of southern Arizona. Acreage of this activity is increased in a few regions, as compared with Model III, and is eliminated in producing regions 1 of New York, 29 of central Kentucky, 36 of southeastern Illinois, 43 of eastern Wisconsin, 50 of eastern Missouri, 56 of southwestern Minnesota, 59 of northern Wisconsin and 97 of southwestern Texas. Feed-grain acreage declines in six scattered regions.

The optimal solution for Model IV-B introduces soybeans in regions 10 of eastern South Carolina, 59 and 62 of Minnesota, 85 of northern Kansas, 88 of central Kansas, 126 of western Mississippi and 133 of eastern Texas, and increases their acreage in three other

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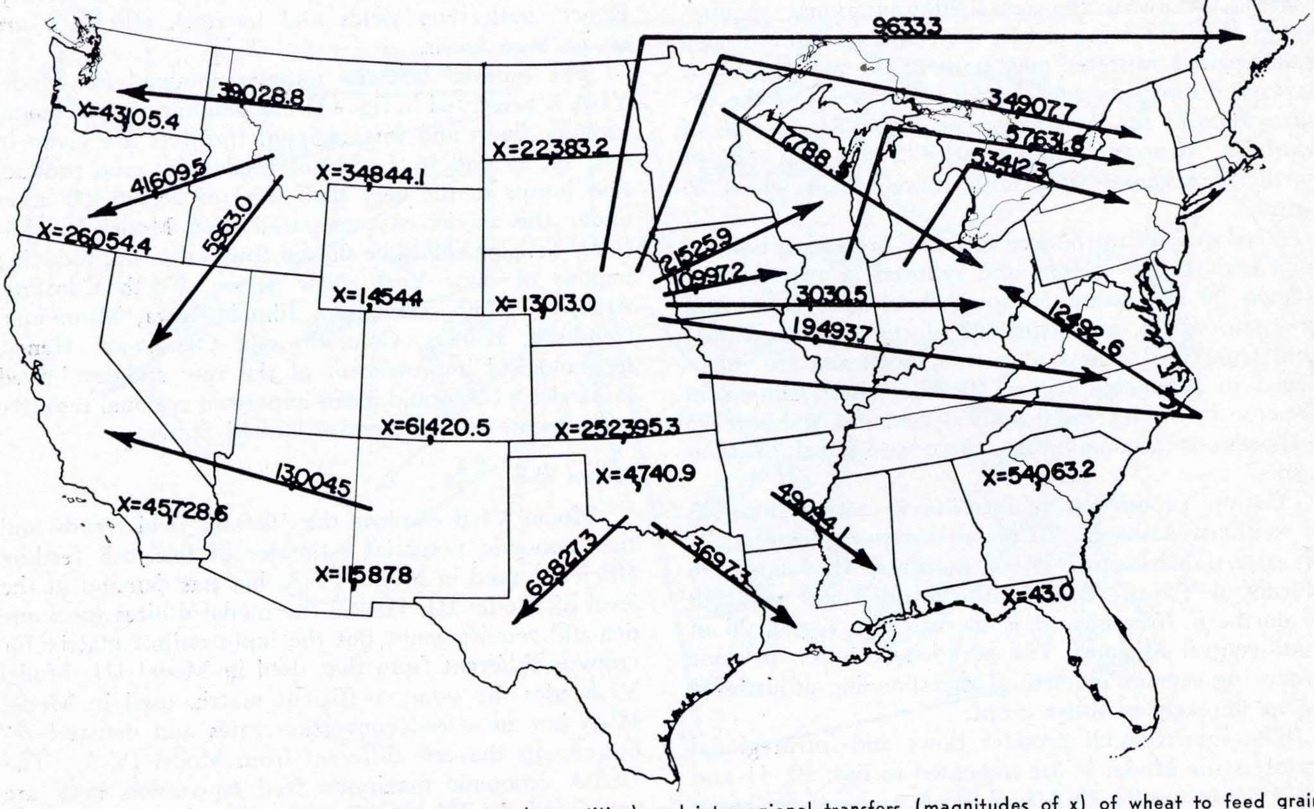

Fig. 40. Interregional flows (indicated by arrows and quantities) and intraregional transfers (magnitudes of x) of wheat to feed grains (thousands of bushels), Model V.

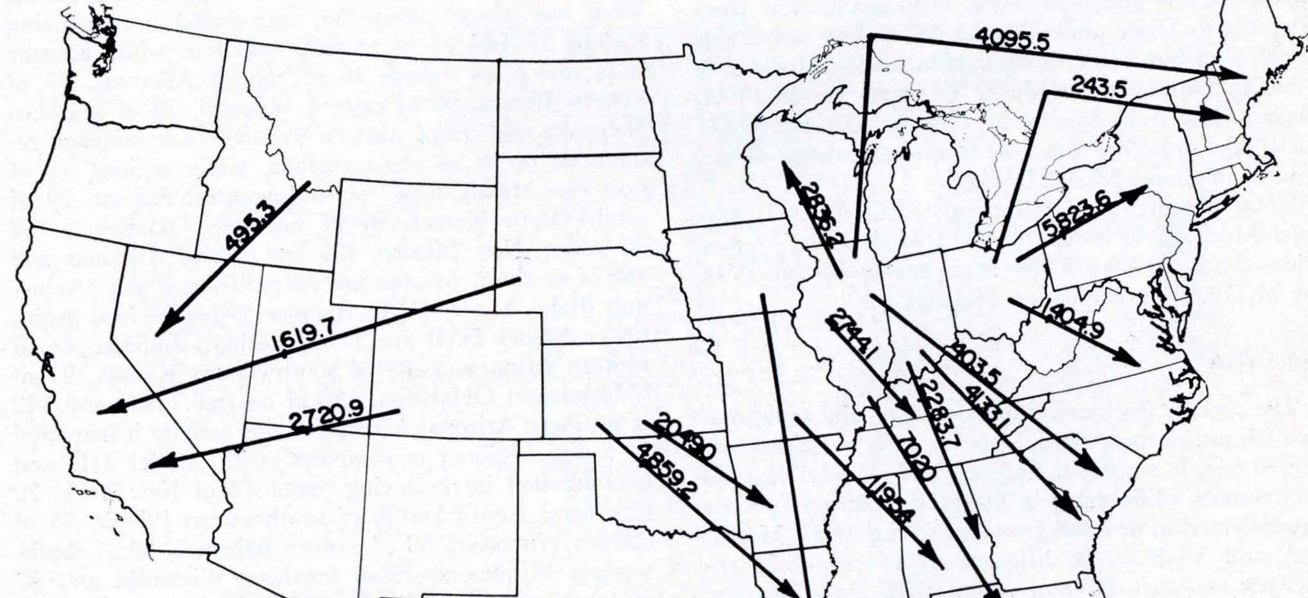

Fig. 41. Interregional flows (indicated by arrows and quantities) of feed grains (thousands of tons of feed units), Model V.

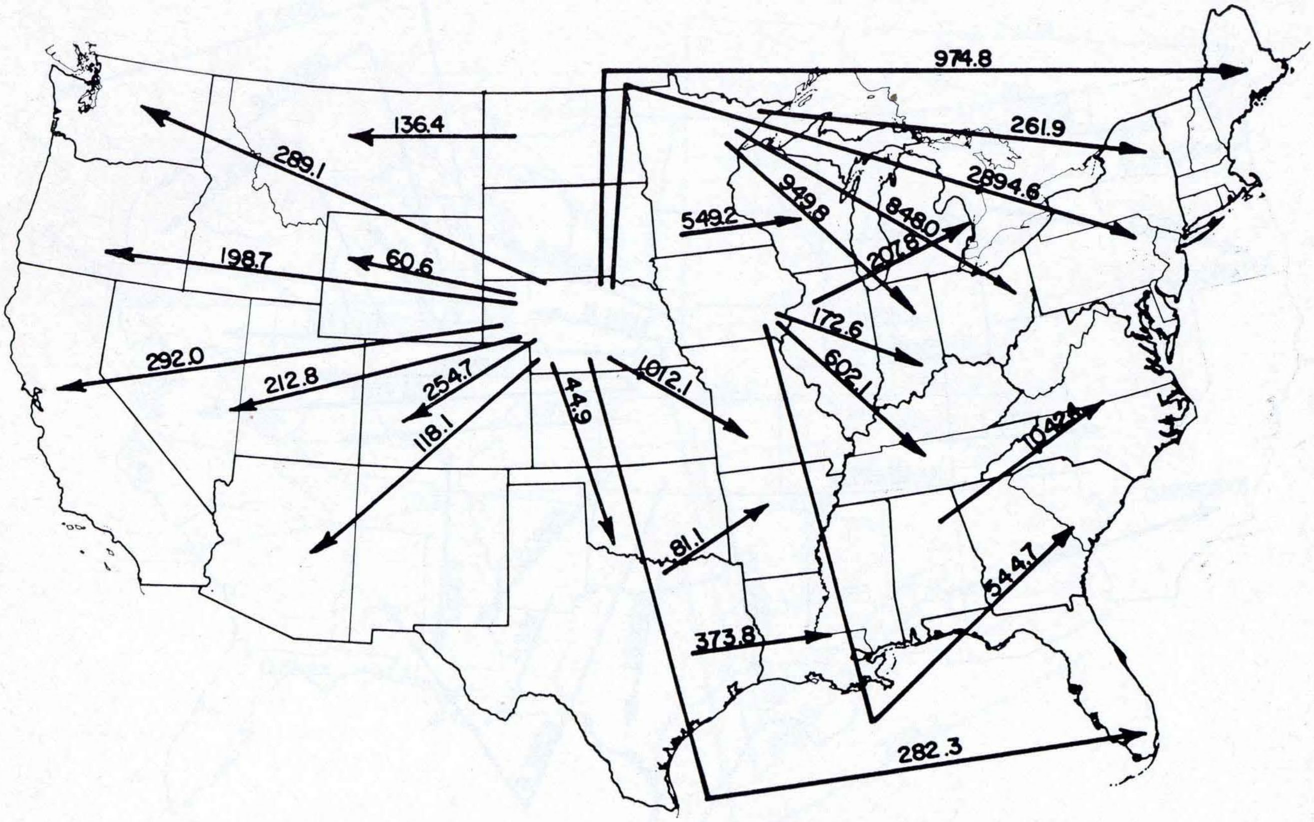

Fig. 42. Interregional flows (indicated by arrows and quantities) of oilmeals (thousands of tons of feed units), Model V.

