Incorporating Soil Differences Within Regions in an Interregional Competition Model

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RESEARCH ON THE interregional allocation of farm production has been underway for several years under the joint auspices of Iowa State University and the U.S. Department of Agriculture. A number of linear programming models applicable to the major field crops--wheat, cotton, soybeans, and feed grains (corn, oats, barley, and grain sorghums) have been devised.[1] Other models incorporating livestock and a variety of refinements in technique are in process. The major purpose of this research is to ascertain what would be an efficient interregional allocation of farm production in the United States under specified assumptions. The objectives of these studies are (a) to find the interregional allocation of production under specific objective functions, (b) to indicate the amount and location of land that might be withdrawn from field crop production to bring supplies and utilization into balance, and (c) to study the effect of different types of supply control policies on interregional production patterns and the magnitudes of land-use shifts.

This paper discusses two models representing recent refinements. Model I assumes that all of the cropland within a region is of equal productivity. Model II divides the cropland within a region into three groups reflecting differences in productivity. Soil differences within regions were incorporated to provide more realistic and complete representation of the production possibilities within regions.

To show the effects of recognizing differences in soil productivity within regions, the results from model I and model II are compared.

[1] Earl O. Heady and A. C. Egbert, "Efficient Regional Allocation of Farm Products and Programmed Supply Prices," Agr. Econ. Res. 16: 1-11, Jan. 1964. Also see A. C. Egbert and Earl O. Heady, "Regional Adjustments in Grain Production: A Linear Programming Analysis," U.S. Dept. Agr., Tech. Bul. 1241, 1961.

Structure of the Models

The models used here follow a basic pattern which has been reported in the earlier studies cited. They differ from models used in the earlier stages of the project in that they have (a) more demand regions and more producing areas, (b) transportation activities to provide for the optional distribution of food and feed products, and (c) input-output data that are projected to estimate as accurately as possible the conditions of 1965.

The 144 producing regions were delineated along county lines to form regions that are relatively homogeneous with respect to climate, historical yields, and production costs. The regions include approximately 96 percent of the national production of the seven crops named above. Geographic areas not suited to the crops (e.g., mountainous, grazing, and similar regions) are excluded from the programming regions.

The 48 States were divided into 31 demand regions based on State boundaries. A regional demand requirement was specified for each of the three major products: food wheat, feed grains, and oilmeals. The demands represent discrete quantities for livestock, human, industrial, and export uses in each demand region. A single national demand was specified for cotton lint. Demand constraints are based on 1965 projected levels of population, per capita consumption, and "normal" price levels. Foreign exports, being somewhat indeterminate, were set at 1957-61 average levels. To provide a proper spatial allocation of production, the product demands at each coastal consuming region include expected exports. Each of the two models had similar demand requirements for food and feed products. These commodity requirements are listed in table 1.

An activity for each crop was included for all regions previously producing the particular crop. Cropland availability served as the overall constraint on production in each producing

Table 1.--Demands for specific commodities employed in models I and II

Commodity	Unit	Quantity[1]
Corn	Million bushels	4,337.9
Oats	do.	1,143.7
Barley	do.	478.5
Grain sorghums	do.	456.3
Wheat	do.	1,047.8
Soybeans	do.	676.4
Cotton	Million pounds	6,466.0

[1] During the actual programming all demands for feed grains and wheat were expressed in their feed unit equivalents. Thus, demands could be satisfied by those grains with a comparative advantage in production and location.

region. Additional acreage restraints for wheat, feed grains, and cotton in each producing region were used to simulate various land retirement or supply control schemes. These restraints were based on the historical acreages of each crop in each region. Soybeans, not currently in surplus, were restricted to the use of not more than 40 percent of total cropland in each region. This restriction was imposed as an estimate of the acreage that could be used to produce soybeans without reducing yields or increasing production costs. Hence, the four major producing activities (wheat, feed grains, soybeans, and cotton) are each restrained by total cropland plus an acreage quota restraint reflecting the base acreage of that crop (except as noted above for soybeans).

Approximately 1,400 transportation activities were included to allow an optimum distribution of production among consuming regions. The movement of products was assumed to originate and terminate at the center of each consuming region. Transportation costs were not included for crops produced and consumed within a consuming region. A transfer activity for each consuming region allowed the use for livestock feed of any wheat not needed for human consumption. The cost of this activity was zero, thereby simulating a multiple-price plan for wheat (assuming that the price of food wheat would be maintained at or near its current level). This assumption induces the use of larger amounts of wheat for feed than under our recent one-price plan for wheat.

