AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D. C. 20523

BIBLIOGRAPHIC INPUT SHEET

FOR AID USE ONLY
Batch 54

1. SUBJECT CLASSIFICATION

A. PRIMARY
Food production and nutrition

AE10-0000-G430

B. SECONDARY
Agricultural economics--USA

2. TITLE AND SUBTITLE
A world food analysis: grain supply and export capacity of American agriculture under various production and consumption alternatives

3. AUTHOR(S)
Heady,E.O.; Faber,D.C.; Sonka,S.T.

4. DOCUMENT DATE	5. NUMBER OF PAGES	6. ARC NUMBER
1975	88p.	ARC

7. REFERENCE ORGANIZATION NAME AND ADDRESS
Iowa State

8. SUPPLEMENTARY NOTES (Sponsoring Organization, Publishers, Availability)
(In CARD rpt.,60)

9. ABSTRACT

This analysis examines several alternatives in American agricultural production and consumption patterns as they relate to recent concern and emphasis on the world food situation which has raised questions about the crop exporting capacities of the U.S. Dietary adjustments in any of the following would make it possible to increase U.S. grain exports by 1980: (1) level of meat consumption, (2) substitution of soy protein for animal protein, (3) substitution of silage for feed grain and, (4) allocating crop production among regions in an optimal comparative advantage method. These alternatives are examined and quantitative estimates are made. Potential prices and production for American farm commodities are examined, and estimates are made which assume that consumption patterns of the American public will shift in response to higher meat prices caused by higher livestock feed prices. This analysis indicates that U.S. agriculture has great capacity and flexibility in grain and food production. If the world's food situation is to improve, however, there must be policies and institutions which will guarantee U.S. farmers prices that cover production costs and give market level returns to their resources.

10. CONTROL NUMBER
PN-AAD-442

11. PRICE OF DOCUMENT

12. DESCRIPTORS
Exports
Food supply
Grain crops
Livestock
Models
Production engineering
USA

13. PROJECT NUMBER

14. CONTRACT NUMBER
CSD-2824 211(d)

15. TYPE OF DOCUMENT

AID 590-1 (4-74)

A WORLD FOOD ANALYSIS: GRAIN SUPPLY AND EXPORT CAPACITY OF AMERICAN AGRICULTURE UNDER VARIOUS PRODUCTION AND CONSUMPTION ALTERNATIVES

by

Earl O. Heady
Doeke C. Faber
Steven T. Sonka

CARD REPORT 60

The Center for Agricultural and Rural Development
Iowa State University
Ames, Iowa 50010
September 1975

TABLE OF CONTENTS

	Page
LIST OF FIGURES	iv
LIST OF TABLES	v
I. INTRODUCTION	1
Objectives of This Analysis	4
Limited study objectives	8
Intent of study	10
Goals and Alternatives Analyzed	11
Description of the Programming Model	15
Regional Delineations	24
Livestock Consumption	26
II. RESULTS	28
National Acreage, Output, and Yields	28
Alternative A, 1971-73 export proportions	30
Alternative B, emphasis on soybean and feed grain exports	32
Alternative C, emphasis on wheat exports	33
Alternative D, substitution of silage for grain in beef production	34
Alternative E, 25 percent substitution of vegetable for animal protein	37
Alternative F, 25 percent reduction in per capita meat consumption	38
Alternative G, simultaneous application of the previous variants	39
Regional Distribution of Production	40
Regional distributions under Alternative A	41
Regional distributions under Alternative B	47
Regional distributions under Alternative C	48
Regional distributions under Alternative D	48
Regional distributions under Alternative E	48
Regional distributions under Alternative F	49
Regional distributions under Alternative G	50

	Page
Supply Prices	50
Alternative A prices	52
Alternative B prices	52
Alternative C prices	53
Prices of other alternatives	54
Export Capacity	55
Alternative A exports	55
Alternative B exports	58
Alternative C exports	58
Alternative D exports	58
Alternative E exports	59
Alternative F exports	59
Alternative G exports	60
Price and program caution	60
III. SUMMARY AND POLICY REQUIREMENTS	62
Policy Requirements	72
APPENDIX: MATHEMATICAL STRUCTURE OF THE MODEL	75
REFERENCES	79

LIST OF FIGURES

		Page
1.	Direct and indirect grain consumption by per capita income, selected countries.	7
2.	Location of rural areas and farm production regions used in this study.	23
3.	Location of consuming regions used in this study.	25
4.	Estimated production and exports of wheat, feed grain, and soybeans for each model alternative (expressed in millions of tons of feed units).	31
5.	Estimated silage production for each model alternative (in million tons).	36
6.	Estimates of wheat, feed grain, and soybean exports for each model alternative (in millions of tons of feed units).	56

LIST OF TABLES

		Page
1.	Index numbers of world and per capita food production, 1961-65=100.	2
2.	U.S. exports of wheat, feed grains, and soybeans in specified years.	4
3.	Alternative situations analyzed.	16
4.	Estimates of per capita consumption and prices for selected livestock products.	27
5.	Estimated production, acreages, and yields for each of the model alternatives with 1971-73 values for comparison.	29
6.	Estimates of harvested acres for wheat for each of the model alternatives for the United States and for each of the ten farm production regions with 1971-73 figures for comparison.	42
7.	Estimates of harvested acres for feed grains for each of the model alternatives for the United States and for each of the ten farm production regions with 1971-73 figures for comparison.	43
8.	Estimates of harvested acres for soybeans for each of the model alternatives for the United States and for each of the ten farm production regions with 1971-73 figures for comparison.	44
9.	Estimates of harvested acres for cotton for each of the model alternatives for the United States and for each of the ten farm production regions with 1971-73 figures for comparison.	45
10.	Estimates of harvested acres for silage for each of the model alternataves for the United States and for each of the ten farm production regions with 1971-73 figures for comparison.	46
11.	Supply prices for the seven alternatives in 1972 and 1974 dollars.	51
12.	Estimated exports for each model alternative with 1971-73 average exports for comparison.	57

I. INTRODUCTION

Widespread starvation in countries such as India, Bangladesh, and those bordering the Sahelian desert, and rapidly rising retail food prices in the developed nations, have led to doubts about the ability of the world's agriculture to cope with present and future food needs. These events provide new support for the pessimistic Malthusian viewpoint that the world population will only be able to sustain itself if some major catastrophe occurs, such as widespread famine caused by "acts of God" or otherwise.

