American Agriculture in 1980 Under a Fertilizer Allocation System

MISCELLANEOUS REPORT

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AMERICAN AGRICULTURE IN 1980 UNDER A FERTILIZER ALLOCATION SYSTEM

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LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

American farmers have depended heavily on fertilizer to increase crop production needed by growing populations at home and abroad. Even when foreign demand was smaller and low crop prices resulted in the government programs to hold land from crop production, farmers profitability increased yields by using more fertilizer. However, since 1973, the fertilizer price situation has changed drastically. Further changes may come about depending on events in the international petroleum market and national energy policies.

The most important recent change confronting farmers with respect to fertilizer was the increase in fertilizer prices after 1973. As shown in Table 1, changes in fertilizer price were small relative to changes for other inputs over the period 1955 through 1972. Prices of other inputs of nonfarm origin increased rather sharply over this period. After price ceilings were removed in the fall of 1973, fertilizer prices nearly doubled. Prices of other inputs also continued to increase, but less rapidly than for fertilizer. However, when price changes over the entire period 1955 through 1975 are considered, real increases in fertilizer prices are still less than those for motor vehicles, farm machinery, and building and fencing materials. In other words, price increases of fertilizer in recent years have brought fertilizer prices more in line with long-run real prices of other inputs of nonfarm origin. Whether these similarities will remain in the future will depend especially on energy prices and their impacts on fertilizer prices.

Table 1. Price indices for inputs of nonfarm origin

Year	Motor Supplies	Motor Vehicles	Farm Machinery	Farm Supplies	Building and Fencing Materials	Fertilizer
			(1910-14 = 100)			
1955	164	358	312	259	356	155
1960	175	420	382	262	393	152
1965	176	464	426	270	391	152
1970	194	567	537	293	469	148
1971	202	607	573	303	505	155
1972	206	634	614	313	548	158
1973	220	671	664	330	628	176
1974	292	758	769	409	778	299
1975	320	897	949	477	862	342

SOURCE: [9, 10, 11].

Fertilizer consumption in both the United States and the world has increased greatly since 1960 (Tables 2 and 3). Rapid expansion in world fertilizer usage and higher energy prices could cause sharp rises in the prices of nitrogen and other fertilizer compounds in the future. The growing world demand for food, the pricing policies used by developing countries and grain importing countries to obtain food and fertilizer and potential U.S. energy policies pose the possibility of higher fertilizer prices for American farmers in the future.

Other potential problems also may affect fertilizer supplies for U.S. farmers. Other sectors, such as plastics, food processing, and transportation compete similarly for limited and higher-priced supplies of energy. Since anhydrous ammonia is the base product for nitrogen fertilizers produced in the United States, and until an economical substitution for natural gas in anhydrous ammonia is found, the dwindling supplies and higher prices will influence nitrogen production. Nitrogen manufacturers, remembering overproduction and low prices in the late 1960s and early 1970s, have been cautious in expanding production capacity. Environmentalists continue to be concerned about environmental impacts of heavy fertilization.

Table 2. United states consumption of plant nutrients, 1960-75

Year Ended June 30	N	Available P_2O_5	K_2O
		(thousand tons)	
1960	2,738.0	2,572.0	2,153.3
1961	3,030.8	2,645.1	2,168.5
1962	3,370.0	2,807.0	2,270.5
1963	3,929.1	3,072.9	2,503.4
1964	4,352.8	3,377.8	2,729.7
1965	4,638.5	3,512.2	2,834.5
1966	5,326.3	3,897.1	3,221.2
1967	6,027.1	4,304.7	3,641.8
1968	6,787.6	4,453.3	3,792.6
1969	6,957.6	4,665.6	3,891.6
1970	7,459.0	4,573.8	4,035.5
1971	8,133.6	4,803.4	4,231.4
1972	8,022.3	4,863.7	4,326.8
1973	8,295.1	5,085.2	4,648.7
1974	9,157.2	5,098.6	5,082.6
1975	8,593.2	4,494.1	4,414.8

SOURCE: [12].

Hence, the future of the fertilizer situation for the United States is not totally clear. Higher prices likely will result in expanded production of fertilizer and an increase in farmer motivation to apply fertilizer more efficiently. As world population expands, and unless other economical sources of nitrogen can be developed for plants, fertilizer production will need to grow to provide greater food supplies. Greater pressure on natural gas supplies thus will develop among

Table 3. World fertilizer nutrient production and consumption, 1960-74

Year	Nitrogen		Phosphate (P_2O_5)		Potash (K_2O)	
	Production	Consumption	Production	Consumption	Production	Consumption
			(million short tons)			
1960	11.0	10.1	10.74	10.58	9.60	9.04
1961	12.0	11.3	11.13	10.99	9.67	9.37
1962	13.1	12.1	11.44	11.49	10.32	9.56
1963	14.5	13.7	12.20	12.19	10.82	10.23
1964	16.4	15.4	13.74	13.50	11.90	11.06
1965	18.6	17.0	15.26	14.71	13.37	12.07
1966	21.1	19.2	16.63	15.86	15.18	13.40
1967	24.7	24.0	18.78	17.78	16.00	14.31
1968	28.2	26.4	19.87	18.70	16.86	13.58
1969	31.3	29.3	20.49	20.06	17.51	16.13
1970	33.3	31.6	21.26	20.74	18.43	17.02
1971	36.3	35.0	22.97	21.90	19.52	18.19
1972	38.7	37.2	24.81	23.25	21.21	19.27
1973	41.7	39.4	26.13	24.88	22.27	20.78
1974	44.6	42.6	27.72	26.74	24.49	22.80

SOURCE: [1, 8].

food producers of different countries, as well as among different types of users such as industry, agriculture, home heating, and others. The natural gas situation will be closely watched as the American energy supply tries to keep pace with growing energy needs.