The objective function for each model is one of minimizing national costs of production and interregional transportation costs. The objective function is:

(1) $$\text{Min } f(X) = CX$$

where C is an nk + t row vector including production and transfer and transportation costs conforming to k crops, n producing regions, and t transfer and transportation activities; X is an nk + t vector representing levels of crop production, transfer, and transport activities. We also have the conventional restraints:

(2) $AX' \geq b'$ and (3) $X \geq 0$

where A is a coefficient matrix of (nk + t) (nk + mp) order (conforming with the n regions and k land restraints representing the regional crop activities, the m demand regions and the p regional demand restraints), and b is an nk + mp column vector reflecting the maximum acreage restraints within each producing region and the minimum demand requirements in each consuming region.

Soil productivity differences exist within regions, as well as between regions. Recognition of this variability can add realism to spatial equilibrium models by allowing submarginal land even in the most productive areas to be retired. In areas which have least competitive advantage, based on average coefficients, above-overage cropland can continue in use. In model II, cropland in each of the 144 producing regions was divided into three classes and acreage restraints were specified for each class. The most productive land was designated Class 1, with Class 2 and Class 3 progressively less productive.

We have grouped land in the 144 regions by Land Use Capability Class and Subclass, a classification used by the Conservation Needs Inventory Committee of the U.S. Department of Agriculture. This classification was originally designed to indicate the susceptibility of land to erosion or other hazards, but we used it as the best available method of classifying soil according to productivity. Shrader and Landgren pioneered this approach, using CNI soil classes to rank soils for corn productivity in the North Central region.[2] Their success was sufficient to encourage the use of a similar method in this study.

Demand restraints and total regional acreage restraints were the same for both models. The only major difference between the two models is the assignment of acreage restraints to classes of soils and estimation of coefficients for each class.

Model I Production Results

The results from model I indicate that 41 million acres of cropland now used for cotton, food wheat, feed grains, and oilmeals would not be needed to meet projected requirements. This assumes that production is allocated efficiently among regions and that the structure of the model and data used are reasonably appropriate. (Soybeans have a rapidly increasing demand and were allowed to exceed the historical soybean acreage.) The land could be converted to less intensive agricultural uses or to nonagriculture. The amount and location of this land by regions are indicated in figure 1. With the objective function used here, an efficient allocation of production among regions, to eliminate surpluses and conform with regional comparative advantage, would concentrate land diversion in the Northern Plains and the Southeast, with other areas having relatively less diverted land. The areas diverted are major regional aggregates with low yields, less efficient technologies, or small inefficient farms. In contrast, the major feed and livestock regions east of the Missouri River, the major winter wheat regions, and the field crop regions of the Pacific States would remain in production. The results of model I suggest that if currently applied Government programs were to be discontinued, these regions would become more important in the Nation's agriculture and food production.

Production of at least one crop was specified for nearly every producing region. Approximately 80 percent of the aggregate wheat base and feed grain base was needed to fulfill assumed regional and national demands. About 76 percent of the total cotton base was used. Soybeans exceeded their base acreage by about 11 percent. Approximately 82 percent of the 223.9 million cropland acres available in the model was needed to meet the specified demands. The remaining land, as indicated by figure 1, would be diverted to less intensive agriculture or to nonagricultural uses.

Interregional Transportation, Model I

Patterns specified for interregional flows of the three commodity aggregates (wheat for food, feed grains, and oilmeals) were developed. The general movement of feed grains was from the Corn Belt into the Southern and Eastern States. The States shipping the largest amounts were Illinois and Iowa. Kansas and Montana produced and shipped substantial amounts of wheat for use as feed grain. Under the assumptions of model I, 310 million bushels of wheat would be used for livestock feed. This amount contrasts with average use in recent years of 50 million to 80 million bushels. According to the results from this model, wheat can be produced as a livestock feed more cheaply than the four major feed grains in the Mountain States, the Pacific States, and Kansas. Wheat was also fed to livestock in Wisconsin and parts of the Southeast.