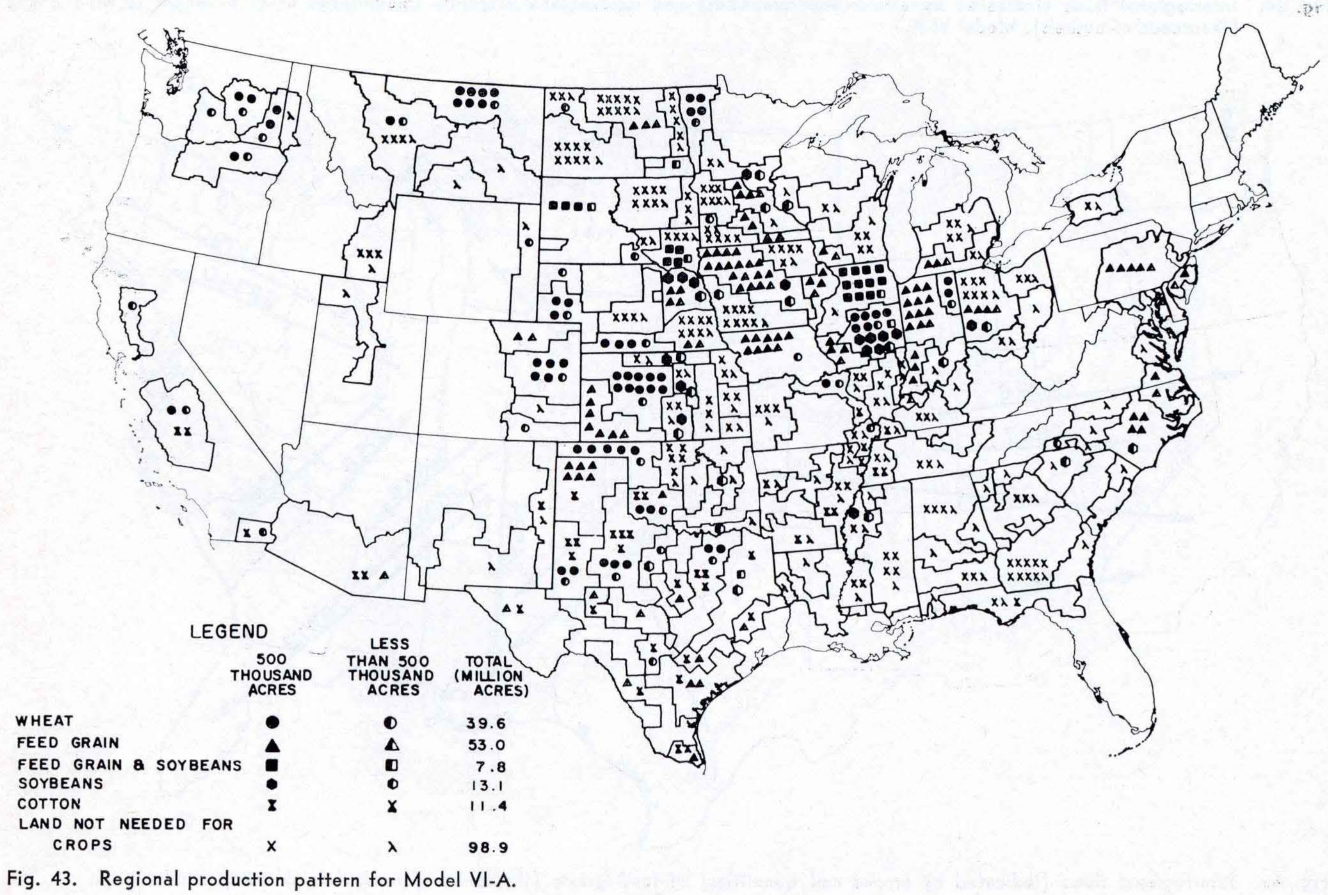

Fig. 43. Regional production pattern for Model VI-A.

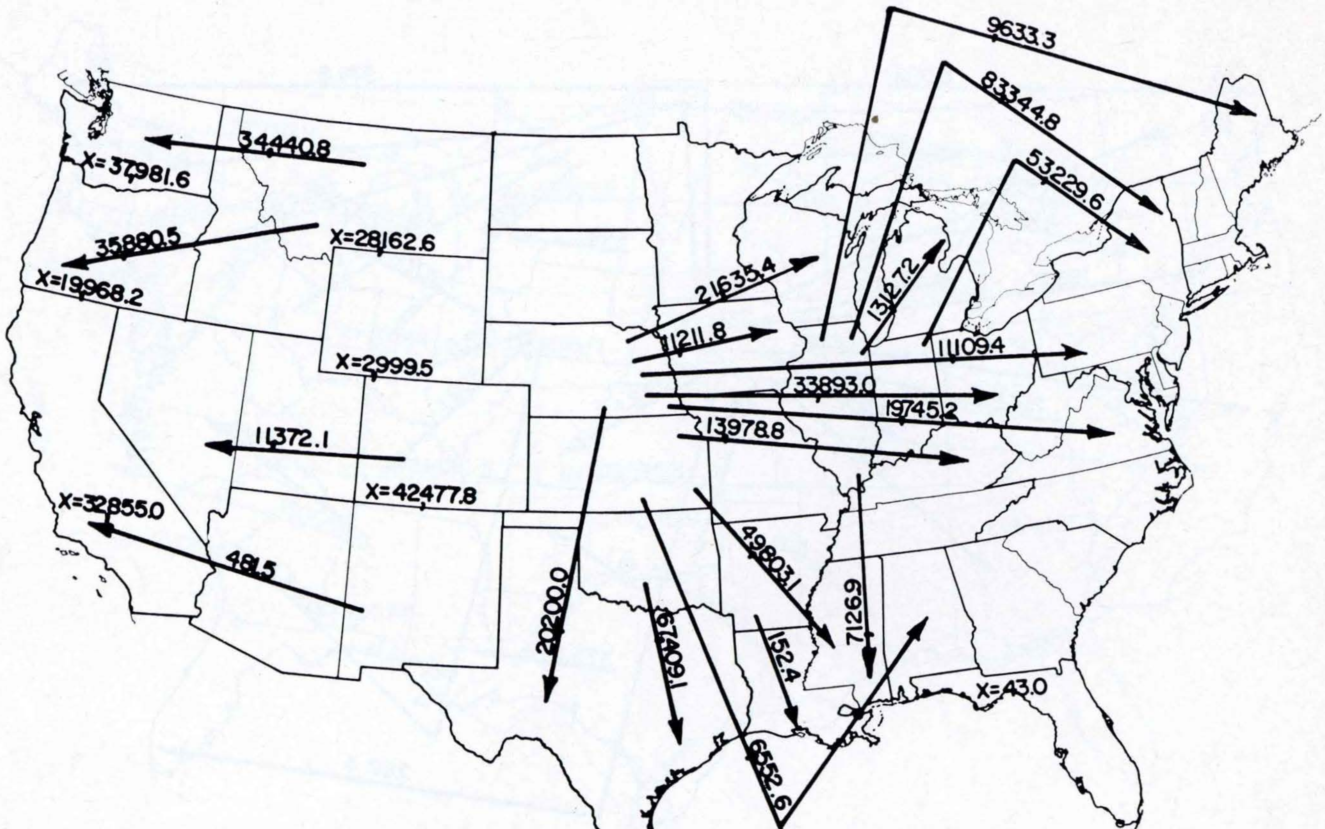

Fig. 44. Interregional flows (indicated by arrows and quantities) and intraregional transfers (magnitudes of x) of wheat to feed grains (thousands of bushels), Model VI-A.

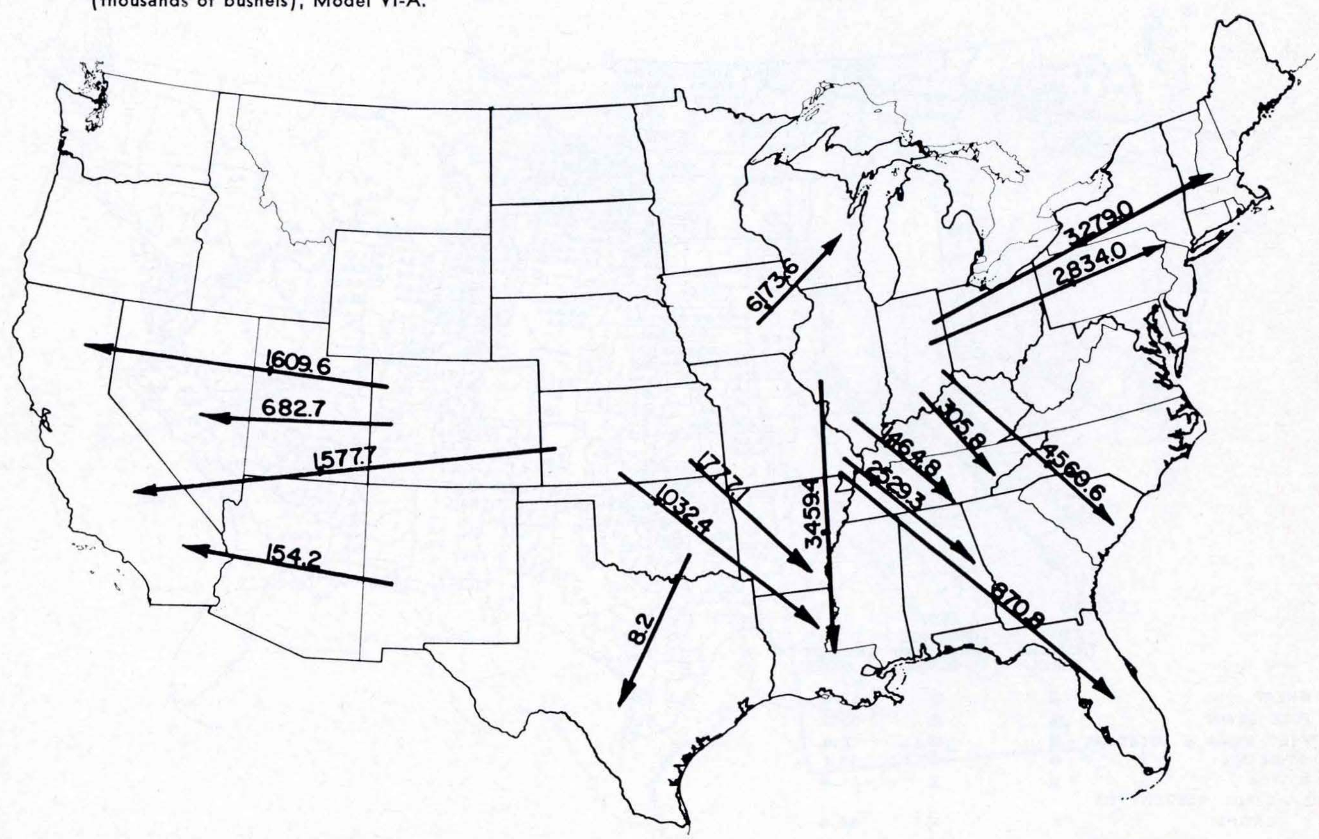

Fig. 45. Interregional flows (indicated by arrows and quantities) of feed grains (thousands of tons of feed units), Model VI-A.