If future fertilizer demand should exceed available supplies, several measures could be used by the federal government. Fertilizer imports could be subsidized to increase domestic supplies. An information network could spot areas with surpluses and shortages, and a transportation system could be developed to insure an adequate mode of moving supplies between them. The federal government also could consider tax incentives or a high priority for natural gas usage in fertilizer production to spur domestic production. Prices could be allowed to rise to levels reflecting all possible anhydrous ammonia users, with the price of nitrogen fertilizer settling at conforming equilibrium levels. As an extreme measure, fertilizer could be rationed. One allocation method could be based on previous use or crop acreages, but this action could reduce yields and production below potential levels. Another method would be to distribute fertilizer on the basis of productivity, a more economically efficient but complex method. The emphasis in this study is on determination of the impact of different fertilization availabilities, as these might be determined by market supplies and prices or institutional means, when exports are at different levels.

II. NATURE OF STUDY

This study is concerned with potential impacts of limited fertilizer supplies in the future. Limitations could come through either (a) high prices for fertilizer in competition with world food producers or alternative uses of anhydrous ammonia, or (b) government rationing of fertilizer, if this extreme were ever needed. Hence, the analysis is not concerned with the means by which the limitations in use are attained. It is concerned more with the impact of limited fertilizer availability and use on American agriculture. Hence, we suppose a limited amount of fertilizer is allocated over the regions and crops of the United States. We wish to examine the implications of this allocation on interregional and regional shifts in crop production and land use. The method of allocation of available fertilizer is based on equating the marginal value productivities of fertilizer with the cost of the fertilizer in different producing regions. The marginal value product equals the yield increase times the selling price per yield unit. This allocation method maximizes profits from fertilization for the farmer, considering the productivity of fertilizer and for the different prices for fertilizer throughout the nation. Under this procedure we assume that farmers fertilize all acres at optimum rates relative to commodity and input prices.[1]

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[1] We realize that many farmers have limited funds and may need to allocate capital so that its marginal value productivity is equal to all uses including fertilization. However, to apply such a model implied by this condition is beyond the scope of this study.

Two marginal value product levels have been selected for this study. The high fertilization level is based on a corn price at $2.50 per bushel and the low fertilization level on corn at $1.50 per bushel. These are not predictions of future corn prices but are used as criteria to determine fertilizer applications under the specified conditions. Other feed grain, a combination of oats, barley and grain sorghum, is priced at 110 percent of the corn price. Other grain prices are based on their relationships to corn prices in the 1972 through 1975 crop years. The wheat price is equal to 134 percent of the corn price and soybeans is 239 percent of the corn price. Cotton lint price is set at 38 cents per pound for the high fertilization level and at 19 cents under the low level.

Under a given production function and constant fertilizer costs, a decrease in the crop price requires an increase in the marginal product of fertilizer if profits from fertilization are to be maximized. An increased marginal product is attained if less fertilizer is used, since the marginal productivity of fertilizer decreases with increased fertilizer use. Therefore, the low fertilization level is based on a set of low crop prices which reduces fertilizer usage while still considering fertilizer productivity and regional fertilizer prices. While crop prices are lowered to examine the effects of a higher fertilizer/crop price ratio, the effect on the marginal productivity of fertilizer is the same as if crop prices were held constant and fertilizer prices were increased to attain the same price ratio. Limiting fertilizer usage on the basis of productivity insures that the fertilizer will be used in the most efficient manner.

III. METHOD OF ANALYSIS

Relationships between fertilization levels and crop yields were estimated by Ibach and Adams [2]. From these basic data, Spillman production functions were developed by Stoecker [3]. To account for increases in crop yields due to other factors (e.g., hybrid seeds, farming practices, etc.), Stoecker also developed state yield increases that must be added to the Spillman data in order to predict crop yields in 1980. This study uses the Spillman production functions developed from Ibach and Adams data plus Stoecker's adjustments for other factors than fertilizer.

Seven crops are included in this study: wheat for grain, corn for grain, oats for grain, barley for grain, grain sorghum, soybeans for beans, and cotton. These seven crops have been reduced to five crops by combining oats, barley, and grain sorghum into other feed grain. The respective weights of these three crops are based on their 1969 acreage weights from the 1969 Census of Agriculture [14]. Production costs are based on 1975 costs by updating previous cost budgets by the change in input prices over time.

National Programming Model

A national linear programming model is used to analyze the effects of the particular fertilizer allocations. A total of 595 production activities for the five crops are defined for the 150 producing areas shown in

Figure 1. Land available for crop production in these areas equals the 1969 harvested acres of the five crops and an adjustment to include land retired under federal farm programs in 1969. Bounds restrict individual crop production from 50 percent of 1969 harvested acres to 67 percent of the total land available (except wheat production in the West where all land may be used to produce wheat). Production outside of the areas shown in Figure 1 is determined by multiplying 1969 acreages by estimated yields. Two sets of production activities are used for the two fertilization levels. All four grain crops have demands defined on the consuming region basis while the cotton lint demand is handled at the national level only.

Consuming regions are shown in Figure 2. A transportation submatrix consisting of 1,805 activities allows grain crops produced in one consuming region to be moved to other consuming regions. Each consuming region allows wheat to be substituted for corn and(or) other feed grain up to a level of 50 percent of the total feed grains fed to livestock in that region. Minimizing production and transportation costs results in crop production locations which reflect interregional comparative advantages and transportation expenditures. While the objective function involves national minimization of crop production and transportation costs, all farm resources receive their market rate of return. Hence, a competitive equilibrium in resource use is assumed. The 10 farm production regions displayed in Figure 3 are used in summarizing the major results from the model.