However, in recent studies by Gasser [10], Economic Research Service [7], and Blakeslee, Heady and Framingham[2], one observes that total world food statistics do not give us nearly such a bleak outlook. Although the world population has been increasing at a rate of 2 percent per annum, world food production has increased steadily at a rate of 2.8 percent, thus exceeding population growth by 0.8 percent since 1954 [10, p. 1]. In addition, the rate of growth of food production in less developed countries (LDC's) has increased faster and, in fact, has surpassed the growth rate in the developed countries (DC's). But, on a per capita basis, the LDC's have a smaller rate of growth in food availability because of the high birth rate in these countries. Table 1 shows that, although food production has increased considerably in the last 12 years (33 percent), per capita food production has only increased 7 percent.

Why, then, does it appear as if the world food situation has been transformed from one of food surplusses -- as we knew it before 1972 -- to one of relative food scarcity and high prices? Several propositions about world food scarcity have been advanced, all representing judgments with

Table 1. Index numbers of world and per capita food production, 1961-65=100.

Item	Year											
	1961	'62	'63	'64	'65	'66	'67	'68	'69	'70	'71	'72
World Food Prod.	94	98	100	104	105	109	114	117	118	122	126	125
Per Cap. Food Prod.	98	100	100	102	101	103	106	107	105	106	108	105
U.S. Food Prod.	95	96	101	102	105	107	115	115	115	114	124	122
U.S. Per Cap. Food Prod.	98	98	101	101	102	103	110	109	107	105	113	110

Source: Production Yearbook [23].

respect to severity and duration of the problem, the probable causes of the problem, and how it might be corrected. Mackie in a recent article [16] mentions four causes for the phenomenon:

1. disappointing crops because of adverse weather conditions in major world regions,
2. increases in world-wide demand because of increases in affluence and population growth,
3. limited technology, and
4. U.S. dollar devaluations.

Although there is little doubt that the above factors have contributed to the present situation, there is reason to believe that part of their contribution is transitory, although possibly having a permanent component fixed to them [13]. Taking into account weather cycles and other data pertaining to the above four factors, it seems that their simultaneous occurence was extremely unusual.

It may be useful to briefly examine the first two points mentioned by Mackie. Because of poor anchovy fish harvests off the coast of Peru and

adverse weather conditions elsewhere, demand indeed seems to have taken a quantum jump upwards. However, as noted in CARD Report 50, "total world food demand generally does not leap from the trend line in a stair step jump in the span of a year or two" [15]. Indeed, it seems that demand changes occur rather gradually as do the major variables (per capita income and population growth) which are most closely allied with food demand. Both per capita incomes and population have gradual and continuous inter-year changes (except in years of major depression or recession).

Because of the importance and role of the United States in world grain trade, however, jumps in the demand for American farm products can occur because of the stochastic nature of trade. The United States is the world's largest "marginal" food exporter. Because its food producing capacity is so great, and because it does export such a large proportion of its production, weather conditions elsewhere in the world can have a very great impact on U.S. export demand. A crop shortfall or supply decline in a country such as Russia, with a large population and meager grain stock facilities, can become a very large increment in export demand for U.S. farm products. When weather and yields worldwide are favorable, however, demand for exports from the United States also can decline sharply within the span of a single year. As mentioned, adverse weather conditions elsewhere in the world add to the demand for U.S. grain reserves. And it appears that poor weather was a primary reason that the East block countries, and Russia in particular, entered the market for wheat in 1972. Purchases from this group of nations contribute greatly to the variability of demand for U.S. farm products. Mackie notes that the purchases of these countries explain about 90 percent of the erratic behavior or recent United States grain trade [16].

Recent fluctuations in exports and world markets have had an impact on U.S. agriculture. During 1973, the United States exported a record quantity of cereals (Table 2) and at the same time experienced record farm commodity prices. In 1974, U.S. agricultural exports again rose to a record level of $22 billion dollars, one-fourth above the 1973 level. But the increase in dollar value was totally because of higher prices, as the total volume of

Table 2. U.S. exports of wheat, feed grains, and soybeans in specified years.

Commodity	1969-73	1971-73	1973	1974
Wheat (mil. bu.)	862.0	979.8	1423.0	980.0
Feed grains (mil. ton)	29.1	31.7	45.9	37.6
Soybean (mil. bu.)	448.0	450.2	485.8	523.3

Sources: Economic Research Service [5]

exported commodities fell from 1973 levels. The value increases were mostly experienced in soybeans and soybean oil, wheat, feed grains, and cotton. But, even though the value of exports rose, net farm income fell by $5 billion from 1973 because of sharp increases in production costs not completely offset by higher prices [6].

The above figures emphasize the price and income effects that export levels have on U.S. agriculture. And, although the short-run outcome of the present situation is indeed critical, it is important to look ahead and analyze the possible implications for U.S. agricultu whether the current situation persists or proves to be only temporary.

Objectives of This Analysis

The recent concern and emphasis on the world food situation, including the World Food Conference held in Rome in 1974, has raised many questions

relative to the crop exporting capacities of the United States and other countries. There are many ways in which exportable quantities of food could be increased. Important groups and world leaders have recently and frequently asked why shifts in food uses and the resources used to produce food have not occurred to allow greater exportable quantities of grain and thus an upgrading of human diets over the world. Some persons suggest that developed countries could eat less livestock products, thus freeing grain for export purposes. The amount of grain required to produce a given caloric or protein level through livestock is, of course, much greater than the amount required if the grains were consumed directly by humans. Grain usage per capita in the more affluent countries, such as Canada, United States, West Germany, England, and the U.S.S.R., is very large because of the large proportion of grain processed through livestock. In contrast, in the LDC's, total grain used per capita is only slightly greater than that consumed directly as food per capita. These differences are emphasized in Figure 1. In countries such as China and India, the quantity of grain fed to livestock is so small, and such a vast proportion of human food is direct consumption of grain, that grain use per capita is both (1) small and (2) only slightly greater than direct food use. In contrast, in countries such as Canada and the United States, both (1) total grain use per capita is vast because the major proportion of it is processed through livestock, and (2) the amount of grain consumed directly as food is small.