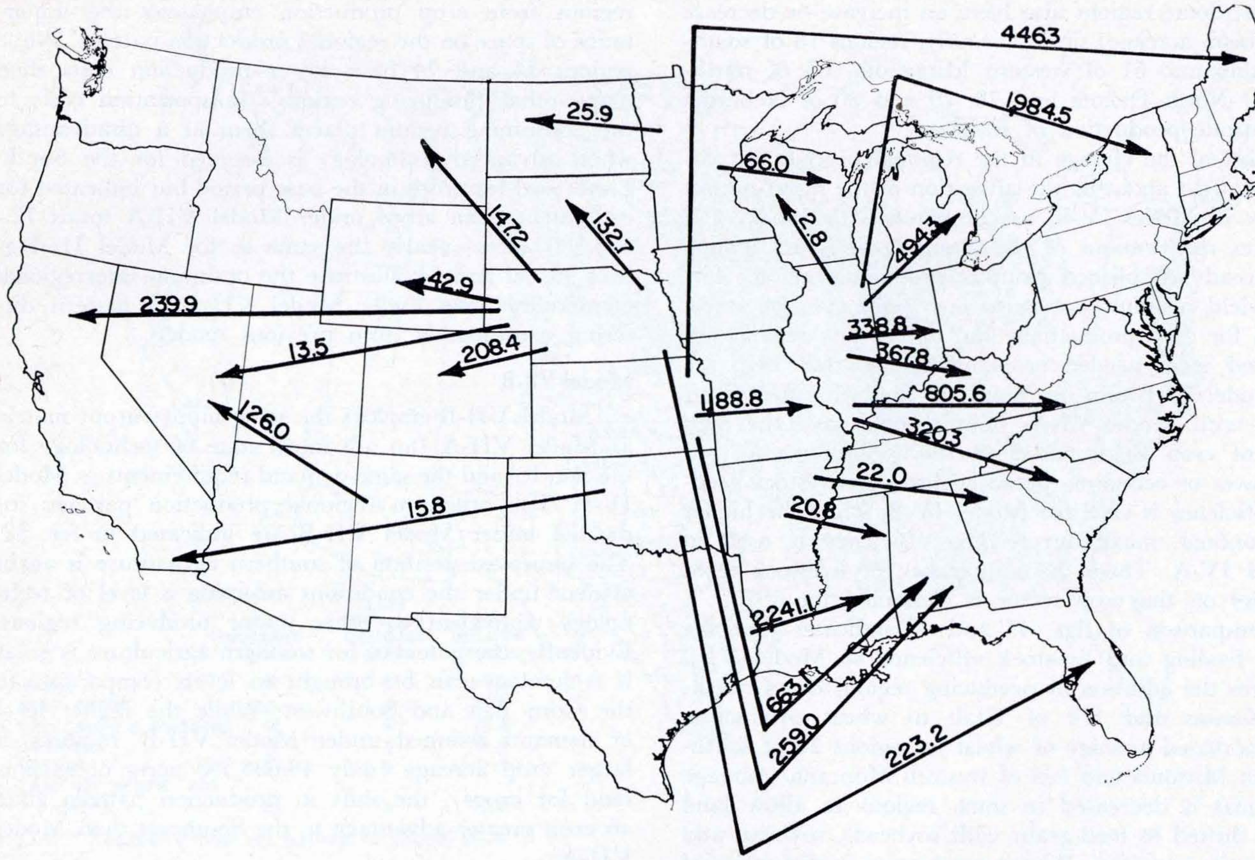

Fig. 46. Interregional flows (indicated by arrows and quantities) of oilmeals (thousands of tons of feed units), Model VI-A.

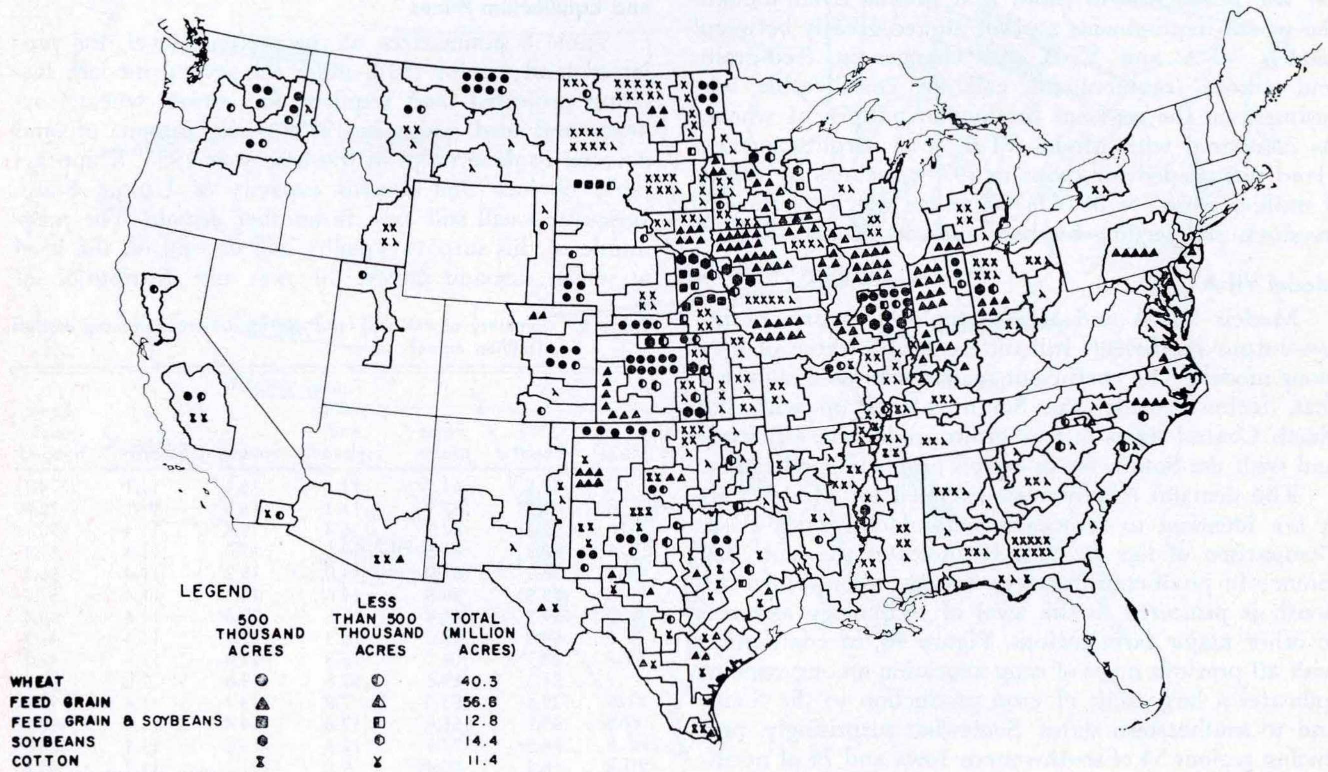

Fig. 47. Regional production pattern for Model VI-B.

regions. Some regions also have an increase or decrease in soybean acreage; simultaneously, regions 18 of southern Alabama, 61 of western Minnesota, 65 of north-central North Dakota and 78, 79 and 80 of Nebraska discontinue production of soybeans.

Most of the change in the regional production pattern brought about by the alteration of the input-output matrix in Model IV-B, as compared with Model III, involves reallocations of the cropping activities among the already established group of producing regions. The new yield assumptions cause few regions to be introduced for crop production, and only a few regions are dropped from needed cropland acreage for 1975.

Model VI-B also has points of similarity and divergence with Model VI-A. Both models have the high level of crop yields based on the 1950-62 trend, but the lower or economic potential level of livestock feeding efficiency is used for Model IV-B, while the higher or economic maximum feeding efficiency is used in Model IV-A. Thus, the importance of livestock technologies on the crop sector is examined for 1975.

Comparison of figs. 43 and 47 indicates that the lower feeding and livestock efficiency of Model VI-B requires the addition of producing regions 85 of northern Kansas and 114 of Utah to wheat production and increased acreage of wheat in regions 26 of southeastern Missouri and 105 of western Montana. Acreage of wheat is decreased in some regions to allow land to be shifted to feed-grain with soybeans, soybean and feed-grain activities. Wheat production is discontinued entirely in region 52 of northern Missouri, to allow for the production of more feed grains. Even though the wheat requirements are not altered greatly between models VI-A and VI-B, the changes in feed-grain and oilmeal requirements call for considerable adjustment in the regional production pattern of wheat. As compared with Model VI-B, total surplus acreage (land not needed for crops in 1975) declines by about 9 million acres, to 88,079,700 under the less efficient livestock and feeding methods used in Model VI-B.