Food wheat was indicated to be in surplus in the Great Plains States and Montana. A deficit supply existed elsewhere. North Dakota, South Dakota, Nebraska, Kansas, and Oklahoma supplied most of the excess demand for food wheat of the eastern United States, while Montana regions shipped wheat to the Pacific coast. Most of the wheat demands in the Pacific coast regions were for export purposes.

Because of combined advantages in production and location, the soybean producing regions of Nebraska served as the main shippers of oilmeal to Mountain and Pacific States. The Nebraska regions also served as the producing origin for a considerable amount of oilmeal that moves to the Southeast. Otherwise, the Central Corn Belt served as the main source of oilmeal shipments to other regions. An efficient national production pattern under the specified assumptions would require increased production of soybeans and oilmeal in the Mississippi Delta. However, the East and South would continue as deficit areas and would still depend upon the Corn Belt for a portion of their oilmeal supply.

[2] William D. Shrader and Norman E. Landgren, "Land use implications of agricultural production potentials," unpublished paper, Ames, Iowa, 1962.

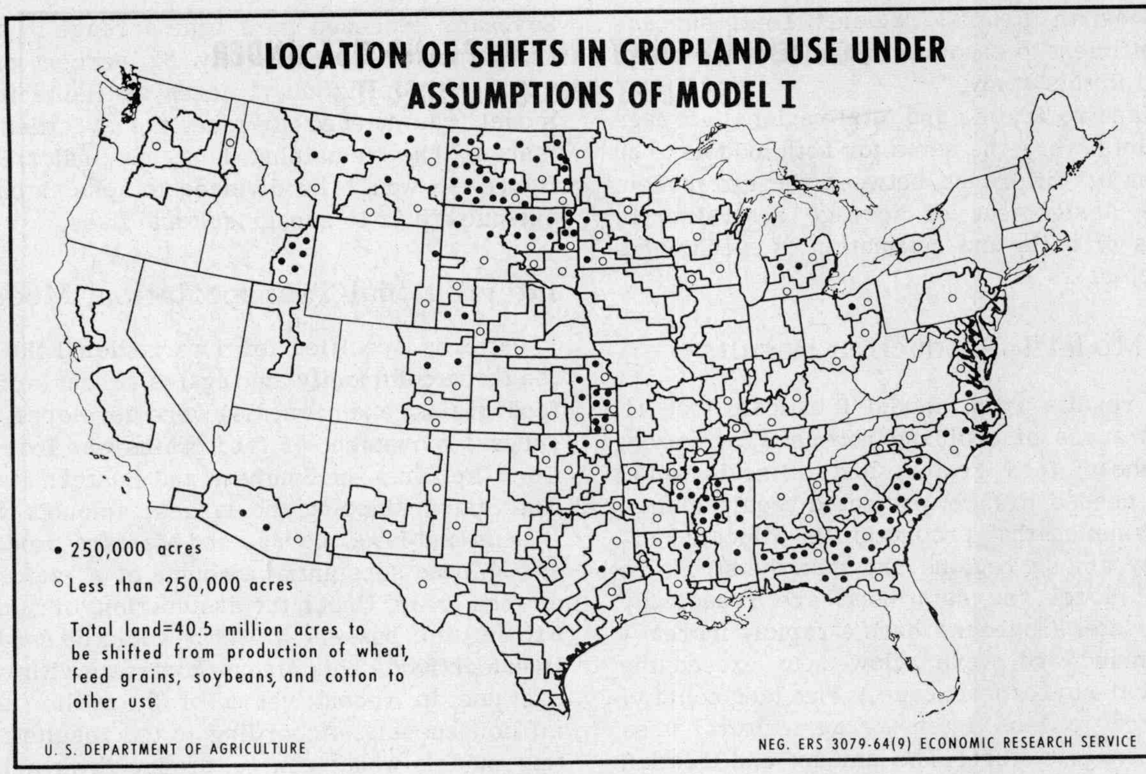

Figure 1

An indication of the efficiency of production achieved by the solution as formulated in model I is the average equilibrium product prices (excluding fixed costs) shown in table 2. Prices received by producers and those paid at points of consumption are shown separately. The difference between the two sets of prices represents transportation costs. The prices received indicate that wheat and feed grains can be produced at nearly the same cost per unit. However, the prices paid show that a much greater percentage of wheat than of feed grains must be transported before it is consumed.