Because of these great differences in grain usage and because a redistribution of grain among livestock and people over the world would have a vast impact on increasing the amount of food available to humans, numerous people ask why this should not be done. It is, of course, only one of

numerous production and consumption adjustments in agriculture that might be made to increase per capita food supplies the world over.

Another possible means is to change the composition of diets or rations of livestock themselves. For example, possibilities do exist for using a greater proportion of forage and a smaller proportion of grain in the ration of ruminants. This could be feasible through several types of adjustments. One way to substitute forages for grain in livestock production would be a greater use of harvest aftermath, or crop residues, from feed grains and wheat. Only a small fraction of dry corn stalks is used for this purpose, and the proportion of wheat, grain sorghum, and barley straw so used is a relatively small proportion of that available. Experiments and farmer experience have proven that the cellulose in these residues, supplemented by protein in urea, serve successfully as feeds [33; 38]. Rather than to feed the residues after grain harvesting, when stalks or straw have become dry and brittle, another method, of course, is simply to make silage from corn and grain sorghum so that the whole plant is fed and a greater proportion of it is forage.

Experiments and experience indicate that using crop residues is an efficient and feasible way to increase the feed productivity of land and to produce beef with a feed mix represented by a greater proportion of forage [3; 8; 9; 11; 12; 18; 24; 32]. Also, results from previous national programming models have shown that very large savings might be made in the amount of grain required to produce the nation's beef supply if a much larger amount

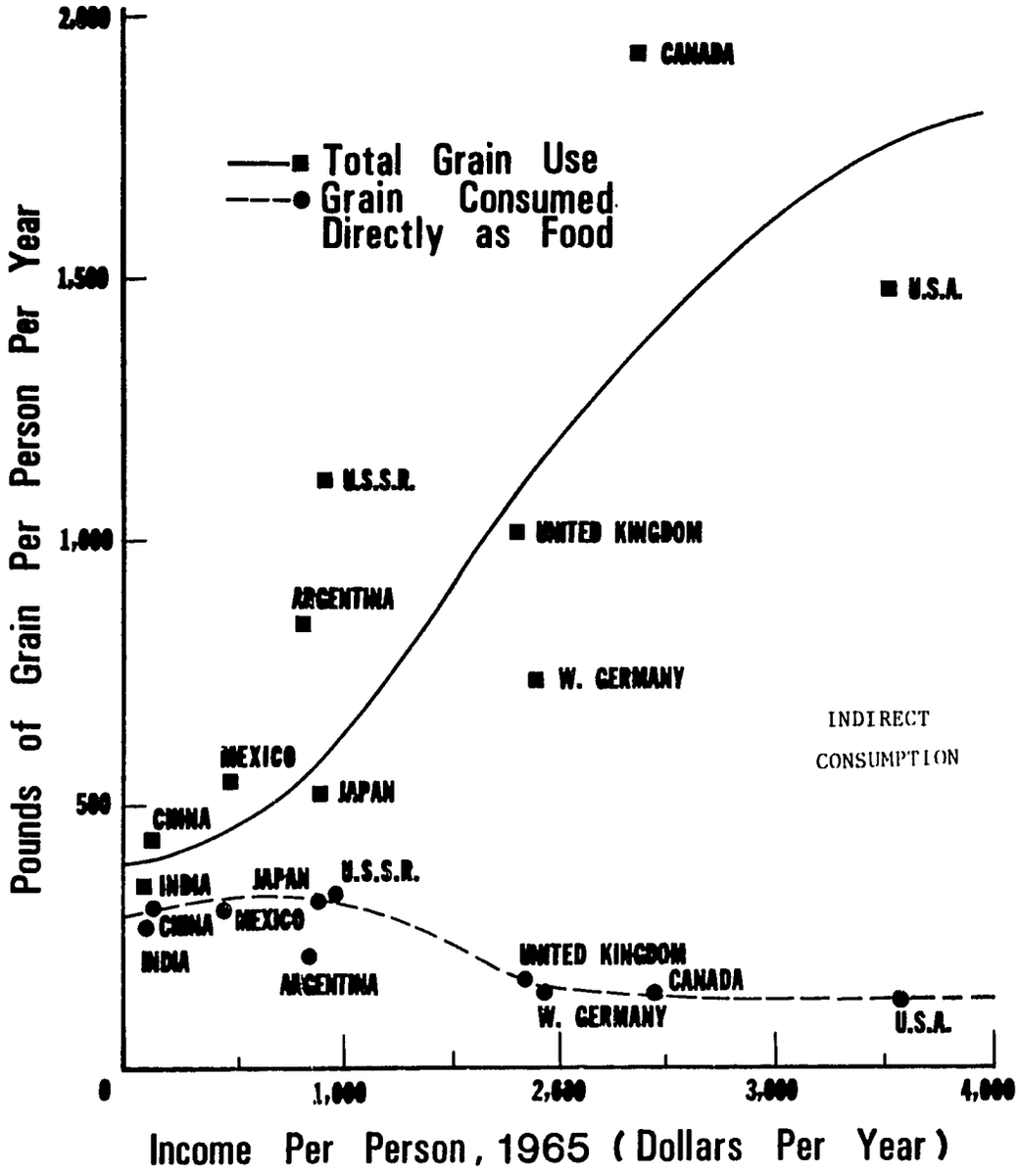

Figure 1. Direct and indirect grain consumption by per capita income, selected countries.

of silage was used in the ration [4; 19; 21].[1]

There are numerous other ways by which U.S. output of food could be increased for export to hungry nations, if both this nation and the rest of the world were serious about doing so. This seriousness would need to be reflected by the creation of institutions, market schemes, and other methods which would continue a viable export market and stabilize prices at a level whereby American farmers did not sacrifice during years of surplus. One approach would be greater investment in research. Another would be to lower the price of inputs relative to commodities. Another one, still with some great promise in the United States, would be to allocate irrigation water where it has the greatest margin of productivity (rather than so much on the basis of "rights" mechanisms) and to allocate all resources and crops interregionally in accordance with their comparative advantage. Various CARD models have shown these possibilities [14; 21].[2]

Limited study objectives

While many means exist for producing more food and increasing the supply of grain available for export from the United States, the objectives of this study are more limited. We estimate that increases in U.S. grain exports

---

[1] In all of these models, the use of silage proved to be an efficient means of beef production (in relevant rotations) and only where equations of restraints on silage use were included, much more of the land was kept from being so allocated and beef so produced.