Model VII-A

Models VII-A and VII-B employ a matrix of input-output coefficients still different from those of previous models. The coefficient matrix now used supposes that, technologically, the South catches up with the North Central states in feed-grain production efficiency and with the Southwest in cotton production efficiency.

The demand requirements assumed for Model VII-A are identical to those assumed under Model IV-B. Comparison of figs. 47 and 48 indicates the wide difference in production patterns brought about when the South is projected to the level of technology assumed in other major farm regions. Figure 48, in comparison with all previous maps of crop allocation among regions, indicates a large shift of crop production to the South and to southeastern states. Somewhat surprisingly, producing regions 54 of southwestern Iowa and 74 of northeastern Nebraska are indicated as "surplus acreage" under Model VII-A. The suggested retirement of these regions from crop production emphasizes the importance of space on the regional production pattern. While regions 54 and 74 have lower production costs than many other producing regions, transportation costs to the consuming regions places them at a disadvantage when advanced technology is assumed for the South. Land used for crops in the base period but indicated for retirement from crops under Model VII-A totals 72,571,500 acres—nearly the same as for Model II. Figures 49, 50 and 51 illustrate the optimum interregional commodity flows under Model VII-A; a pattern differing considerably from previous models.

Model VII-B

Model VII-B employs the same input-output matrix as Model VII-A (an advanced state of technology for the South) and the same demand requirements as Model IV-F. The optimum regional production patterns indicated under Model VII-B are indicated in fig. 52. The improved position of southern agriculture is again evident under the conditions assuming a level of technology equivalent to other major producing regions. Evidently, the potential for southern agriculture is great if technology can be brought to levels comparable to the Corn Belt and Southwest. While the higher level of demand assumed under Model VII-B requires a larger crop acreage (only 48,604,500 acres of surplus land for crops), the shift in production pattern gives an even greater advantage to the Southeast than Model VII-A.

National Land Use and Equilibrium Prices

Table 8 summarizes, at the national level, the projected land use for 1975 under the several models. Relating projected land required for cotton, wheat, soybeans and feed grains in 1975 to the amount of land devoted to these crops in the base year 1953, it appears fairly obvious that surplus capacity of United States agriculture will still exist in another decade. The magnitude of this surplus capacity will depend on the level at which demand grows, the rate and distribution of

Table 8. Summary of national land use for 14 programming models (million acres).

Model	Wheat	Feed grains	Feed grains and soybeans	Soybeans	Cotton	Land not needed[a]
I	49.5	61.7	11.1	16.4	11.1	74.1
II	49.2	62.9	11.3	16.6	11.1	72.8
III	52.3	67.7	5.8	15.8	11.4	70.7
IV-A	50.3	61.5	13.8	17.0	11.4	69.9
IV-B	52.3	62.0	14.0	18.2	11.4	66.1
IV-C	55.9	64.8	14.6	19.5	11.4	57.7
IV-D	59.9	66.4	15.5	22.4	11.4	48.4
IV-E	58.9	67.0	15.3	22.7	11.4	48.7
IV-F	63.7	68.1	15.8	22.6	11.4	42.2
V	54.3	64.6	13.6	13.8	12.0	65.7
VI-A	39.6	53.0	7.8	13.1	11.4	98.9
VI-B	40.3	56.8	12.8	14.4	11.4	88.1
VII-A	34.5	77.3	12.8	15.5	11.3	72.6
VII-B	48.8	85.3	9.0	21.1	11.2	48.6

[a] Land not needed for specified crop production in meeting demands of the various models.

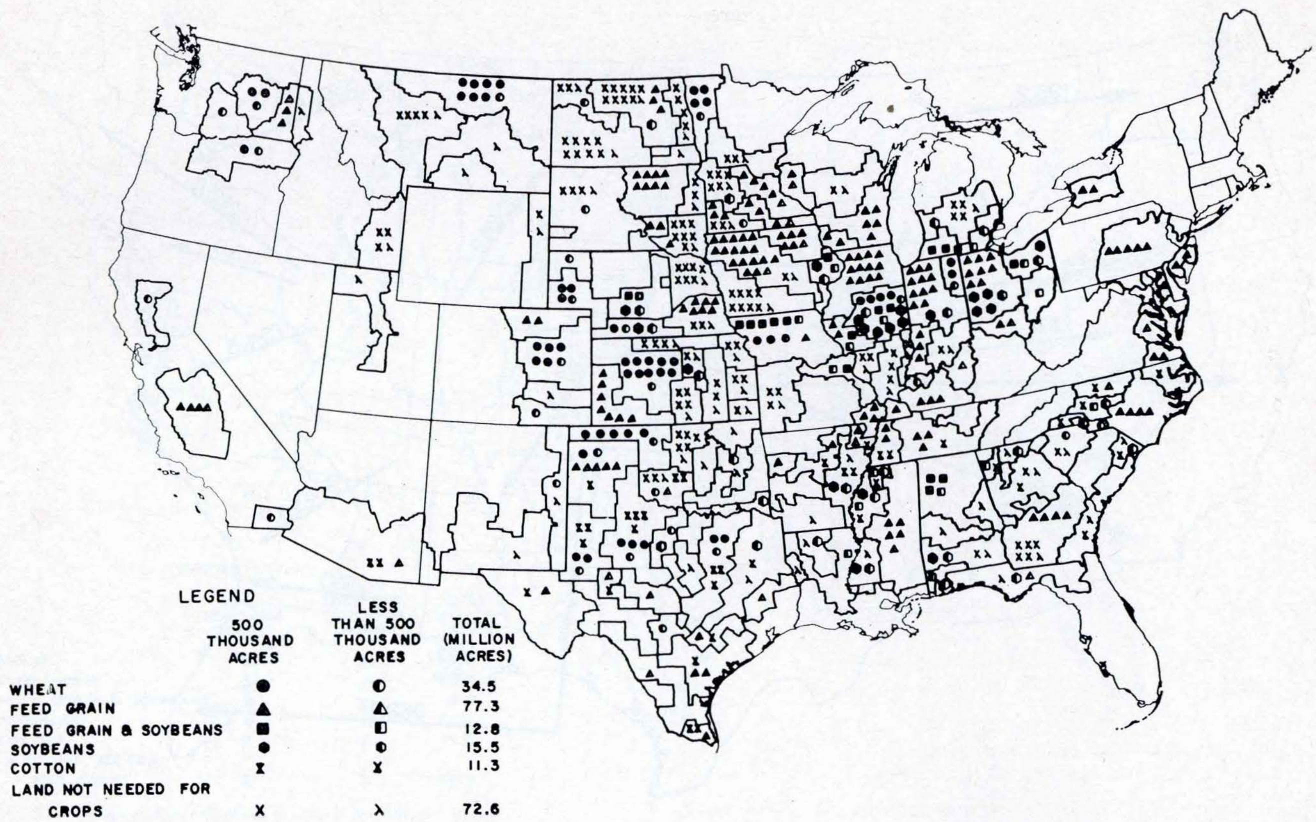

Fig. 48. Regional production pattern for Model VII-A.

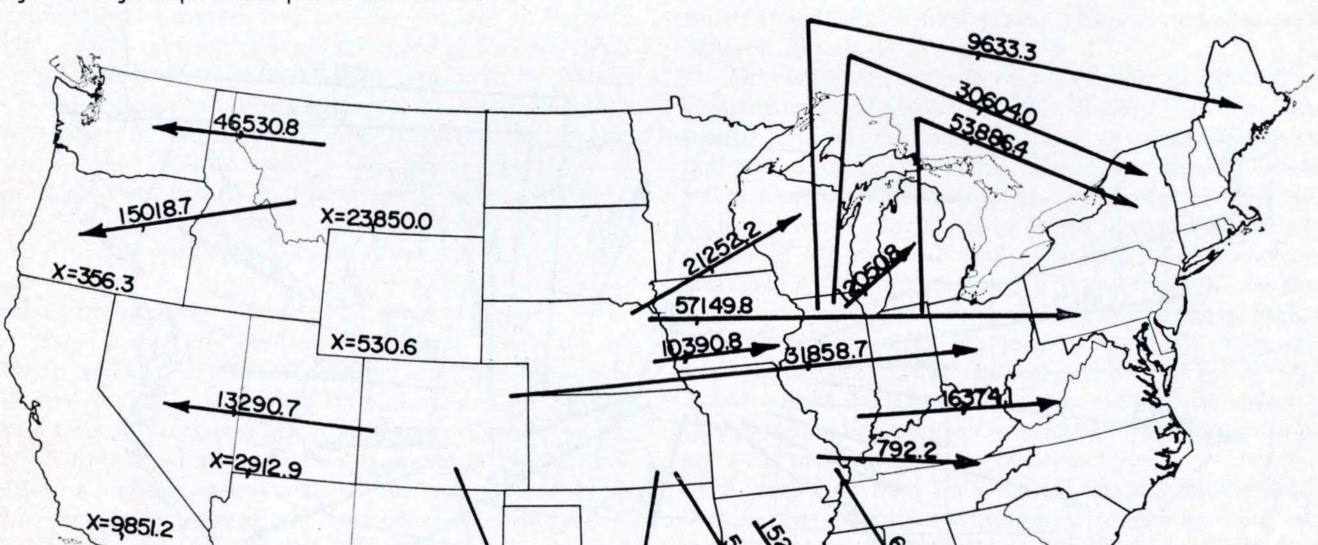

Fig. 49. Interregional flows (indicated by arrows and quantities) and intraregional transfers (magnitudes of x) of wheat to feed grains (thousands of bushels), Model VII-A.