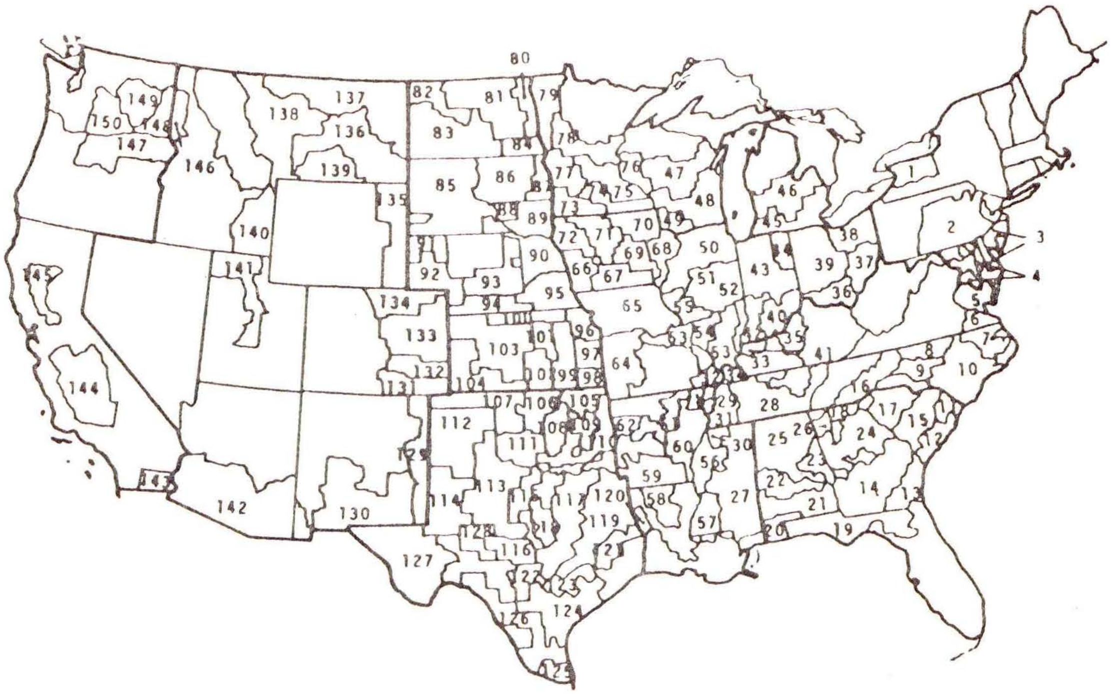

Figure 1. The 150 producing areas

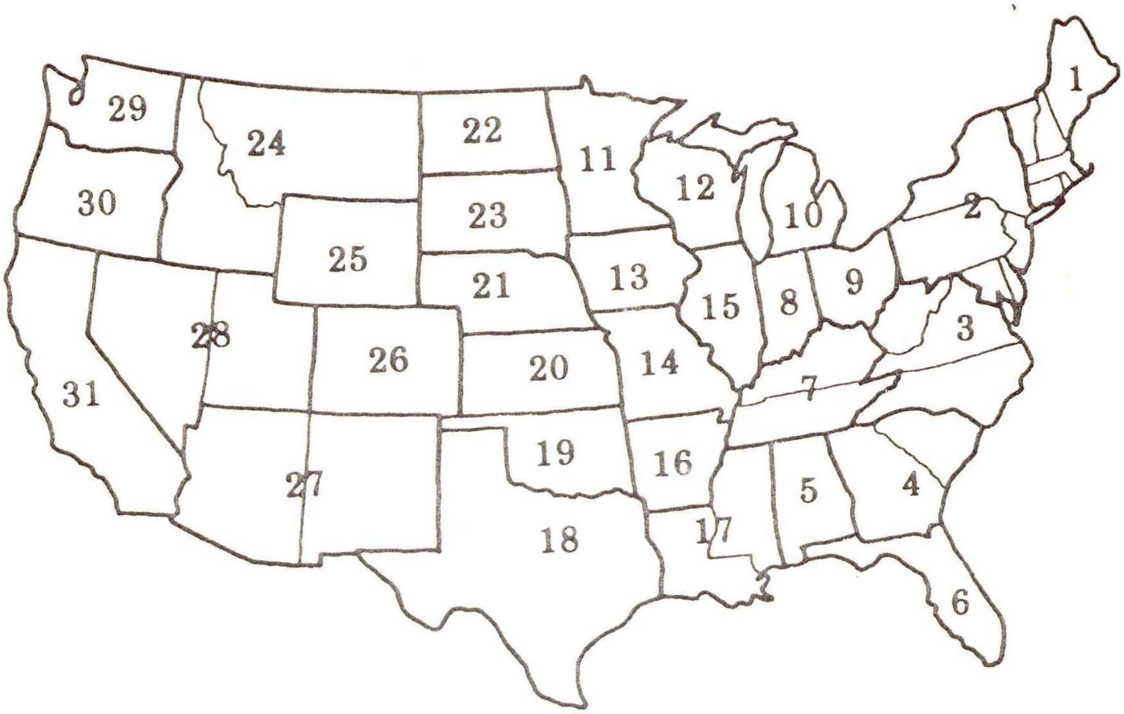

Figure 2. The 31 consuming regions

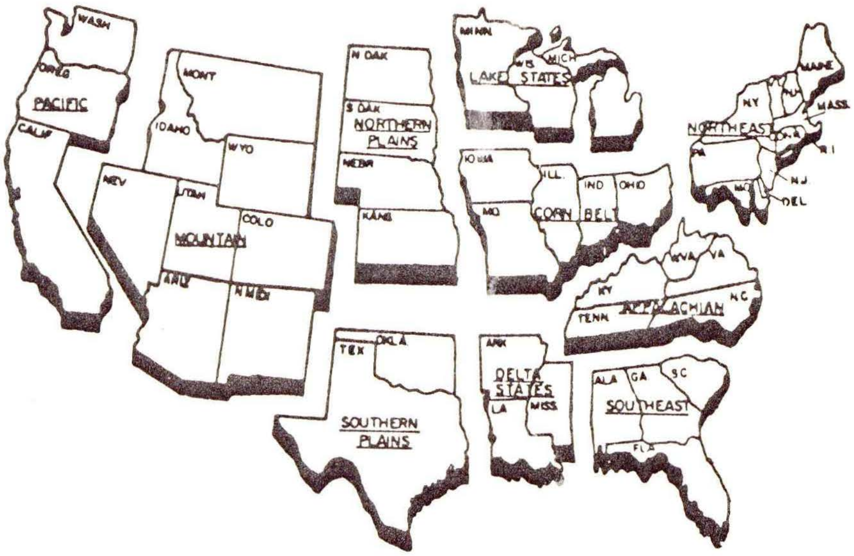

Figure 3. The 10 farm production regions used in summarizing results

Livestock production is determined exogenously. Seven livestock products are included: beef and veal, pork, lamb and mutton, chicken, turkey, eggs and milk products. Per capita domestic demands for these commodities were estimated by regression analysis and are multiplied by a projected resident population level of 225,708,000 to specify national demands. These demands are adjusted for livestock product exports and imports. Feed requirements of the four grain crops which are needed to produce these seven products must be met by production within the continental United States. A set of livestock-grain relationships based on livestock budgets insure that livestock prices reflect grain prices. Feed requirements for horses, mules, zoo animals, and pets are also included in demands for the four grain crops.

Table 4. Crop and livestock quantities held constant throughout the study

Item	Unit	Level
Livestock product net trade[a]		
Beef and veal	Million lbs. (carcass wt.)	1,683.3
Pork (excl. lard)	Million lbs. (carcass wt.)	212.3
Lamb and mutton	Million lbs. (carcass wt.)	27.7
Chicken	Million lbs. (ready-to-cook wt.)	-200.0
Turkey	Million lbs. (ready-to-cook wt.)	- 36.0
Eggs	Million doz.	- 44.7
Milk	Million lbs. (fat solids basis)	-1,296.0
Per capita domestic consumptions[b]		
Cotton lint	Pounds	15.00
Corn	Bushels	2.22
Wheat	Bushels	2.50
Oats	Bushels	0.24
Barley	Bushels	0.61
Grain sorghum	Bushels	0.03
Soybeans	Pounds	0.01
Eggs	Number (including products)	285.00
Turkey	Pounds (ready-to-cook wt.)	10.00
Milk	Pounds (fat solids basis)	545.00

[a]A negative number indicates a net export.

[b]Some grains include exports as grain products.

In addition to feed demands by livestock, crop demands include domestic usages for food and industry. Table 4 includes the exports and imports of livestock products and the domestic consumption of the five crops used in the analysis. These parameters are held constant throughout the analysis.

Alternatives Analyzed

Four alternatives are analyzed in this study. These alternatives are differentiated by the fertilization levels and crop export levels shown in Table 5. Alternatives A and B both use high fertilization rates based on the higher set of crop prices, but Alternative B has a much higher level of crop exports. The lower level of crop prices determines the fertilization level in Alternatives C and D but Alternative D has the high level of crop exports. Comparisons between A and B show the effects of high crop exports when fertilizer use is at a given level. Alternatives A and C have nearly the same livestock and crop demands, but the different fertilizer levels lead to some differing results. Alternative D is included to show results of lower fertilization rates when national land use is nearly the same as in Alternative B.