[2] Water is allocated more nearly in terms of historic legal rights rather than marginal productivity. To shift to a marginal productivity system would, of course, have a cost in asset value to those who would lose rights and a capital gain value to those who received the water. Hence, it could be politically feasible only on a full capital value compensation basis.

would be possible in 1980 if any one of three dietary adjustments were made: (1) substituting soy protein for 25 percent of the meat consumed by U.S. consumers; (2) reducing meat consumption in the United States by 25 percent; and (3) substituting silage for 25 percent of the grain used in producing beef in the United States. We also examine export possibilities when all of these alternatives are applied simultaneously.

We also consider export possibilities when (1) exports might be oriented more to the developed and affluent countries, therefore emphasizing feed grain, and (2) exports might be more oriented to the poorer nations with many undernourished persons, thereby emphasizing wheat. An auxiliary objective of the analysis is the application of a linear programming model that allows crop production (but not water) to be allocated among regions in line with comparative advantage and the attainment of the greatest economic production when yields, production costs, and transport costs are considered. The model used assumes a market equilibrium where all factors receive their market price and where production is organized over the nation to minimize costs of production and transportation of all commodities.

As mentioned previously, the study has been made to help answer the query of many people: How much more food could the United States produce for export to a hungry world and how could it be done? Of course, it shouldn't be done unless all countries and world organizations become serious enough to create market conditions and institutions that would allow more to be produced and exported from the United States at prices that are realistic in terms of factor costs and farmer incomes. Given these conditions, however, the United States could increase output and exports very considerably in the years ahead. We illustrate the possibilities with four simple adjustments:

(1) in level of meat consumption, (2) in substitution of soy protein for animal protein, (3) in substitution of silage for feed grain and, (4) in allocating crop production among regions in an optimal comparative advantage method.

Intent of study

The authors do not propose that the alternatives examined in this study be implemented. Rather, these alternatives are examined in response to proposals that have been made by various national and world leaders relative to U.S. agricultural production and consumption. Quantitative estimates are made so that national and world authorities can have better knowledge of the quantities and price relationships consistent with such proposals. Knowledge of these relationships is necessary to foresee which programs would have to be implemented if these changes were to come about in a manner profitable to food producers and acceptable to consumers in the United States.

In this study we examine potential prices and production for American farm commodities supposing, as many U.S. and world leaders emphasize, that the present world demand for these products will remain high. This supposition assumes that the countries of the world will have enough ongoing ingenuity and sincerity to create means of utilizing increased output in moving it to the poorer countries and undernourished people of the world. Estimates are made assuming differing export policies and assuming that consumption patterns of the American public shift in response to higher livestock prices caused by higher livestock feed prices.

Goals and Alternatives Analyzed

As discussed previously, many questions about this nation's ability to produce food and the potential export demand for this food output have prevailed recently. In this analysis, we attempt to answer only the first of these questions in relation to a limited number of changes in American agriculture. As cautioned previously also, we believe it is a relevant question only if countries of the world and international organizations establish market and institutional means which guarantee favorable prices for U.S. farmers if they are to be requested to produce more food to meet world hunger needs. In recent years, U.S. farmers and consumers have been subjected to wide price fluctuations, in part caused by the policies of both the United States and other countries. U.S. policies, including vast and quickly executed sales of public stocks to Russia and independent action of private grain traders, have been an important element behind these gyrations, but so have the policies of other countries. Many are either unable or unwilling to invest in reserve grain stocks and thus must reach into the international markets in years of their own crop shortfalls. Another factor contributing to international market instability is the policy of some countries to employ high tariffs or other barriers in years of abundant domestic production, but to lower these barriers and increase imports in years of shortages in domestic production. Problems such as these, causing extreme price, and income fluctuations to fall on American farmers and consumers, must be eliminated before the world should expect the United States to "go all out" in food production for the world. Our analysis of how much exports can be increased under selected adjustment in U.S. agricultural and consumption patterns assumes that such problems can and will be

solved before the United States actually implements continuous, year-after-year, "all out" food production.

Although the year of reference for the study is 1980, the results can be interpreted as relating to an "average" year in the next decade. Emphasis in the report on the supply side of the nation's food production certainly does not imply that the demand question is any less important. Indeed the question of potential demand, and the distinction between market demands and world food needs, is extremely important and requires clarification. By examining potential supply quantities for various alternatives, however, we hope to quantify what "all out production" can be and some of the variety of forms that "all out production" might take. A further goal of the analysis is to show what commitment (in costs of production) farmers would need to make if they farmed from "fence-row to fence-row."

Seven alternative situations are examined for the year 1980 in this study. These seven alternatives can be divided into two subsets which relate to two separate, basic issues. The first subset assumes "all out production" but allows the mix of grains exported (wheat, feed grains, and soybeans) to vary. In this subsection, the effects on American agriculture of differing demands for each of the crops are compared. This subset contains three alternatives. In the second set of alternatives, it is assumed that actions are taken to shift grains from livestock production to the export market in order that more hungry people of the world can be fed (by consuming grain directly). This subset supposes that the countries of the world organize markets, institutions, and programs which are effective in diverting more of the U.S. grain exports to human foods and improving nutrition in poor countries. These actions include changes in the

feeding methods for beef and shifts in the consumption patterns of the American public. This subsector includes four model alternatives.

The seven situations analyzed in this report will be referred to as Alternatives A through F. The first of these, Alternative A, serves as a base situation for the other six. For Alternative A, domestic demands are first satisfied and then exports of wheat, feed grains, and soybeans are expanded until the land base available for these crops is fully utilized. In this manner, potential production capacity in each instance is tied to the nation's land base. For Alternative A, the export proportions of the three grain commodities are forced to equal their actual export mix for the years 1971-73. Cotton lint exports are fixed at 4.2 million bales for all of the situations analyzed.

The remaining two alternatives of the first subset, Alternatives B and C, allow the grain export mix to shift considerably. For Alternative B, wheat exports are forced to remain at the 1971-73 average level while exports of feed grains and soybeans expand to utilize the model's marginal productive capacity. This alternative would be consistant with an affluent world's demand for grains to feed livestock and a relatively low demand for food grains. It would suppose the world's richest and most developed countries dominate international export markets for grain to increase their consumption of meat. The alternative associated with Alternative C represents the opposite view of the world economy in the future. Here feed grain and soybean exports are held at 1971-73 average levels, and wheat exports are allowed to expand. The situation described here is consistant with a world desperately in need of food grains for human consumption, the major problem emphasized at the Rome Food Conference.