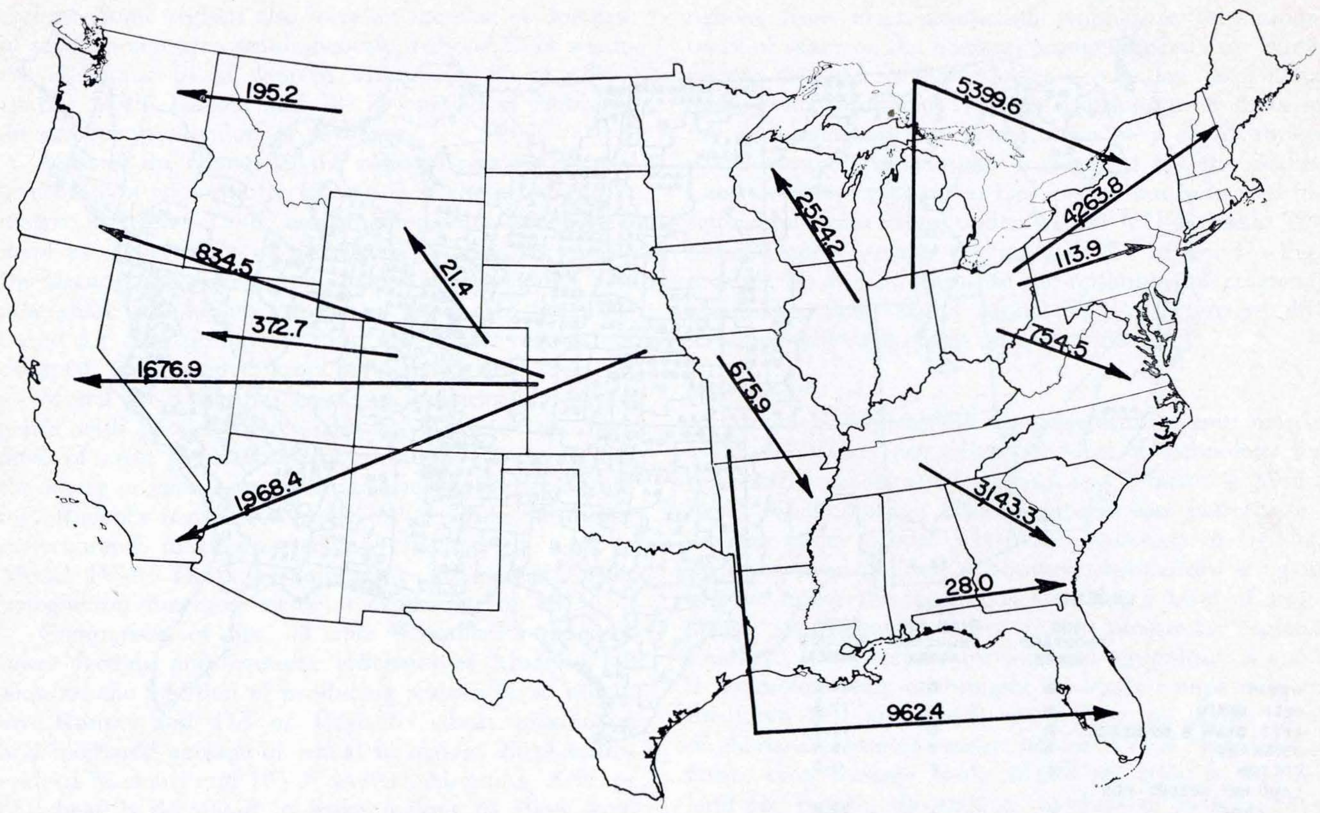

Fig. 50. Interregional flows (indicated by arrows and quantities) of feed grains (thousands of tons of feed units), Model VII-A.

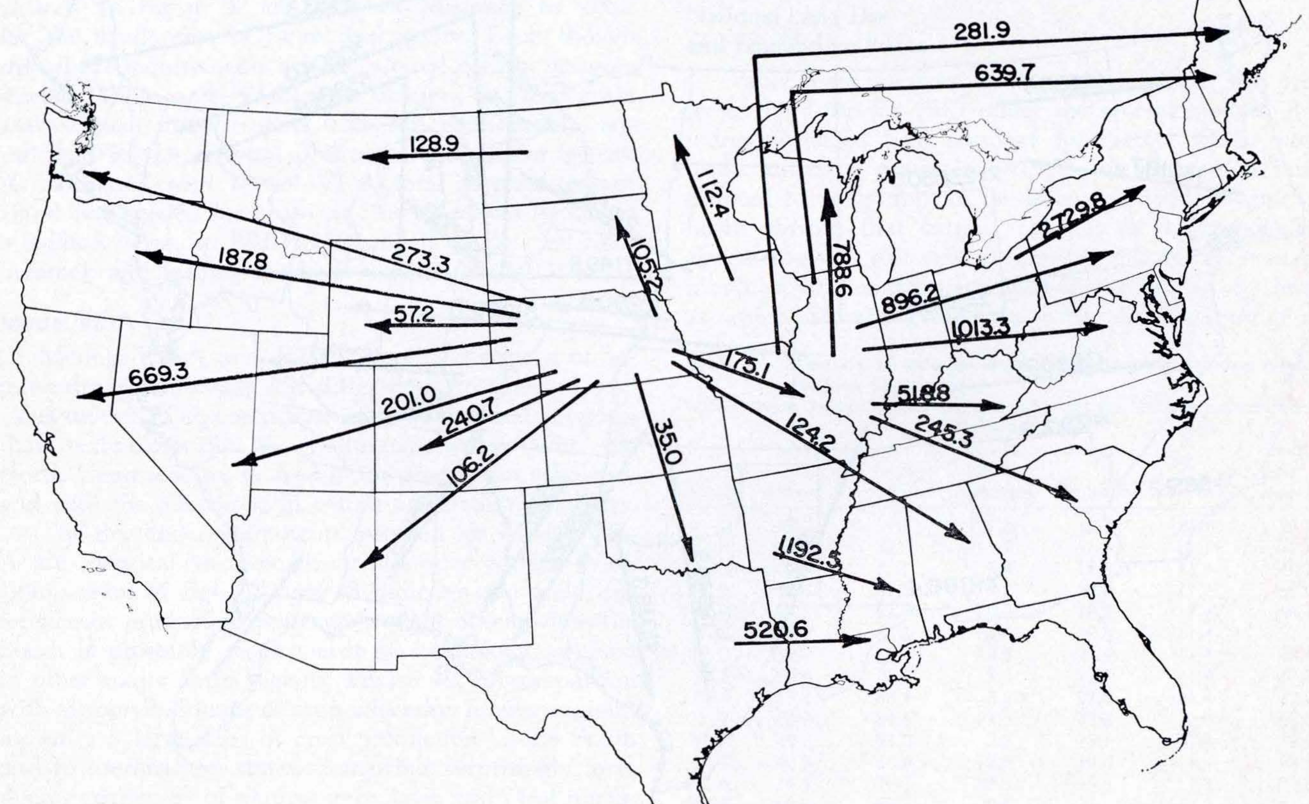

Fig. 51. Interregional flows (indicated by arrows and quantities) of oilmeals (thousands of tons of feed units), Model VII-A.

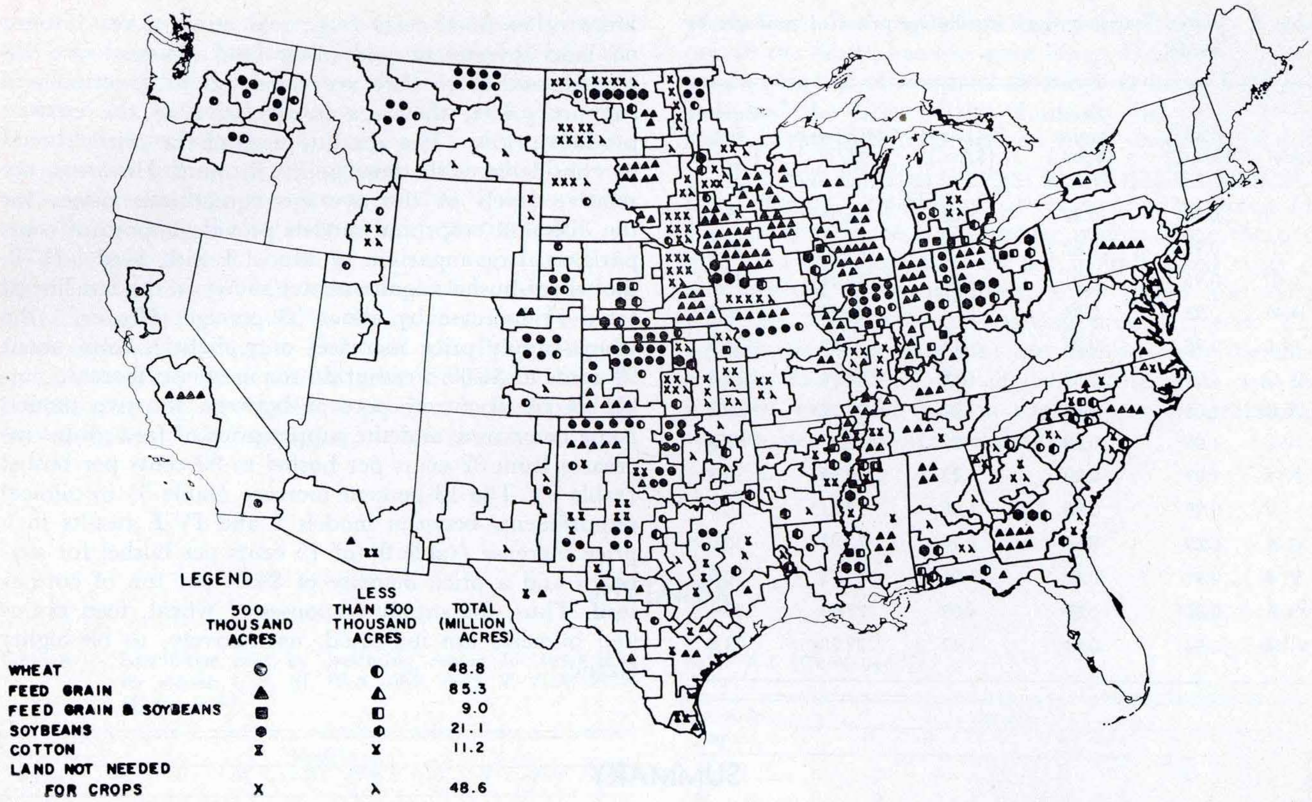

Fig. 52. Regional production pattern for Model VII-B.

technological progress and possible changes in exports. The largest acreage of land not needed for the specified crops is 98.9 million acres indicated by Model VI-A—a model assuming a low demand growth and a high level of technological improvement (i.e., extension of the 1950-62 trend). The smallest surplus of land for crops is 42.2 million acres specified by Model IV-F—a model assuming a large growth in export demand and a somewhat restrained rate of technical improvement (i.e., crop-yield improvement and feeding efficiency following the 1940-62 trend).