The production and transportation patterns resulting from the two models were similar. However, the aggregate results indicate some significant changes brought about by model II (table 2). The most important change was the amount and distribution of unused cropland. By permitting the disposal of submarginal rather than average cropland within regions, approximately 8.1 million fewer acres were required to satisfy the product demands. In addition, there was a much wider distribution of unused cropland, as shown in figure 2. Many areas of the central Corn Belt and the Great Plains were left with some unused land, where model I indicated employment of all land. The greatest concentrations of land withdrawal were still in the Southeastern States and the Northern Plains States. Greater diversification of crop

Table 2.--Output, prices received, and prices paid for specified commodities, models I and II

Item	Units	Model I	Model II
Wheat production.....	Mil. acres	47.0	45.8
Feed grain production	do.	102.4	96.7
Soybean production....	do.	19.9	21.3
Cotton production....	do.	14.1	11.5
Unused cropland......	do.	40.5	48.6
Wheat used for feed..	Mil. bu.	310.3	279.5
Average prices received:[1]			
Wheat...........	Dol. per bu.	.83	.80
Feed grain.......	do.	.83	.80
Soybeans.........	do.	.93	1.04
Cotton...........	Dol. per cwt.	31.99	24.43
Average prices paid:[1]			
Wheat............	Dol. per bu.	1.12	1.12
Feed grain.........	do.	.92	.89
Soybeans..........	do.	1.07	1.17

[1] The differences between prices received and prices paid are a result of transportation costs incurred when moving commodities from the producers to the consumers. Cotton was not transported in our models.

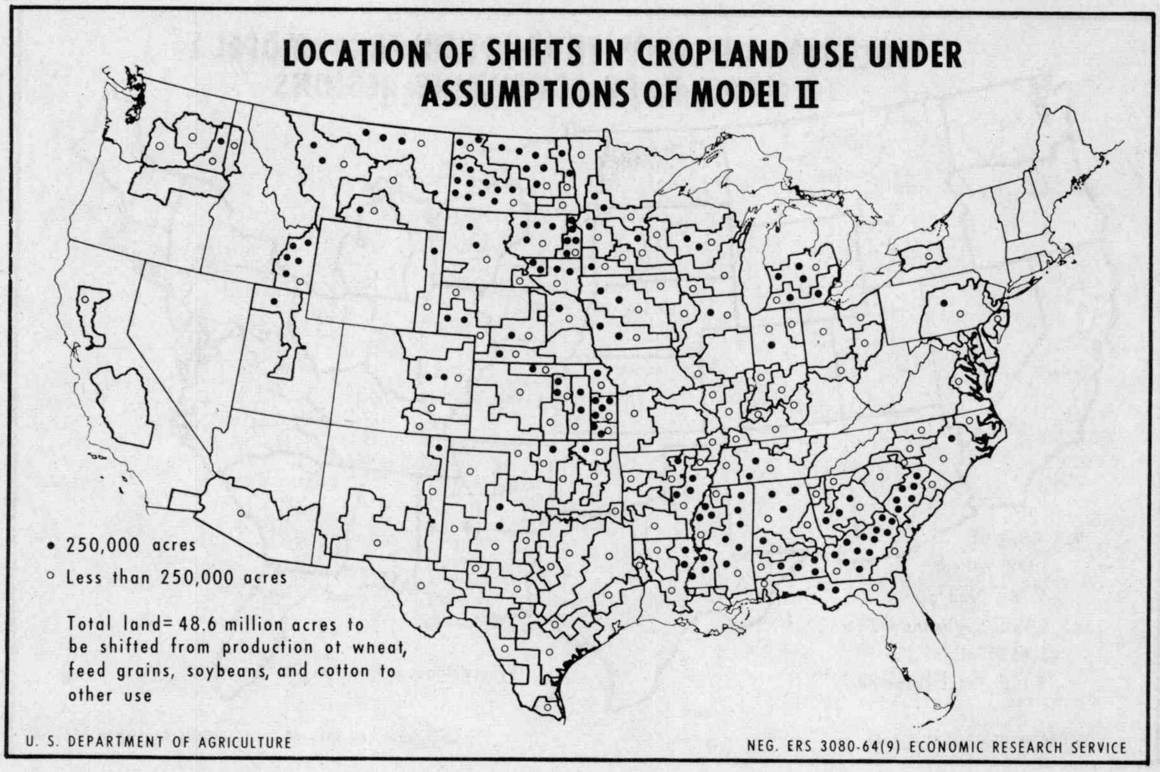

Figure 2

production also occurred as a result of the increased number of production restraints. Several regions had a more diversified cropping pattern under model II than under model I.