Table 5. The four alternatives and their fertilization and endogenous crop export levels

Type of level	Levels under Alternatives A	B	C	D
Fertilization				
High crop prices	X	X		
Low crop prices			X	X
Crop exports				
Wheat (million bu.)	1,219.6	2,300.0	1,219.6	2,150.0
Corn (million bu.)	1,216.7	2,300.0	1,216.7	2,150.0
Other feed grain (million ceb)	273.9	346.7	273.9	346.7
Soybeans (million bu.)	688.1	1,500.0	688.1	1,350.0
Cotton (thousand bales)	5,081.2	6,250.0	5,081.2	6,250.0

IV. RESULTS OF THE FOUR ALTERNATIVES

The national linear programming model provides a set of results for each alternative. Among these results are national supply prices for endogenous crops, crop production locations, regional land use, national yields, and wheat feeding to livestock. In addition to these results, the effects of the alternatives on food consumptions, food costs, and fertilizer usage are reviewed.

National Prices, Production, and Yields

National prices in this study are supply prices, not market equilibrium prices. Endogenous crop prices are the prices needed to cover all nonland production costs in producing the marginal output and in providing a return on the land used in production. Land costs are not included in the crop budgets, but land is assigned values by the linear programming model to reflect its economic value in the above light. If not all land in a producing area is used for crops, there is no return on the land. Thus, land use generates supply prices which differ in nature from market equilibrium prices.

Livestock prices are based importantly on the supply prices of corn and soybeans, the predominate grains used in livestock feeding. An increase in these grain prices results in higher prices for livestock.

Table 6 shows the national supply prices of endogenous crops and livestock for the four alternatives. Livestock supply prices are expressed in 1975 dollars while crop prices are based on crop prices for Alternative A.

Livestock prices for Alternatives A and C are equal because the supply prices of corn and soybeans are nearly equal. Crop supply prices for Alternatives B and D are much higher than for A. However, livestock prices are increased substantially less. This outcome is expected since nonfeed costs remain the same for all alternatives and corn and soybeans are only two of the feeds used in livestock production.

Table 6. National supply prices of endogenous livestock, livestock products and crops for the four alternatives

Commodity	Unit	A	B	C	D
Cattle	$.cwt.	41.71	44.64	41.71	45.15
Hogs	$/cwt.	33.89	37.89	33.89	38.23
Broilers	¢/lb.	19.8	21.9	19.8	21.9
Lamb	$/cwt.	41.51	42.92	41.51	43.08
Turkeys	¢/lb.	29.0	31.7	29.0	31.2
Eggs	¢/doz.	38.3	42.2	38.3	42.3
Milk	$/cwt.	8.31	8.70	8.31	8.72
			(Alternative A = 100)		
Wheat	$/bu.	100	133	102	150
Corn	$/bu.	100	134	102	145
Other feed grain	$/ceb.[a]	100	126	97	129
Soybeans	S/bu.	100	162	99	149
Cotton lint	¢/lb.	100	106	99	114

[a]Other feed grain is expressed in corn-equivalent bushels (ceb.).