Except for the last four models in table 8, the wheat acreage is relatively larger and the feed-grain acreage is relatively smaller than contained in the historic mix of crops. This result stems from allowing wheat to be used as feed where it proves to be the most efficient, or least-cost, source of nutrients and allowing this conversion at zero cost for models I through VI-B. (For models VII-A and VII-B, a cost is charged the wheat-to-feed-grain activity in proportion to the current wheat-corn price differential.) Thus, the first 12 models represent situations in which the price support on wheat (if any) is set at a level that would reflect the feeding value of wheat. Models VII-A and VII-B, however, are similar to the existing price-support operations in which the price of wheat is supported at levels in excess of its feed value relative to corn. Models IV-B and VII-A employ an identical set of demand requirements. The matrix of input-output coefficients does differ, however, and the aggregate land-use patterns under the two models reveal a marked shift from wheat to feed grains. Similar analogies exist between models IV-F and VII-B.

The aggregate acreage of feed grains is reduced in comparison of Model IV-D with Model IV-E. The two models require the same amount of product at the national and export levels. However, Model IV-E forces more exports through the St. Lawrence Seaway, with the result that fewer acres of feed grains are required at the national level. The shift of demand requirements, in forcing more exports through the St. Lawrence Seaway, toward the higher yielding North Central states enables the production of the required amount of feed grains on fewer acres. *A priori,* one would expect the imposition of an additional restriction (i.e., specification of port of export) to require more acres for producing the necessary output.

Acreages of land indicated as surplus by the various models could be considered to include land already idled by the Soil Bank programs. In 1960, Soil Bank retirements amounted to about 29 million acres. Thus, the additional land (above that already in the Soil Bank) indicated to be idled by the models varies between 13 million acres and 70 million acres.

Equilibrium programming prices. The United States average product equilibrium prices, as derived from the dual of the programming models, are summarized in table 9. (Similar equilibrium prices by individual products and regions also are available from the programming solutions and are included in the Appendix.) These equilibrium programming prices are functions only of variable production costs and some fixed costs.

Table 9. United States average equilibrium prices of products by model.

Model	Wheat ($/bu.)	Feed grains ($/bu.)	Soybeans ($/bu.)	Cottonseed ($/T)	Cotton lint (c/lb.)
I	0.94	0.82	1.08	26.34	29.8
II	0.95	0.82	1.08	26.49	29.9
III	0.96	0.81	1.06	25.36	30.2
IV-A	0.98	0.84	1.11	27.29	30.7
IV-B	0.98	0.85	1.13	27.86	30.8
IV-C	1.01	0.87	1.18	29.06	30.8
IV-D	1.05	0.89	1.21	29.97	30.8
IV-E	1.05	0.88	1.21	29.79	30.8
IV-F	1.09	0.90	1.23	30.58	30.8
V	0.99	0.85	1.05	27.01	30.0
VI-A	0.89	0.66	0.96	22.93	30.0
VI-B	0.91	0.68	1.01	24.43	30.0
VII-A	0.86	0.80	1.09	27.03	23.6
VII-B	0.96	0.84	1.17	29.28	23.8

Since other fixed costs (e.g., real estate taxes, interest on land investment and other land charges) are excluded, and since they are unrelated to governmental support prices, they are low relative to the current product prices. (The absolute level of the prices should be considered with these points in mind. However, the relative levels of the average equilibrium prices for the different crops and models provide important comparisons. In comparison of Model I with Model IV-F, the wheat-bushel requirements (shown in the last line of table 1) increase by about 53 percent. However, the wheat-supply price increases only slightly, from about 94 cents to $1.09. Feed-grain requirements increase (table 2) by about 11 percent between the two models being compared, and the supply price of feed grains increases from 82 cents per bushel to 90 cents per bushel (table 9). The 13-percent increase (table 3) in oilmeal requirements between models I and IV-F results in a price increase (table 9) of 15 cents per bushel for soybeans and a price increase of $4.24 per ton of cottonseed. Thus, the supply responses of wheat, feed grains and oilmeals are indicated, normatively, to be highly elastic.

SUMMARY

This study analyzes potential adjustments necessary in the major field-crop economy of the United States in response to projected changes in technology and demand by 1975. Linear-programming models are used to specify the most efficient production and land-use patterns over 144 producing regions of the nation. Each region has the potential of five different crop activities: wheat, feed grains, feed grains with soybeans, soybeans and cotton.

Also, 31 consuming regions, each possessing demands for wheat, feed grains and oilmeals, are delineated. Transportation activities are defined to allow transfer of the three demand entities (wheat, feed grains and oilmeals) among consuming regions. Activities are included to allow the transfer of wheat into feed use, if wheat is the cheapest source of feed nutrients. Output within each producing region is restrained only by the land resource. Alternative empirical models are used to express different assumptions regarding major variables related to growth in food demand and technological improvement. The effects of different levels of income, population, livestock feeding efficiency, exports, crop yields and per-acre production costs on the optimal regional production and distribution of crops and land use are analyzed. Projections also are made of the surplus capacity of American agriculture in 1975 as reflected in acreage not required for specified crops. The programming models used determine the least-cost production location and product distribution patterns to satisfy regional demand requirements. The models include up to 402 equations and 2,417 variables (excluding disposal activities).

All empirical models used indicate surplus potential in American agriculture for 1975. In fact, surplus potential is projected to grow. Land not necessary to achieve projected domestic demand and export levels varies between 45 and 98 million acres. The smaller surplus acreage is specified under models assuming lower rates of technological improvement and higher rates of domestic population increase and export growth. The larger surplus acreage is specified under a model assuming a lower level of population growth, exports held at 1956-61 levels and a rate of technological improvement paralleling 1950-60 and allowing the South to catch up with other major farm states. The empirical models are in general agreement with respect to the location of land not necessary to achieve the required levels of production. (Of course, the models that suppose the greatest demand requirements specify less surplus land.) Solutions to the models indicate that the major areas where land needs to be shifted to noncrop uses are in the South Atlantic states, the Delta states, the Appalachian states, the Great Plains and fringe regions of the Corn Belt. Surplus land and projected land use is identified by a number of regions within each state.

Although a wide geographical dispersion of land withdrawal from crops is indicated, the general crop-production pattern follows existing areas of specialization, but production contracts toward the center of these. Feed-grain production becomes more concentrated in the central Corn Belt and in the North Atlantic states. Soybeans are increased importantly in the South and in the fringes of the Corn Belt. Wheat becomes more heavily concentrated in the most productive regions of the northern Plains states and the Pacific Northwest. Cotton production shifts westward, being replaced by soybeans over part of the previous areas of specialization. From the analysis of factors affecting comparative advantage, it appears that natural conditions and technology are "stronger" than transportation costs in orienting the location of crop production.

The models that allow producing regions of the South to "catch up" with other regions in the level of farming technology result in the greatest interregional adjustment of production and land use. Producing regions stretching from the Atlantic Seaboard through Louisiana rise to a competitive position in feed production and livestock—paralleling, and surpassing in some cases, Corn Belt regions. A high level of crop technology in the South has the main effect of crowding grain production out of marginal or fringe areas of the Corn Belt and the Great Plains. Land in the Great Plains states is specified to be shifted from wheat to grazing.

By using the dual solution to the simplex programming models, equilibrium prices were determined for each product in each consuming region. Since the per-acre cost estimates used do not include fixed costs or any charges to management, these prices are somewhat low relative to the existing product prices. The equilibrium land rents also are derived from the dual solution for each of the models. These rents are the imputed values to land in each of the programming regions under the various solutions.

APPENDIX

Table A-1. Equilibrium rent by producing region for total land for models I, II, III, IV-A, IV-B, IV-D, V, VI-A, VII-A ($ per acre).

Producing region	Model I	II	III	IV-A	IV-B	IV-D	V	VI-A	VII-A
1	2.36	2.51	1.49	3.41	3.97	6.08	4.04	0	12.04
2	10.58	10.73	9.68	11.66	12.24	14.42	12.31	9.00	12.78
3	26.72	26.92	25.61	28.07	28.79	31.50	28.88	13.82	16.49
4	22.33	22.51	21.32	23.56	24.21	26.69	24.30	13.19	9.86
5	5.69	5.86	3.75	6.85	7.47	9.81	7.55	0	9.00
6	16.44	16.63	14.26	17.75	18.44	21.07	18.53	9.99	10.47
7	0	0	0	0	0	0	0	0	4.23
8	2.73	2.86	1.26	3.61	4.08	5.85	4.14	0	0.05
9	8.49	8.65	6.55	9.64	10.26	12.58	10.33	5.35	8.70
10	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	1.27	0	0	0
12	0	0	0	0	0	0	0	0	0
13	2.70	2.80	2.15	3.44	3.72	5.07	4.07	0	0.82
14	0	0	0	0.35	0.64	2.04	1.00	0	0
15	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	2.28	0	0	4.42
18	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	4.40
20	0	0	0	0	0	0	0	0	11.75
21	0	0	0	0	0	0	0	0	8.75
22	0	0	0	0	0	0	0	0	2.62
23	0	0	0	0	0	0	0	0	16.32
24	0	0	0	0	0	0	0	0	1.03
25	1.05	1.07	1.07	1.07	1.07	1.07	1.07	0	6.51
26	0	0.08	1.60	4.04	4.57	5.23	5.22	0	2.89
27	0	0	0	0	0	0	0	0	13.56
28	0	0	0	0	0	0.58	0	0	17.02
29	0.78	0.95	0	1.98	2.63	5.06	2.71	0	11.71
30	0	0	0	1.21	1.97	4.81	2.06	0	2.83
31	0	0	0	0	0	0	0	0	1.34
32	0	0	0	0	0	0	0	0	1.34
33	3.89	4.10	2.69	5.34	6.12	9.05	6.22	0	6.36
34	0	0	0	0	0	1.03	0	0	0
35	24.08	24.26	23.02	25.35	26.04	28.61	26.12	22.08	5.34
36	1.63	1.81	0.55	2.93	3.63	6.27	3.72	0	0
37	16.56	16.76	15.42	18.10	18.69	21.48	19.41	9.84	3.17
38	13.03	13.25	11.76	14.73	15.38	18.46	16.17	5.24	5.18
39	14.02	14.26	13.69	15.55	16.42	19.73	16.50	7.99	7.95
40	0	0	0	0.12	0.79	3.11	0.79	0	2.44