In the second subset of alternatives, the export mix for grains remains constant at the 1971-73 average level. In this part of the analysis, the effects of shifts of grain from the livestock feed sector to the export market are examined. Undoubtedly, some readers are interested in the combined effect of these shifts and a different export mix. Those combinations, however, are not detailed in this manuscript. Although these combinations would be relatively simple to handle computationally, the authors chose not to because of the considerable amount of data that would be generated in the process and the length which would be added to the report. It was felt that too many alternatives and too many numerical estimates could serve to cloud the major implications of the analysis.

For Alternative D, a shift within the farming industry itself is proposed. Since recent research shows that more beef animals can be fed per acre with corn silage than with grain [11], the effects of an increased use of corn silage are examined. A rather modest substitution of silage for grain in beef production, 25 percent over trend levels, is assumed for this situation. Acreage freed from grain production by this shift is then diverted to the production of grains for export.

Changes in the consumption patterns of the American public are hypothesized in the remaining three alternatives. The source of protein consumed is altered in Alternative E. For this circumstance, the consumption of meat (beef, pork, broilers, lamb, and turkeys) is forced to decline by 25 percent from projected levels but is fully substituted by consumption of vegetable protein. For this analysis, soybeans are assumed to be the source of this vegetable protein.

As in Alternative E, Alternative F also assumes meat consumption to decline by 25 percent from projected levels. In the latter alternative (F), however, the reduced meat is not replaced by soy protein; rather Americans would eat less. Discussion with a nutritionist assures us that reductions of this magnitude would not (on the average) present health problems to the nation's populace.[3]

In the remaining situation described in this manuscript, Alternative G, the substitutions assumed individually for Alternatives D, E, and F are forced to occur simultaneously. For this scenario, Americans are assumed to consume 25 percent less protein from meat sources. Then 25 percent of the remaining protein from meat would be replaced with soy-protein substitutes. The remaining demand for grain by beef would be reduced by a 25 percent substitution of silage. The results of Alternative G, then, show the cumulative effect of these substitutions. To better depict the seven situations examined in the study, each alternative and its basic assumptions are outlined in Table 3.

Description of the Programming Model

We describe the model used to derive the solutions and provide the basis for the different alternatives in this section. Readers interested only in the results and their implications may wish to turn immediately to the Livestock Consumption section.

---

[3]Private communication with Dr. Thelma J. McMillan, Professor of Food and Nutrition Iowa State University, Ames, Iowa.

Table 3. Alternative situations analyzed.

	Alternative Situations						
	A	B	C	D	E	F	G
Grain exports	1971-73 average proportion	Wheat at 1971-73 average quantities; feed grains and soybeans expanded	Feed grains and soybeans at 1971-73 average quantities; wheat expanded	1971-73 average proportions	1971-73 average proportions	1971-73 average proportions	1971-73 average proportions
Beef feeding patterns	Trend level feed mix	Trend level feed mix	Trend level feed mix	25 percent of the beef demand for feed grains replaced by silage	Trend level feed mix	Trend level feed mix	25 percent of the beef demand for feed grains replaced by silage
Vegetable protein consumption	Trend level	Trend level	Trend level	Trend level	25 percent of the projected animal protein demand replaced with vegetable protein	Trend level	25 percent of the projected animal protein demand replaced with vegetable protein
Animal protein (meat) consumption	Projected levels[a]	Projected levels	Projected levels	Projected levels	25 percent cutback from projected levels	25 percent cutback from projected levels	25 percent cutback from projected levels

[a] Here projected levels refer to per capita consumption estimates presented in the Livestock Consumption section of the report.

A linear programming model is used to estimate the base data for this analysis. This national model describes the wheat, feed grain, silage, soybeans, and cotton production sectors of American agriculture. It incorporates an interregional comparative advantage production sector, a transportation submodel, and fulfillment of consumer demands in 31 market or consuming regions. Costs of production, crop yields, and consumer demands for the model are based on parameters estimated for the year 1980.

The programming model minimizes the cost of producing its endogenous commodities (wheat, feed grains, silage, soybeans, and cotton) in 150 rural areas and of transporting them among 31 consuming regions. (The concept of a "rural area" and the regional delineations used in this analysis are given in the following section.) The model simulates production equilibrium in that the supply price of each crop commodity must cover the cost of producing that commodity in each rural area. Market equilibrium is simulated in that the quanitity of each commodity supplied must equal the demand for that commodity in each consuming region.

Demands for spring and winter wheat, feed grains, silage, and oilmeals are specified for 31 consuming regions. The demand for cotton lint, however, is specified only at the national level. The demand levels specified for these five commodities (spring and winter wheat, feed grains, oilmeals, silage, and cotton lint) are the summation of their estimated use as seed, livestock feed, domestic food, industrial inputs, and exports---both in raw and processed forms.

Transportation activities are defined to allow the production of a commodity in one consuming region to be used to satisfy the demand for that

commodity in another consuming region. Potentially there exist 31 x 30 = 930 transportation activities for each of the commodities for which regional demands are specified, or a total of 4 x 930 = 3720 potential transportation activities. (Transportation activities are only defined for spring and winter wheat, feed grains, and oilmeals.) Patterns of historic grain movements and regional production potentials are used to reduce the number of transportation activities to 202 for spring wheat, 467 for winter wheat, 458 for feed grains and 476 for oilmeals. Rail rates reflect transportation costs between all consuming regions. No transportation costs are defined from the rural area to the center of its consuming region.

The production and demand for spring and winter wheat, feed grains, and oilmeals are determined on a feed unit basis. Use of the feed unit concept allows the aggregation of the four feed grain crops (barley, corn grain, oats, and grain sorghum) to a single commodity. It also allows the demand for oilmeals to be satisfied by the production of either soybean oilmeal or cottonseed oilmeal.

The programming model contains 307 equations and 2,214 real variables. Land in the 150 rural areas and demands specified by the 31 consuming regions (plus the national cotton lint demand) serve as constraints for the equations. The real variables include crop production and transportation activities.