Figure 3 has been included to focus upon the changes in land use patterns brought about by model II. Model II affected total land use in North Dakota more than any other State. Wheat was increased over 1 million acres in this State with only a slight decrease in feed grain acreage.

Most of the decrease in total wheat acreage occurred in the Eastern and Southern States. Wheat production shifted westward, in terms of both acres and bushels, under model II. Several States west of the Missouri River showed increases in wheat production; the opposite was true for States east of this line. Most States, including the Great Plains States, showed decreases in total land devoted to the specified crops, but recognition of land quality differentials allowed these States to expand wheat production. Even under the assumptions of model I the Western and Great Plains States could produce wheat as cheaply as those in the East. These States could not exploit this advantage, however, because of their distance from centers of consumption. The range in land qualities was greater in the West than in the East. Recognition of this point shifted the comparative advantage of wheat production westward.

Feed grain production was increased slightly under model II, to offset a decrease in the use of feed wheat (table 2). However, fewer acres of feed grains were required because they utilized the more productive land, allowing other land to be shifted to other crops (or to be diverted from crops).

Mississippi and Louisiana were the only States to increase feed grain acreage under model II. This increase was accompanied by an even greater decrease in cotton acreage, however. Significantly, the increase in feed grains in Louisiana did not come at the expense of feed grain production in the Corn Belt. It was the non-Corn Belt States which absorbed the 5.8-million-acre decrease in feed grains. The Corn Belt strengthened its comparative advantage in feed grain production despite a decrease in total land use in these areas. Wheat and soybean production were reduced

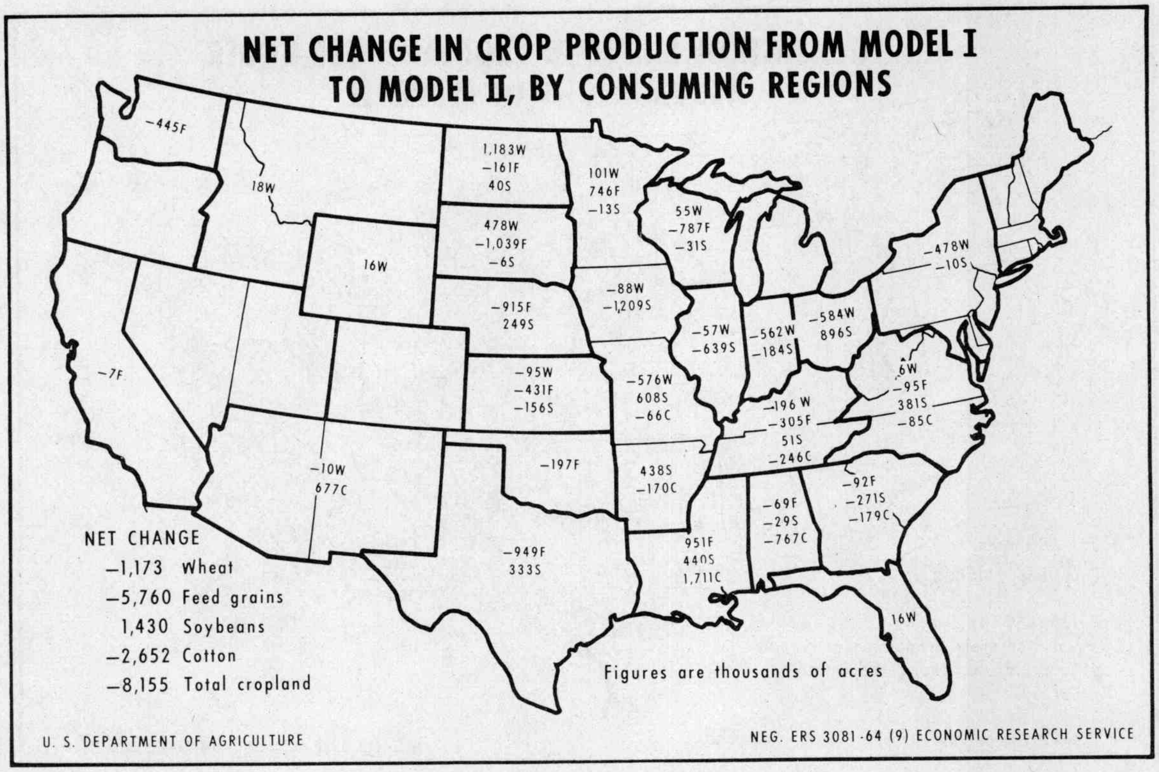

Figure 3

in the Corn Belt to maintain the high level of feed grain acreage.