Table A-1 (Continued)

Producing region	Model I	II	III	IV-A	IV-B	IV-D	V	VI-A	VII-A
41	0	0	0	0	0	0	0	0	0
42	0	0	0	0	0	0	0	0	0
43	6.62	6.79	5.67	7.78	8.40	10.52	8.47	0	8.57
44	18.02	18.20	16.95	19.30	19.99	22.35	20.08	9.37	11.23
45	5.74	5.96	4.50	7.25	8.05	11.09	8.15	0	8.58
46	3.05	3.25	1.91	4.43	5.17	7.70	7.34	0.50	4.14
47	10.34	10.57	10.02	11.79	12.62	15.74	12.69	4.62	4.59
48	0	0	0	0	0	0	0	0	0
49	0	0	0	0	0	1.55	0	0	0
50	8.32	8.50	7.33	9.66	10.18	12.10	10.80	5.78	2.19
51	0	0	0	0	0	0	0	0	0
52	10.40	10.57	9.40	11.74	12.25	14.17	12.88	5.94	0.72
53	7.92	8.14	6.60	9.44	10.26	13.33	10.36	1.84	0.99
54	0	0	0	0	0	0	0	0	0
55	4.45	4.63	3.45	5.67	6.32	8.55	8.23	2.34	0
56	0	0	0	0	0	1.71	0.30	0	0
57	0.98	1.15	0	2.17	2.80	4.98	4.67	0	1.41
58	9.12	9.12	9.12	9.12	9.12	11.29	9.50	6.87	5.03
59	6.76	6.91	5.92	7.78	8.33	10.21	8.40	0	3.73
60	2.06	2.09	2.06	2.19	2.28	4.29	2.45	0	3.62
61	1.43	1.46	1.41	1.57	1.66	3.34	1.76	0	0
62	0	0	0	0	0	0	0	0	0
63	5.91	5.98	7.26	7.26	7.26	8.82	7.54	7.26	7.26
64	0	0	0	0	0	0	0	0	0
65	0	0	0	0	0	0	0	0	0
66	0	0	0.62	0	0	0	0.62	0	0
67	0	0	0	0	0	0	0	0	0
68	0	0	0	0	0	0	0	0.35	0
69	0	0	0	0	0	0	0	0.50	0
70	0	0	0	0	0	0	0	0	1.59
71	0	0	0	0	0	0	0	0	0
72	0	0	0	0	0	0	0	0	1.68
73	0	0	3.29	0	0	0	0	0	0
74	0.53	0.73	0.81	1.84	2.59	4.92	2.64	1.18	0
75	6.31	6.46	6.53	7.27	7.82	9.90	7.87	2.52	2.50
76	7.96	8.12	8.19	8.99	9.57	11.78	9.62	3.92	3.90
77	5.81	6.07	6.19	7.51	8.48	11.50	8.57	6.55	1.49
78	0	0	0	0	0	0.84	0	0	2.24
79	7.14	7.28	7.34	8.06	8.59	10.60	8.64	3.47	3.45
80	0.19	0.43	0.52	1.74	2.63	5.41	2.69	0	0
81	0	0	0	0	0	0.86	0	0	0
82	0	0	0	0	0	0	0	0	0
83	0	0	0	0	0	0	0	0	0

Table A-1 (Continued)

Producing region	Model I	II	III	IV-A	IV-B	IV-D	V	VI-A	VII-A
84	0	0	0	0	0	0	0	0	0
85	2.09	2.16	2.18	3.16	3.44	4.99	3.71	0	0
86	0	0	0	0	0	1.23	0	0	0
87	0	0.06	0.08	0.98	1.24	2.66	1.49	0	0
88	8.18	8.24	8.26	9.23	9.50	11.02	9.77	5.38	4.93
89	9.38	9.44	9.45	10.30	10.54	11.86	10.77	7.55	6.91
90	0	0	0	0	0	0	0	0	0
91	0	0	0	0	0	3.21	0	0	0
92	2.33	2.34	3.14	2.34	2.34	5.69	2.34	1.15	0.98
93	0	0	0	0	0	0	0	0	0
94	1.56	1.57	2.50	1.57	1.57	5.45	1.57	0.19	0
95	16.80	16.81	19.07	16.81	16.81	22.56	16.81	23.87	15.31
96	9.83	9.83	10.55	9.83	9.83	12.83	9.83	8.77	8.62
97	12.50	12.51	13.28	12.51	12.51	15.72	12.51	11.37	11.21
98	5.09	5.10	5.78	5.10	5.10	7.94	5.10	4.09	3.95
99	8.00	8.01	9.15	8.01	8.01	10.92	8.01	7.13	7.25
100	12.14	12.15	13.06	12.15	12.15	15.94	12.15	10.80	10.62
101	13.70	13.71	14.49	13.71	13.71	16.97	13.71	12.55	12.39
102	8.72	8.73	10.40	8.73	8.73	12.99	8.73	10.32	7.62
103	16.59	16.60	18.46	16.60	16.60	21.35	16.60	15.23	15.36
104	1.65	1.65	1.65	1.65	1.65	4.81	1.65	1.65	0.65
105	0	0	0	0	0	3.61	0	0	0
106	0	0	0	0	0	0	0	0	0
107	0	0	0	0	0	0	0	0	0
108	0	0	0	0	0	0	0	0	0
109	5.59	5.69	5.74	6.26	6.64	7.83	6.68	2.53	1.16
110	0	0	0	0	0.29	1.23	0.31	0	0
111	5.76	5.84	5.88	6.30	6.61	7.57	6.64	3.30	2.20
112	1.29	1.36	1.39	1.77	2.04	2.89	2.06	0	0
113	0	0	0	0	0	0	0	0	0
114	0.67	0.67	0.67	0.67	0.67	3.46	0.67	0	0
115	0	0	0	0	0	5.99	0	0	0
116	24.74	24.74	24.74	24.74	24.74	31.97	24.74	24.74	22.45
117	12.72	12.72	12.72	12.72	12.72	18.33	12.72	12.72	15.50
118	17.23	17.23	17.23	17.23	17.23	22.48	17.23	17.23	15.57
119	10.57	10.57	10.57	10.57	10.57	15.30	10.57	10.57	9.07
120	33.01	33.24	33.32	34.20	34.85	36.85	34.90	27.91	20.96
121	21.77	21.89	21.95	22.59	23.06	24.52	23.10	18.01	14.54
122	0	0	0	0	0	0	0	0	0
123	0	0	0	0	0.30	1.76	0.68	0	0
124	0	0	0	0	0	0	0	0	0
125	0	0	0	0	0	0	0	0	0
126	0	0	0	0	0	0	0	0	7.23
127	0	0	0	0	0	0	0	0	0
128	0	0.02	0.02	0.02	0.02	0.02	0.02	0	3.06
129	2.36	2.38	2.38	2.38	2.38	2.38	2.38	0	0
130	0	0	0	0	0	0	0	0	0
131	0	0	0	0	0	0	0	0	0
132	1.92	1.92	3.12	1.92	1.92	4.98	1.92	5.83	1.13
133	0	0	0	0	0	1.80	0	2.07	0
134	0	0	0	0	0	0.18	0	0	0
135	0	0	0	0	0	0	0	0	0
136	0	0	0	0	0	0.44	0	0.08	0
137	12.78	12.79	15.07	12.79	12.79	18.61	12.79	8.04	11.27
138	7.16	7.16	8.52	7.16	7.16	10.63	7.16	6.49	6.26
139	5.17	5.17	6.23	5.17	5.17	7.86	5.17	3.94	4.47
140	12.87	12.88	15.32	12.88	12.88	19.10	12.88	12.68	11.26
141	0	0	0	0	0	0	0	0	0
142	19.92	20.21	20.34	21.82	22.91	26.29	23.00	12.59	1.14
143	35.82	36.07	36.18	37.37	38.26	41.00	38.33	28.79	19.31
144	0	0	0	0	0	0	0	0	5.33

Table A-2. Equilibrium wheat prices by consuming regions for models I, II, III, IV-A, IV-B, IV-D, V, VI-A, and VII-A ($ per bushel).

Consuming region	Model I	II	III	IV-A	IV-B	IV-D	V	VI-A	VII-A
1	1.37	1.37	1.36	1.40	1.41	1.48	1.41	1.25	1.25
2	1.31	1.32	1.31	1.34	1.36	1.42	1.36	1.20	1.19
3	1.34	1.34	1.33	1.37	1.38	1.45	1.38	1.22	1.22
4	1.28	1.28	1.26	1.29	1.30	1.35	1.31	1.19	1.28
5	1.40	1.40	1.40	1.41	1.41	1.41	1.41	1.30	1.28
6	1.29	1.29	1.27	1.31	1.32	1.37	1.36	1.09	0.95
7	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.16	1.14
8	0.98	0.99	0.98	1.01	1.03	1.09	1.03	0.86	0.86
9	1.12	1.13	1.13	1.16	1.17	1.22	1.18	1.01	1.00
10	1.12	1.12	1.12	1.12	1.12	1.12	1.12	1.07	1.07
11	0.88	0.89	0.93	0.93	0.93	0.98	0.94	0.93	0.93
12	1.02	1.03	1.03	1.05	1.07	1.13	1.07	0.90	0.90
13	1.01	1.01	1.01	1.04	1.05	1.12	1.06	0.89	0.89
14	0.83	0.83	0.86	0.92	0.93	0.94	0.94	0.83	0.71
15	0.86	0.84	0.86	0.89	0.91	0.97	0.91	0.75	0.74
16	1.07	1.07	1.07	1.07	1.07	1.07	1.07	0.99	0.97
17	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.20	1.19
18	1.14	1.14	1.17	1.14	1.14	1.28	1.14	1.08	1.08
19	0.71	0.71	0.75	0.71	0.71	0.86	0.71	0.66	0.65
20	0.65	0.65	0.65	0.69	0.70	0.75	0.71	0.56	0.54
21	0.64	0.65	0.65	0.67	0.69	0.75	0.69	0.53	0.53
22	0.82	0.82	0.86	0.82	0.82	0.82	0.86	0.82	0.82
23	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.89
24	0.53	0.53	0.53	0.53	0.53	0.68	0.53	0.53	0.48
25	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.58
26	0.62	0.63	0.63	0.65	0.67	0.72	0.67	0.49	0.43
27	0.85	0.86	0.86	0.88	0.90	0.95	0.90	0.72	0.77
28	1.05	1.05	1.05	1.05	1.05	1.20	1.05	1.01	0.95
29	0.89	0.89	0.89	0.89	0.89	1.04	0.89	0.89	0.84
30	0.98	0.98	0.98	0.98	0.98	1.13	0.98	0.98	0.93
31	1.19	1.20	1.20	1.22	1.24	1.29	1.24	1.06	0.87

Table A-3. Equilibrium feed-grain prices (corn equivalent) by consuming regions for models I, II, III, IV-A, IV-B, IV-D, V, VI-A and VII-A ($ per bushel).