Another basis for the changes in crop supply prices under the different alternatives is in Table 7. These nonland production costs are based on 1975 prices, but reflect crops allocated according to interregional comparative advantages. This allocation tends to make the derived crop costs lower than actual costs in a given year. Shifts in location of production greatly influence these costs. Alternatives A and B are based on the high fertilization level, but the larger crop production under B does not increase nonland costs much above those of A.

Table 7. National average nonland production costs of endogenous crops for the four alternatives

Crop	Unit	Nonland Production Costs Per Unit Under Alternatives			
		A	B	C	D
		($/unit)			
Wheat	bu.	1.57	1.55	1.50	1.53
Corn	bu.	1.20	1.25	1.16	1.20
Other feed grain	ceb.[a]	1.35	1.33	1.27	1.25
Soybeans	bu.	2.2	2.22	2.02	2.12
Cotton	lb.	0.265	0.262	0.263	0.259

[a]Other feed grain is measured in corn-equivalent bushels (ceb.).

Although Alternatives C and D represent lower levels of fertilization than Alternatives A and B, their nonland production costs are not much lower than for Alternative A. Fertilizer costs are reduced for C and D, but other nonland production costs increase above the A levels. For example, greater expenditures are required for tillage, herbicides, insecticides, seed, and labor as more land is used for crops to compensate for reduced yields under the fertilization lower levels.

National production and yields are shown in Table 8. As expected, national yields under normal weather are less for the lower fertilization levels (Alternatives C and D) than for Alternatives A and B. At the lower level of crop prices for C and D, the fertilization level is cut rather heavily. However, crop yields are not reduced correspondingly since diminishing marginal physical productivity prevails for fertilizer use (i.e., the elasticity of the production function is considerably less than 1.0 in the range being examined).

Table 8. Nation production and yields of endogenous crops for the four alternatives

Crop	Unit	Alternative A	B	C	D
Wheat	Million bu.	1,903.1	3,073.9	1,943.4	2,917.2
	Bu./acre	45.8	43.1	39.4	37.7
Corn	Million bu.	5,205.9	6,293.7	5,172.0	6,138.3
	Bu./acre	99.4	98.1	87.5	85.6
Other feed grain	Million ceb.	1,465.1	1,531.3	1,453.6	1,527.9
	Ceb./acre[a]	55.0	56.8	51.5	53.6
Soybeans	Million bu.	1,182.0	2,543.9	1,180.9	1,852.9
	Bu./acre	40.8	40.0	38.6	38.3
Cotton lint	Million lbs.	5,824.7	6,385.6	5,824.7	6,385.6
	Lbs./acre	763.7	767.8	723.3	727.1

[a]Measured in corn-equivalent bushels (ceb.).

Acreages

Tables 9 through 13 show the harvested acres for the four alternatives in each farm production region. Table 14 contains the average of the endogenous crops harvested in 1973-75 as a basis for comparison. Wheat acreage remains concentrated in the Northern Plains and Southern Plains regions. Corn acres remain concentrated in the Corn Belt, as has been the pattern of recent years. Other feed grain acres are spread more broadly over the nation's farm production regions than has prevailed during the period 1973-76. Soybean acreages remain concentrated in the Corn

Table 9. Harvested acres of wheat among the 10 farm production regions for the four alternatives

Farm Production Region	Harvested Acres Under Alternative: A	B	C	D
	(million acres)			
Northeast	1.169	2.022	1.169	2.004
Appalachian	1.133	1.067	1.709	1.589
Southeast	0.325	0.331	0.325	0.652
Delta	0.156	1.422	0.156	2.858
Corn Belt	3.973	2.895	4.469	4.650
Lake	2.397	5.568	2.482	6.195
Northern Plains	14.005	30.984	19.646	32.415
Southern Plains	7.229	12.267	7.229	12.093
Mountain	6.633	10.373	7.750	10.535
Pacific	4.490	4.408	4.361	4.361
United States[a]	41.511	71.337	49.296	77.352

[a]Totals may not equal summations over regions because of rounding.

Table 10. Harvested acres of corn among the 10 farm production regions for the four alternatives

Farm Production Region	Harvested Acres Under Alternative: A	B	C	D
	(million acres)			
Northeast	1.423	1.918	1.423	1.937
Appalachian	3.224	4.982	3.145	4.570
Southeast	1.674	2.749	1.636	2.503
Delta	0.182	0.182	0.182	0.182
Corn Belt	30.910	34.027	36.103	38.854
Lake	5.163	6.616	5.785	7.549
Northern Plains	4.339	6.521	5.213	8.547
Southern Plains	3.462	4.904	3.294	5.119
Mountain	0.818	0.996	0.998	1.076
Pacific	1.204	1.286	1.333	1.333
United States[a]	52.399	64.181	59.110	71.667

[a]Totals may not equal summations over regions because of rounding.

Table 11. Harvested acres of other feed grain (oats, barley and grain sorghum) among the 10 farm production regions for the four alternatives

Farm Production Region	Harvested Acres Under Alternative:			
	A	B	C	D
	(million acres)			
Northeast	0.901	0.901	0.901	0.901
Appalachian	1.286	0.494	0.427	0.470
Southeast	0.113	0.459	0.113	0.260
Delta	0.450	0.581	0.581	0.581
Corn Belt	3.140	2.112	3.377	2.112
Lake	4.273	4.872	4.872	4.872
Northern Plains	6.427	6.867	7.388	8.365
Southern Plains	5.394	5.830	5.799	6.085
Mountain	2.911	3.096	3.049	3.113
Pacific	1.741	1.741	1.741	1.741
United States[a]	26.637	26.853	28.248	28.500

[a]Totals may not equal summations over regions because of rounding.