Production of soybeans, the crop most competitive with feed grains for land, was shifted onto land of "below average" productivity under model II. Thus, a considerable amount of soybean production was moved from the Corn Belt into the Southern and Eastern States. Iowa actually reduced soybean acreage by 1.2 million acres. Ohio had the largest single increase, however, of 896,000 acres. The Southern States of Arkansas, Missouri, Mississippi, Louisiana, and Texas all shared in the expanded soybean acreage. Because the average yield of soybeans is lower on this land, unit production costs are higher and soybean acreage is greater. Higher production costs caused the equilibrium price of soybeans to go up in model II (table 2).

Wheat equilibrium prices were not greatly affected by model II despite a shift in production location. Ohio reduced its own production and increased inshipments by about 21 million bushels, raising its equilibrium wheat price by 9 cents per bushel. Illinois, a self-sufficient region in the model, had wheat pushed onto land with higher unit production costs, raising the price of wheat by 10 cents per bushel. All other regions had smaller changes, usually reductions, in wheat prices.

Feed grains, accounting for over 50 percent of total acreage used, often utilized the better quality of land at the expense of wheat and soybeans. Consequently, feed grain equilibrium prices were considerably reduced in model II. Nearly all of the Corn Belt States and States importing from the Corn Belt had a drop of about 5 cents per bushel of corn. Texas, Oklahoma, New Mexico, and Arizona, each allowing cotton to utilize Class I land, had increases in feed grain prices. North Dakota, because of a large increase in wheat production, had slightly higher feed grain prices.

Oilmeal prices were increased rather uniformly in all areas. Soybeans, by utilizing poorer qualities of land in most regions, had higher unit costs of production.

Cotton was affected more than any other crop by the application of the second model. Cotton dominated the best land wherever it was grown, greatly reducing the acreage and increasing the average efficiency of production. In addition, greater concentration of cotton in the

Southwest resulted under model II. All of the Southeastern cotton-producing States were reduced in cotton acreage.

Both models limited the regional production of the problem crops (wheat, feed grains, and cotton) by acreage quotas based upon historical production records. In addition to the regional crop acreage quotas, cropland acreage restraints were applied to represent individual regional capacities. The dual of the programming models produced a set of imputed values for the restraining production factors. Here we find another major difference between the two models. Model I imputed much higher values to the crop quotas and lower values to cropland than model II. This difference between the models becomes quite important if one is considering the application of crop acreage quotas to limit the production of problem crops. Model II, by being more representative of actual crop acreage quotas and cropland constraints, resulted in more realistic rental values of the restraining production factors.

Conclusions

In model I average cropland was removed from production within regions. Model II allowed the diversion of land by grades within regions. This difference resulted in changes in land use patterns, equilibrium product prices, and imputed rental values of production factors between the results of the two models. We believe the recognition of interregional soil quality differences in model II has added an element of realism to interregional competition programming models which was not present in earlier models by Heady, Egbert, Henderson, and others.

Further analysis may include simulation of alternative program characteristics by manipulation of the quota restrictions, product demands, or price assumptions applied to the models.

Not all questions regarding the benefits and effectiveness of alternative supply control programs will be answered by these programming models. Nevertheless, we feel that this approach has advantages over some of the past methods of evaluating, a priori, alternative farm policies. We can now provide more accurate estimates of the potential regional and aggregate effects of alternative agricultural programs. It is possible to consider the separate effects of such things as changes in price level, variations in export demands, increased application of new technology, and different methods of land retirement. It is hoped that the derived information will be useful in considering agricultural policies and programs for the future. While realism of the models has been increased by dividing land into classes, the results are still of long-run nature. The usefulness of the models for more intermediate or short-run policy questions would be increased if other resource restraints in addition to land could be added, and if behavioristic restraints could be added. Further, the more effective consideration of the time dimension would facilitate an analysis of the process of adjustments through time and greatly increase the information available for consideration in policy decisions.