Output of the programming model is used to provide data regarding the location of production and supply prices for feed grains, wheat, soybeans, silage, and cotton for each of the alternatives. By expressing the model in its algebraic form, the method in which this information is obtained is more readily apparent. In this cost minimization model, the objective of the production problem is to find a set of x's such that the function:

$$f(c) = cx \qquad (1.1)$$

is a minimum subject to the following restraints:

$$Ax \geqq b \tag{1.2}$$

$$x \geqq 0 \tag{1.3}$$

where:

x is a column vector of production, transfer, and transportation activities;

c is a row vector of unit costs for those activities;

A is a matrix of transformation or input-output coefficients; and

b is a column vector of resource restraints and demand requirements.

The allocation question is resolved using the system represented in Equations 1.1, 1.2, and 1.3. The pricing question is solved using the dual formulation of that system. The dual problem can be described as:

$$\text{Maximize} \quad g(p) = pb \tag{1.4}$$

subject to:

$$pA \leqq c \tag{1.5}$$

$$p \geqq 0 \tag{1.6}$$

where:

p is a row vector of land rents and supply prices for the products and

b, A, and c are defined previously.

The complete mathematical model is reported in the Appendix.

Except for the silage sector and the model's land base, this programming model is detailed in Sonka and Sonka and Heady [25; 26]. For this report, however, production activities and demands for silage have been added to the programming model. To determine cost and yield coefficients for the

silage activities, coefficients have been modified to be compatible with the programming model used here [20; 21]. The following equation describes the process by which silage cost and yields are generated for each of the model's 150 rural areas:

$$S^k_{2j} = S^k_{1j/FG_{1j}} \; FG_{2j} \tag{1.7}$$

where:

S^k_{1j} is the silage cost (or yield) coefficient in the jth rural area from [20; 21] for the kth silage type;

S^k_{2j} is the silage cost (or yield) coefficient in the jth rural area for this programming model for the kth silage type;

FG_{1j} is the feed grain cost (or yield) coefficient in the jth rural area from [20; 21];

FG_{2j} is the feed grain cost (or yield) coefficient in the jth rural area for this programming model [25; 26];

j is equal to 1,...150

k is equal to 1 for corn silage and 2 for grain sorghum silage.

Composite silage cost and yield coefficients are generated as in Equation 1.8:

$$C_j = (A^1_j \; S^1_{2j} + A^2_j \; S^2_{2j} \; M) \; / (A^1_j + A^2_j) \tag{1.8}$$

where:

C_j is the composite cost (or yield) coefficient for silage in the jth rural area;

M is the ratio of net energy in grain sorghum silage divided by the net energy in corn silage as given in Morrison [17];

A_j^k is the acreage of silage type k grown in the jth rural area as given in the U.S. Census of Agriculture [36]; and

S_j^k, k, and j are as defined previously.

To determine the normal demand for silage in 1980, an equation is needed which incorporates both beef and dairy cattle numbers and allows a growing substitution of silage for grains. This equation is given below:

$$D_S^N = 1.365 \text{ GCAU} + 3628.0 \text{ time}$$

where:

D_S^N is the estimated trend demand for silage (expressed in tons);

GCAU is the estimated number of beef and dairy animals (expressed in grain-consuming animal units) required to satisfy the per capita demands specified for beef and milk; and

Time is time in years, 1 = 1952, 2 = 1953..., 20 = 1971.

In situations where more than the trend silage usage is specified, a procedure is needed which determines a substitution ratio of silage for feed grains. This procedure is given by Equation (1.10):

$$D_S^F = 3.33 \text{ FG}_B \tag{1.10}$$

where:

D_S^F is the demand for silage as a replacement for feed grains (expressed in tons);

FG_B is the estimated demand for feed grains for beef production (expressed in corn equivalent units) and 3.33 is the substitution

ratio of silage for feed grains as determined from Geasler et al., [11].[4]

The total demand for silage for any model situation is then given by Equation 1.11.

$$D_S^T = D_S^F + D_S^N \tag{1.11}$$

where:

D_S^T is the total demand for silage (expressed in tons); and

D_S^F and D_S^N are as defined previously.

The estimates for silage as derived above relate to silage usage at the national level. A two-stage process is used to distribute these national estimates to the 31 demand, or consuming, regions. The first step is to distribute that portion of the silage demand attributed to the trend component D_S^N. Each consuming region is apportioned the same proportion of D_S^N as it had of the 1971-73 average national silage production. The second step is to distribute that component of silage demand arising from any silage substitution for feed grains, D_S^F. Each consuming region's proportion of the additional silage demand is based on that region's proportion of the average number of grain-consuming animal units of beef fed nationally in 1968-70.

The land base used as a resource restraint in this programming model is the average acreage harvested as feed grains for grain, corn and grain-sorghum silage; soybeans for beans; wheat, cotton, and the acreage diverted

[4]Personal communication with Dr. Marshall H. Jurgens, Associate Professor of Animal Science, Iowa State University, Ames, Iowa.