Table 12. Harvested acres of soybeans among the 10 farm production regions for the four alternatives

Farm Production Region	Harvested Acres Under Alternative:			
	A	B	C	D
	(million acres)			
Northeast	0.202	0.202	0.202	0.202
Appalachian	1.543	3.283	1.543	2.977
Southeast	0.923	4.641	0.923	4.334
Delta	4.210	6.830	4.210	4.927
Corn Belt	16.490	29.999	17.771	23.417
Lake	2.043	3.985	2.117	2.539
Northern Plains	2.554	12.061	2.857	7.655
Southern Plains	1.009	2.566	0.965	2.270
Mountain	0.000	0.000	0.000	0.000
Pacific	0.000	0.000	0.000	0.000
United States[a]	28.974	63.566	30.586	48.319

[a]Totals may not equal summations over regions because of rounding.

Table 13. Harvested acres of cotton among the 10 farm production regions for the four alternatives

Farm Production Region	Harvested Acres Under Alternative:			
	A	B	C	D
	(million acres)			
Northeast	0.000	0.000	0.000	0.000
Appalachian	0.490	0.490	0.490	0.490
Southeast	0.483	0.483	0.483	0.483
Delta	2.731	3.421	3.157	3.887
Corn Belt	0.150	0.150	0.150	0.150
Lake	0.000	0.000	0.000	0.000
Northern Plains	0.000	0.000	0.000	0.000
Southern Plains	2.734	2.734	2.734	2.734
Mountain	0.589	0.589	0.589	0.589
Pacific	0.450	0.450	0.450	0.450
United States[a]	7.627	8.317	8.052	8.783

[a]Totals may not equal summations over regions because of rounding.

Table 14. 1973-75 actual average harvested acres of endogenous crops by farm production region

Farm Production Region	Harvested Acres				
	Wheat	Corn	Other FG[a]	Soybeans	Cotton
	(million acres)				
Northeast	0.719	2.295	1.104	0.625	0.000
Appalachian	1.076	3.792	0.559	4.672	0.548
Southeast	0.421	3.334	0.318	3.743	1.050
Delta	0.552	0.239	0.326	9.060	2.842
Corn Belt	5.395	33.357	3.380	27.543	0.238
Lake	3.458	9.800	4.801	4.847	0.000
Northern Plains	26.833	10.060	12.981	2.862	0.000
Southern Plains	10.253	0.934	8.273	0.571	5.022
Mountain	9.449	0.616	4.089	0.000	0.480
Pacific	4.890	0.291	1.992	0.000	1.019
United States[b]	63.046	64.719	37.822	53.923	11.199

SOURCE: [13].

[a]Other FC stands for other feed grain.

[b]Totals may not equal summations over regions because of rounding.

Belt. When soybean exports are expanded (Alternative B and D), the Northern Plains pulls ahead of the Delta region in total acreage. Cotton acreages are consistently largest in the Delta and Southern Plains regions for the alternatives, but in contrast to the 1973-75 averages, the former leads the latter.

Production Levels

Given nearly equal crop demands, acreages are expected to increase when fertilizer application is reduced and yields decrease. Even with the same fertilization level, an increase in crop exports requires greater acres for production. Another indication of interregional comparative advantages is the change in production levels among regions for the various alternatives. Tables 15 through 18 present the changes in production levels for the four grain crops included in the study. The changes in production levels parallel the acreage changes for a given crop and farm production region.

Table 19 summarizes the regional shifts shown in Tables 15 through 18. Using Alternative A as a base for comparison, production above 100 indicates a decrease from corresponding levels in Alternative A. Nationally, for example, Alternative B has a 61 percent larger wheat production than A.

Table 15. Distribution of wheat production among the 10 farm production regions for the four alternatives

Farm Production Region	Production Under Alternative: A	B	C	D
	(million bushels)			
Northeast	54.7	93.8	49.7	84.1
Appalachian	78.3	78.3	96.2	89.3
Southeast	17.0	17.3	15.6	25.8
Delta	7.1	66.2	6.1	110.7
Corn Belt	200.9	145.2	195.8	191.1
Lake	96.0	209.0	89.1	204.7
Northern Plains	583.4	1,218.3	691.1	1,123.3
Southern Plains	365.3	573.5	320.0	501.2
Mountain	280.7	456.1	296.0	403.2
Pacific	219.7	216.2	183.9	183.9
United States[a]	1,903.1	3,073.9	1,943.4	2,917.2

[a]Totals may not equal summations over regions because of rounding.

Table 16. Distribution of corn production among the 10 farm production regions for the four alternatives

Farm Production Region	Production Under Alternative: A	B	C	D
	(million bushels)			
Northeast	117.9	153.9	102.8	133.7
Appalachian	249.3	394.5	210.8	283.4
Southeast	89.0	149.8	60.6	97.9
Delta	7.8	7.8	5.9	5.9
Corn Belt	3,394.5	3,766.5	3,473.5	3,749.8
Lake	446.9	577.8	446.9	588.4
Northern Plains	424.5	652.7	435.2	730.8
Southern Plains	269.6	354.3	226.5	331.3
Mountain	70.5	89.6	79.0	86.3
Pacific	135.8	146.7	130.8	130.8
United States[a]	5,205.9	6,293.7	5,172.0	6,138.3

[a]Totals may not equal summations over regions because of rounding.

Table 17. Distribution of other feed grain (oats; barley and grain sorghum) among the 10 farm production regions for the four alternatives

Farm Production Region	Production Under Alternative: A	B	C	D
	(million corn-equivalent bushels)			
Northeast	29.7	29.7	28.1	28.1
Appalachian	79.6	19.8	15.6	17.3
Southeast	3.1	17.0	2.2	7.6
Delta	46.1	63.3	57.4	57.4
Corn Belt	151.6	104.3	145.8	91.3
Lake	211.8	253.7	228.5	228.5
Northern Plains	389.8	438.4	442.5	544.1
Southern Plains	307.1	335.3	301.6	315.6
Mountain	167.5	190.0	158.5	164.6
Pacific	78.9	78.9	73.4	73.4
United States[a]	1,465.1	1,531.3	1,453.6	1,527.9

[a]Totals may not equal summations over regions because of rounding.