Consuming region	Model I	II	III	IV-A	IV-B	IV-D	V	VI-A	VII-A
1.........	1.11	1.11	1.09	1.13	1.14	1.18	1.14	0.93	1.05
2.........	1.06	1.06	1.04	1.07	1.08	1.12	1.09	0.87	1.00
3.........	1.08	1.08	1.04	1.10	1.11	1.15	1.11	0.88	1.02
4.........	1.13	1.13	1.11	1.15	1.16	1.20	1.17	0.94	0.98
5.........	1.12	1.12	1.10	1.14	1.15	1.18	1.16	0.91	0.85
6.........	1.15	1.15	1.13	1.17	1.18	1.21	1.21	0.97	1.07
7.........	0.97	0.98	0.96	0.99	1.00	1.04	1.00	0.81	0.79
8.........	0.74	0.75	0.73	0.77	0.77	0.81	0.78	0.56	0.69
9.........	0.78	0.78	0.76	0.80	0.81	0.85	0.81	0.65	0.72
10.........	0.81	0.81	0.81	0.81	0.82	0.86	0.82	0.73	0.74
11.........	0.67	0.67	0.67	0.67	0.67	0.70	0.67	0.52	0.71
12.........	0.83	0.84	0.82	0.85	0.86	0.90	0.86	0.66	0.81
13.........	0.63	0.63	0.61	0.65	0.66	0.69	0.69	0.45	0.64
14.........	0.74	0.74	0.72	0.76	0.77	0.80	0.78	0.53	0.63
15.........	0.63	0.63	0.61	0.65	0.66	0.70	0.66	0.47	0.61
16.........	0.83	0.83	0.83	0.86	0.87	0.92	0.88	0.69	0.87
17.........	1.02	1.02	1.02	1.05	1.06	1.10	1.07	0.88	0.80
18.........	0.80	0.80	0.84	0.80	0.80	0.90	0.80	0.78	0.77
19.........	0.63	0.63	0.67	0.63	0.63	0.77	0.63	0.47	0.69
20.........	0.58	0.58	0.58	0.61	0.62	0.67	0.63	0.44	0.67
21.........	0.57	0.58	0.58	0.60	0.61	0.66	0.61	0.46	0.68
22.........	0.73	0.73	0.76	0.73	0.73	0.73	0.76	0.69	0.76
23.........	0.69	0.69	0.78	0.69	0.69	0.69	0.69	0.66	0.88
24.........	0.47	0.47	0.47	0.47	0.47	0.61	0.47	0.47	0.77
25.........	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.98
26.........	0.55	0.56	0.56	0.58	0.59	0.64	0.60	0.43	0.72
27.........	0.76	0.76	0.76	0.78	0.80	0.85	0.80	0.60	0.99
28.........	0.83	0.84	0.84	0.86	0.87	0.92	0.87	0.71	1.00
29.........	0.79	0.79	0.79	0.79	0.79	0.93	0.79	0.79	1.14
30.........	0.87	0.87	0.87	0.87	0.87	1.01	0.87	0.87	1.17
31.........	1.06	1.06	1.07	1.09	1.10	1.15	1.10	0.94	1.17

Table A-4. Equilibrium soybean prices by consuming region for models I, II, III, IV-A, IV-B, IV-D, V, VI-A and VII-A ($ per bushel).

Consuming region	Model I	II	III	IV-A	IV-B	IV-D	V	VI-A	VII-A
1.........	1.25	1.26	1.24	1.28	1.31	1.39	1.28	1.14	1.30
2.........	1.27	1.28	1.26	1.30	1.32	1.41	1.29	1.14	1.26
3.........	1.28	1.29	1.27	1.31	1.34	1.42	1.29	1.15	1.26
4.........	1.16	1.16	1.15	1.19	1.21	1.29	1.18	1.03	1.15
5.........	1.04	1.04	1.04	1.07	1.09	1.17	1.04	0.96	1.10
6.........	1.11	1.12	1.09	1.14	1.16	1.25	1.13	0.97	1.02
7.........	1.06	1.06	1.04	1.09	1.11	1.19	1.09	0.92	1.04
8.........	1.05	1.05	1.04	1.08	1.10	1.18	1.07	0.94	1.00
9.........	1.13	1.13	1.09	1.16	1.18	1.27	1.15	0.98	1.03
10.........	1.14	1.14	1.12	1.17	1.19	1.26	1.19	1.00	1.11
11.........	0.83	0.84	0.83	0.86	0.88	0.97	0.85	0.75	1.03
12.........	0.98	0.99	0.98	1.01	1.04	1.12	1.01	0.90	1.02
13.........	0.87	0.87	0.86	0.90	0.92	1.00	0.89	0.81	0.89
14.........	0.95	0.96	0.94	0.98	1.00	1.09	0.97	0.84	1.00
15.........	0.92	0.93	0.91	0.95	0.97	1.06	0.97	0.79	0.90
16.........	0.99	1.00	0.92	1.03	1.05	1.13	1.01	0.80	0.93
17.........	1.02	1.03	1.01	1.05	1.07	1.16	1.04	0.92	1.05
18.........	0.79	0.80	0.78	0.82	0.85	0.93	0.81	0.69	0.82
19.........	0.75	0.76	0.74	0.98	1.00	1.08	0.97	0.61	0.99
20.........	0.95	0.95	1.00	0.95	0.95	1.01	0.95	0.70	0.95
21.........	0.77	0.77	0.75	0.80	0.82	0.90	0.79	0.67	0.81
22.........	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.98	0.97
23.........	1.02	1.02	1.01	1.02	1.02	1.02	1.02	0.93	1.07
24.........	1.27	1.27	1.27	1.27	1.27	1.27	1.27	1.19	1.27
25.........	0.99	1.00	0.98	1.03	1.05	1.13	1.02	0.90	1.04
26.........	0.91	0.92	0.90	0.94	0.97	1.05	0.94	0.81	0.96
27.........	1.29	1.29	1.04	1.32	1.34	1.42	1.31	0.96	1.33
28.........	1.29	1.29	1.27	1.32	1.34	1.42	1.31	1.19	1.33
29.........	1.29	1.29	1.27	1.32	1.34	1.34	1.31	1.19	1.33
30.........	1.29	1.29	1.27	1.32	1.34	1.42	1.31	1.19	1.33
31.........	1.29	1.29	1.27	1.32	1.34	1.41	1.31	1.19	1.33

Table A-5. Equilibrium cottonseed price by consuming regions for models I, II, III, IV-A, IV-B, IV-D, V, VI-A and VII-A ($ per ton).

Consuming region	Model I	II	III	IV-A	IV-B	IV-D	V	VI-A	VII-A
1.........	..	..	..	..	..	..	..	..	..
2.........	..	..	..	..	..	..	..	..	..
3.........	32.54	32.71	32.17	33.35	33.90	36.03	32.71	29.15	32.04
4.........	29.20	29.36	29.06	30.00	30.55	32.47	29.79	26.11	29.08
5.........	28.03	28.03	27.99	28.71	29.30	31.55	28.03	25.74	29.60
6.........	28.00	28.16	27.63	28.80	29.35	31.47	28.59	24.45	25.85
7.........	27.92	28.08	27.53	28.76	29.33	31.55	28.84	24.37	27.49
8.........	..	..	..	..	..	..	..	..	..
9.........	..	..	..	..	..	..	..	..	..
10.........	..	..	..	..	..	..	..	..	..
11.........	..	..	..	..	..	..	..	..	..
12.........	..	..	..	..	..	..	..	..	..
13.........	..	..	..	..	..	..	..	..	..
14.........	23.15	23.30	22.79	23.92	24.45	26.49	23.71	20.48	24.26
15.........	..	..	..	..	..	..	..	..	..

Table A-5 (Continued)

Consuming region	Model I	II	III	IV-A	IV-B	IV-D	V	VI-A	VII-A
16.........	25.60	25.76	23.67	26.42	26.98	29.14	26.14	20.66	24.03
17.........	25.91	26.07	25.54	26.72	27.27	29.40	26.44	23.39	26.73
18.........	20.61	20.78	20.23	21.44	22.00	24.18	21.15	18.03	21.44
19.........	20.83	21.00	20.42	27.17	27.78	30.10	26.93	16.92	27.55
20.........	..	..	..	..	..	..	..	..	..
21.........	..	..	..	..	..	..	..	..	..
22.........	..	..	..	..	..	..	..	..	..
23.........	..	..	..	..	..	..	..	..	..
24.........	..	..	..	..	..	..	..	..	..
25.........	..	..	..	..	..	..	..	..	..
26.........	..	..	..	..	..	..	..	..	..
27.........	33.33	33.49	26.95	34.15	34.72	36.88	33.93	24.79	34.51
28.........	..	..	..	..	..	..	..	..	..
29.........	..	..	..	..	..	..	..	..	..
30.........	..	..	..	..	..	..	..	..	..
31.........	34.40	34.56	34.00	35.24	35.83	37.72	35.02	31.77	35.61