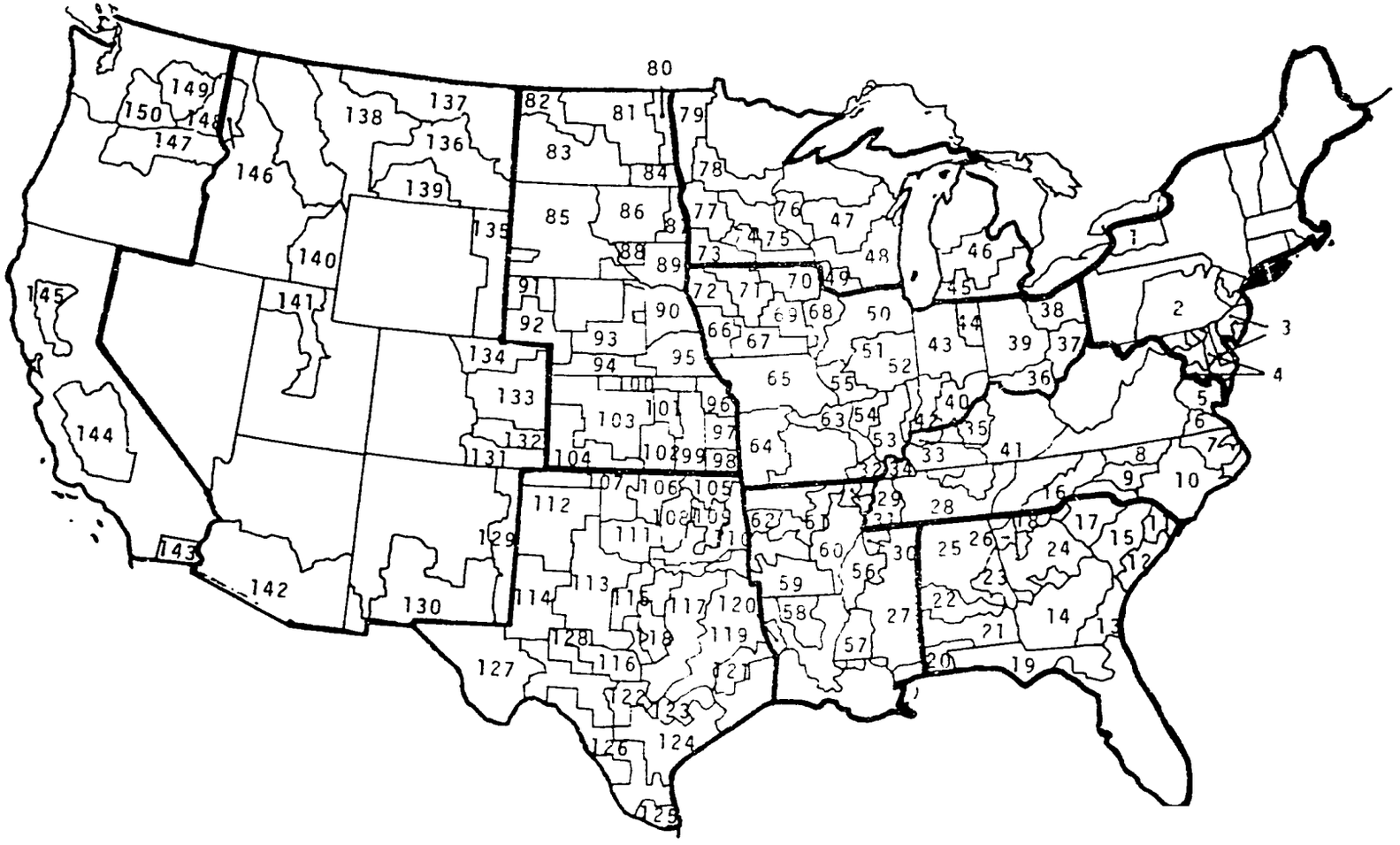

Figure 2. Location of rural areas and farm production regions used in this study.

from production by government programs in the years 1971-73. These data are available by state from the Statistical Reporting Service [29; 30; 31]. Each state's acreage of each of the above-mentioned commodities is distributed to the model's rural areas in that state based on the proportion of the state acreage in that rural area in 1969. The 1969 proportions are given in the Census of Agriculture [36].

Regional Delineations

Within the contiguous 48 states, 150 rural areas have been delineated (Figure 2) for which crop production activities are defined. These rural areas are defined to be internally homogeneous with respect to production possibilities. Factors considered to determine these production possibilities are soil type, climate, historic yields, and production costs. The 150 rural areas are contained within the continental United States but do not completely encompass its entire land base. The areas not included in the 150 rural areas (called White Areas) accounted for only 2 percent of the 1969 production of the four commodities endogenous to the programming model [36]. In this analysis, production from these areas is held equal to their 1969 production, and the demands specified for the programming model are reduced to account for that production.

In the programming model, 31 separate consuming (or demand) regions (Figure 3) are defined for winter and spring wheat, feed grains, and oilmeals. These 31 consuming regions follow state boundaries and are composed of either one state or aggregations of several states.

The third regional concept used in this study is the farm production region. The 10 farm production regions (outlined in the darker lines of