Table 18. Distribution of soybean production among the 10 farm production regions for the four alternatives

Farm Production Region	Production Under Alternative: A	B	C	D
	(million bushels)			
Northeast	5.0	5.0	4.4	4.4
Appalachian	55.5	126.8	53.0	101.4
Southeast	27.4	145.6	25.5	127.4
Delta	126.1	205.5	120.4	140.7
Corn Belt	676.2	1,234.9	681.5	917.5
Lake	64.6	137.0	63.9	78.2
Northern Plains	194.9	603.6	202.3	409.4
Southern Plains	32.2	85.5	29.9	73.9
Mountain	0.0	0.0	0.0	0.0
Pacific	0.0	0.0	0.0	0.0
United States	1,182.0	2,543.9	1,180.9	1,852.9

[a]Totals may not equal summation over regions because of rounding.

Table 19. Endogenous grain crop productions among the 10 farm production regions as compared to Alternative A

Alternative and Crop	Farm Production Region[a]										
	NE	AP	SE	DS	CB	LS	NP	SP	MT	PC	US
B. Wheat	171	100	102	937	72	218	209	157	162	98	161
Corn	131	158	168	100	111	129	154	131	127	108	121
Other feed grain[b]	100	25	556	137	69	120	112	109	114	100	105
Soybeans	100	228	531	163	183	212	310	266	-[c]	-	215
C. Wheat	91	123	92	87	97	93	118	88	105	84	102
Corn	87	85	68	76	102	100	103	84	112	96	99
Other feed grain	94	20	71	124	96	108	114	98	95	93	99
Soybeans	88	95	93	95	101	99	104	93	-[c]	-	100
D. Wheat	154	114	152	1567	95	213	193	137	144	84	153
Corn	113	114	110	76	110	132	172	123	122	96	118
Other feed grain	94	22	247	124	60	108	140	103	98	93	104
Soybeans	88	182	465	112	136	121	210	230	-[c]	-	157

[a]Abbreviations are in the same order as corresponding names in other tables.

[b]Other feed grain is a combination of oats, barley, and grain sorghum.

[c]A slash indicates that the 189 acres in the Mountain region remains constant or no soybean production takes place in the Pacific region.

Fertilizer Usages

With an increase in the fertilizer/crop price ratio in Alternatives C and D, the marginal product of fertilizer must be increased by 66.7 percent for optimization and allocation of fertilizer in terms of its marginal value productivity. This increase in the marginal productivity is achieved by reducing the fertilizer used. Hence, the fertilizer application rates for Alternatives C and D are considerably lower than for

Alternatives A and B. The national average application rates by crop and alternative are shown in Table 20 for the four alternatives.

Table 20. National average application rates on endogenous crops in the 150 producing areas for the four alternatives analyzed

Solution and Crop		Pounds per acre	
	Nitrogen	Phosphorus (P)	Potassium (K)
A. Wheat	59.4	17.3	8.1
Corn	116.7	21.6	38.0
Other feed grain	55.7	15.1	9.7
Soybeans	5.0	22.3	42.2
Cotton	119.3	14.4	21.0
B. Wheat	50.2	15.3	6.7
Corn	120.9	22.4	38.5
Other feed grain	60.5	15.6	9.4
Soybeans	7.8	23.6	40.3
Cotton	115.4	14.4	23.8
C. Wheat	27.7	8.1	3.7
Corn	55.4	10.5	17.9
Other feed grain	33.7	8.1	4.4
Soybeans	3.6	12.9	22.1
Cotton	76.7	8.7	13.9
D. Wheat	23.8	7.1	3.7
Corn	56.9	10.5	16.5
Other feed grain	38.7	8.6	4.5
Soybeans	5.0	13.2	23.4
Cotton	73.9	8.7	15.5

The optimized application rates of nitrogen on soybeans, wheat, and cotton for Alternatives A and B are considerably higher than estimates for recent years. The estimated average rates for 1972-74 on soybeans, wheat, and cotton are 3.3, 29.7, and 57.8 pounds per acre, respectively [5]. Nitrogen applied to corn is slightly above the estimated actual 104.4 pound average for 1972-74. (Comparable data for other feed grain are unavailable).

Using the lower fertilization level (Alternatives C and D), with the marginal value productivity of fertilizer equated to the cost, the nitrogen application levels on wheat and soybeans are more nearly equal to 1972-74 rates. Under Alternatives C and D, corn receives much less nitrogen than during the 1972-74 period, but cotton still receives substantially more than in the three-year period. A higher fertilizer/commodity price ratio and reduced fertilization rates nearly cut application rates of the three nutrients in half in comparison to 1972-74.

Similar results are generated for application rates of phosphorus and potassium. As an average over the period 1972-74, the average application rates of phosphorus on wheat, corn, soybeans, and cotton were 7.5, 24.7, 5.5, and 13.2 pounds per acre, respectively. Average application rates of potassium during this period on wheat, corn, soybeans, and cotton were 5.3, 48.9, 13.5, and 20.6 pounds per acre, respectively. In addition to the changes in fertilization level under the optimization of the programming model, changes in crop demands and interregional comparative advantages lead to differences in application rates under the four alternatives.

Table 21 and 23 contain fertilizer usages for the four alternatives on a farm production region basis.[1] The Corn Belt and Northern Plains regions consume the major shares of the three nutrients under all four alternatives.

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[1]Excluding the areas outside of the 150 producing areas does not significantly effect the usages since the harvested acres excluded are small and generally yield below state averages.

Table 21. Nitrogen usage on endogenous crops by farm production region for the four alternatives[a]

Farm Production Region	Nitrogen Usage by Alternative: A	B	C	D
	(thousand tons)			
Northeast	59.8	89.0	27.2	41.1
Appalachian	232.9	325.6	91.6	93.7
Southeast	135.9	213.8	60.5	97.6
Delta	189.0	274.7	144.9	216.4
Corn Belt	2,168.9	2,420.6	1,201.2	1,318.6
Lake	327.4	476.6	184.0	254.9
Northern Plains	1,117.1	1,818.2	779.0	1,116.5
Southern Plains	728.6	909.8	426.8	535.5
Mountain	248.7	379.4	128.6	163.7
Pacific	299.2	305.1	117.0	117.0
United States	5,561.5	7,212.8	3,160.8	3,955.0

[a]Excluding usages outside of the 150 producing areas.

Table 22. Phosphorus (P) usage on endogenous crops by farm production region for the four alternatives[a]

Farm Production Region	Phosphorus Usage by Alternative A	B	C	D
	(thousand tons)			
Northeast	22.6	33.3	10.5	16.4
Appalachian	90.4	121.3	45.4	56.0
Southeast	33.5	79.6	14.8	38.3
Delta	50.1	88.3	34.3	50.9
Corn Belt	626.3	842.2	343.7	413.2
Lake	117.6	184.8	68.5	93.2
Northern Plains	282.4	562.2	192.7	280.9
Southern Plains	190.7	244.0	108.2	137.5
Mountain	75.9	111.4	33.5	39.6
Pacific	15.1	16.0	4.9	4.9
United States	1,504.6	2,283.1	856.5	1,130.9

[a]Excluding usages outside of the 150 producing areas.

Table 23. Potassium (K) usage on endogenous crops by farm production region for the four alternatives[a]

Farm Production Region	Potassium Usage by Alternative: A	B	C	D
	(thousand tons)			
Northeast	41.9	60.6	19.3	29.6
Appalachian	151.6	231.3	67.8	92.6
Southeast	79.4	203.8	34.9	96.9
Delta	107.8	190.7	79.0	108.8
Corn Belt	1,208.5	1,635.4	630.1	776.9
Lake	132.4	241.9	72.9	111.6
Northern Plains	177.8	299.1	126.0	155.3
Southern Plains	58.6	82.5	35.4	49.3
Mountain	10.6	14.9	7.1	7.6
Pacific	16.5	18.1	2.0	2.0
United States	1,985.3	2,978.3	1,074.5	1,430.6

[a]Excluding usages outside of the 150 producing areas.

Alternatives A and C have nearly identical crop production. However, lower fertilization rates in C results in substantial reductions in fertilizer use, as compared to A. Nitrogen usage in C, 3.2 million tons, is 56.8 percent of the amount used in A. Phosphorus and potassium useages in C are 56.9 and 54.1 percent, respectively, of the amounts used in A. Even though grain production is lower in Alternative D than in B, the differences in fertilizer usages are even more impressive.

V. SUMMARY

American farmers have experienced a vastly different fertilizer situation since the fall of 1973 when fertilizer prices began increasing tremendously. These price increases have brought the long-run real price of fertilizer in line with real prices for other inputs of nonfarm origin. The first reaction to these higher fertilization rates in 1973-74 was to reduce rates of application. However, levels of usage have recovered some since that time.

Fertilizer production is expanding in the United States, but manufacturers are reluctant to increase capacity to levels which would lead to overproduction and price depression. Also, natural gas supplies are limited and may constrain future fertilizer production.

Both the United States and the world face an uncertain future with respect to fertilizer supplies and prices. Controlled and declining supplies of petroleum and natural gas could have a severe impact on fertilizer availability and prices. The energy outlook suggests that the real price of fertilizer, especially nitrogen, is almost certain to rise in the future.

This study has been made accordingly. It examines crop production, land use and fertilizer application on a regional basis under conditions where exports and fertilizer availability are varied. In one case, the amount of fertilizer available to farmers is reduced to such an extent that the fertilizer/commodity price ratio is increased by 66.7 percent.

Fertilizer then is allocated within a programming system so that its marginal value productivity of fertilizer is equated to its cost. This system, rather than an outright rationing or physical allocation of fertilizer, is used in those alternatives assuming a reduced fertilizer supply.

A national linear programming model minimizes production and transportation costs in meeting specified crop demands for the four alternatives analyzed. Alternatives A and B incorporate a high fertilization level with the latter (B) producing a higher level of crop exports. The lower fertilization level is assumed for both Alternatives C and D but D has a much higher level of exports. Alternative D is formulated to use about the same amount of land in production as that used in Alternative B. (See Table 5).

Endogenous crop yields especially reflect the amount of fertilizer applied and the total national crop acreage used in production. Wheat yields per acre in bushels fall from the low 40's to the high 30's when national fertilizer use is lessened. Similarly, at the national level, corn yields per acre in bushels decline from the high 90's to the high 80's and soybeans from around 40 bushels per acre to the high 30's.

The substitution of land for fertilizer is possible at low levels of crop exports. Alternatives A and C have nearly identical crop production, but more land and less fertilizer is used in Alternative C. A total of 18.1 million acres replaces 2.4 million tons of nitrogen, 0.6 million tons of phosphorus and 0.9 million tons of potassium in Alternative C as compared to Alternative A. Crop production levels in Alternative D are below the levels in Alternative B, although nearly the same amount of land is used for both alternatives. In Alternative D, with reduced fertilization levels, domestic demands for the endogenous crops are slightly lower than in Alternative B while exports of corn, wheat, and soybeans are each reduced 150 million bushels below B levels.

Supply prices for crops are lowest under Alternatives A and C with their low export levels. They are highest under Alternative D with its high export level and lower level of fertilizer use.

As the marginal value productivity of fertilizer is equated to the cost in the 150 producing areas used in the analysis, a smaller use of fertilizer is indicated under Alternatives C and D with their lower fertilizer/crop price ratios. Fertilization rates under Alternatives C and D tend to be about half those of Alternatives A and B as the fertilizer/crop price ratio is increased under the former two alternatives. Crop yields and production do not decrease in the same proportion as fertilizer use since diminishing marginal productivity prevails in fertilizer use.

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