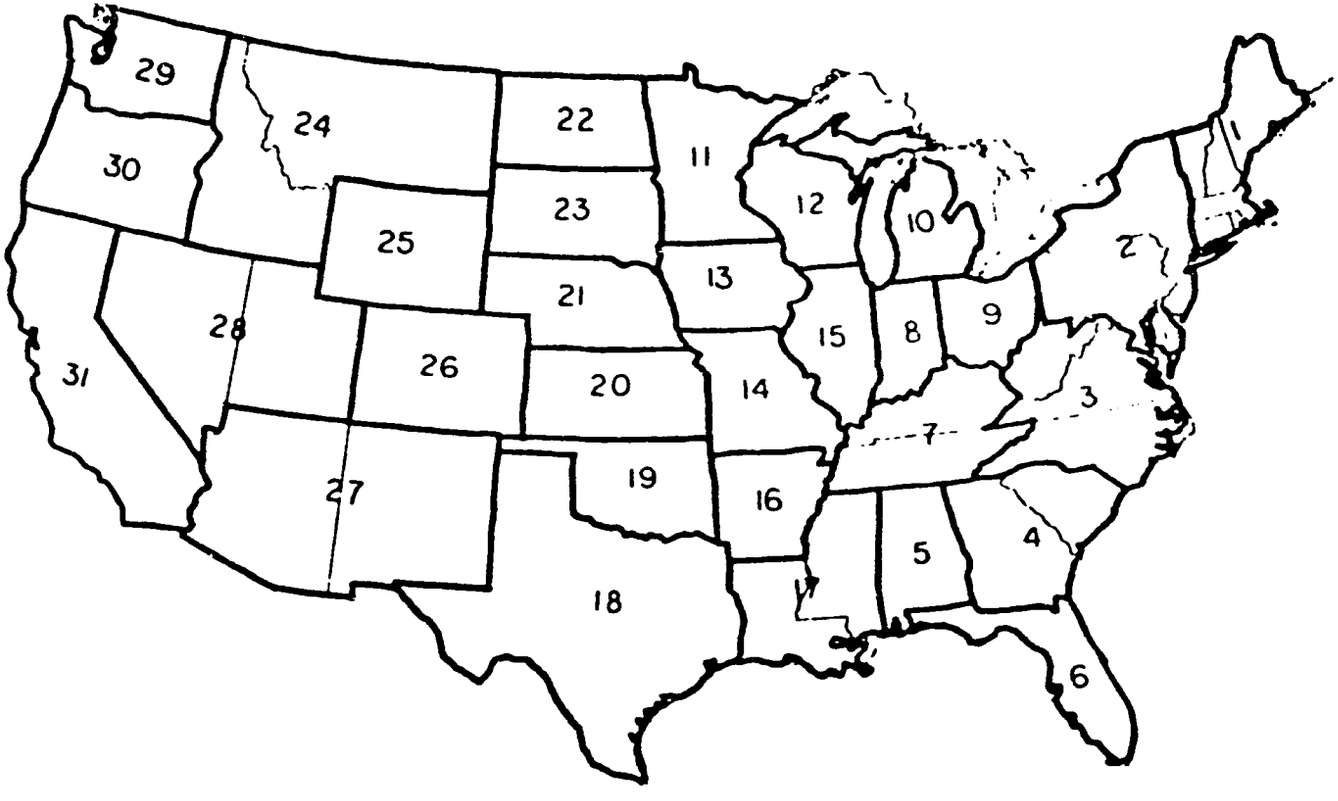

Figure 3. Location of consuming regions used in this study.

Figure 2) entirely encompass the contiguous 48 states. Each rural area and each consuming region is entirely contained in one farm production region. Many of the results of the analysis are presented for the 10 farm production regions.

Livestock Consumption

Although the specific goal of this report is estimation of export potentials, estimates of the domestic demand for the model's commodities are also needed. Indeed, in this analysis domestic demands must first be satisfied before any commodities are available for export. A complete description of the demand analysis is given in Sonka and Heady [26]. But, since livestock feed is such a large component of domestic demands for feed grains and soybeans, and because per capita meat consumption is a major variable of interest in this analysis, demand estimates for meat are detailed in this section.

The basic demand equations for livestock products are those of Waugh [39] as adopted and used in Heady et al., and Sonka [14; 25]. These equations relate the per capita consumption of meat products to per capita income and the price of meat products. Projected per capita income for 1980 was derived from the Bureau of Economic Analysis [37]. The assumed livestock prices used in this report and their resulting consumption estimates are presented in Table 4. These livestock prices were subjectively estimated

to be consistent with the feedstuff prices that result in the programming model under full capacity production.

Table 4. Estimates of per capita consumption and prices for selected livestock products.

Livestock class	Per capita consumption	Prices at the farm level[a]
	(lbs.)	(¢/lb.)
Beef	131.4	48.0
Pork	61.4	37.0
Broilers	40.5	24.0
Lamb	2.7	41.0
Turkeys	5.2	22.4

[a]Prices are expressed in 1972 dollars with no adjustment for inflation to 1980.

II. RESULTS

Many numerical estimates are available from the programming model used in this analysis. Because of space limitations, however, only estimates for major variables are presented here. The variables chosen for presentation are those which would be significantly affected by the changes analyzed in this report.

National Acreage, Output, and Yields

For each model alternative estimates of national production, acreage, and yield can be derived directly from the solution of the programming model (Table 5). Total national acreage is forced to remain stable at around 250 million acres for each of the seven alternatives, even though the model's total land base contains over 251 million acres. For each model alternative the goal was to nearly but not totally exhaust the land base,[5] in order to determine the highest possible exports under different future situations. Consequently, total acreage has been kept nearly constant across alternatives so that each alternative's effect on export potentials will be more isolated and clearcut. Of course, as will be discussed below, the acreage allocated to each crop varies between alternatives. As noted in Table 12, cotton exports are held constant for all the alternatives. This approach is used to facilitate the comparison between the different model alternatives with respect to the potential of increased exports of wheat, feed grains, and soybeans.

---

[5]When the model is forced to use its entire land base, computing costs become relatively high and the supply prices determined in the programming model tend to be unstable.

Table 5. Estimated production, acreages, and yields for each of the model alternatives with 1971-73 values for comparison.

		1971-73 Actual[a]	Model Alternatives A	B	C	D	E	F	G
					Total production (millions)				
Wheat	(bu.)	1627.7	2356.8	1593.3	3310.3	2425.4	2651.0	2719.0	2963.8
Feed grains	(tons)	207.0	252.0	261.6	227.2	239.7	228.2	230.4	205.6
Soybeans	(bu.)	1337.1	1513.2	1821.3	1160.4	1544.1	1653.0	1577.3	1693.4
Cotton	(bales)	12.4	12.1	12.1	12.1	12.1	12.1	12.1	12.1
Silage	(tons)	118.9	166.2	166.2	116.2	214.5	150.3	150.3	164.2
					Harvested acres (million acres)				
Wheat		49.6	70.6	47.0	96.9	72.8	79.0	81.1	87.7
Feed grains		110.8	107.1	118.6	94.8	101.5	96.4	97.1	86.6
Soybeans		48.2	48.9	61.5	35.5	49.5	52.4	50.0	52.7
Cotton		12.1	10.0	10.0	10.1	10.2	10.0	10.0	10.1
Silage		9.4	12.8	12.9	12.3	16.0	11.6	11.6	12.5
Total five crops		220.3	249.6	250.1	249.7	250.2	249.6	250.0	249.9
					Yield per harvested acre				
Wheat	(bu.)	32.80	33.35	33.84	34.16	33.31	33.51	33.52	33.76
Feed grains	(tons)[b]	73.30	83.94	78.78	85.55	84.25	84.46	84.70	84.70
Soybeans	(bu.)	27.70	30.93	29.60	32.61	31.17	31.54	31.49	32.09
Cotton	(lbs.)	488.0	580.26	577.70	575.52	567.11	578.87	578.36	572.61
Silage	(tons)	12.54	12.97	12.88	13.52	10.99	12.94	12.94	13.14

[a]Source: Statistical Reporting Service [29; 30; 31].

[b]Feed grain yields are reported on a corn-equivalent basis.

Alternative A, 1971-73 export proportions

Under Alternative A, exports of the three grain commodities in the model can be increased (in historic proportions) by 78 percent over their 1971-73 actual level. Total land under production, 249.6 million acres, is 29 million acres or 13 percent greater than the 1971-73 acreage. Wheat production takes up 21 million acres of the slack land, a 42 percent increase, whereas soybeans and feed grains each account for 1 and 6 percent of the increased land utilization, respectively. Although cotton acreage would decrease, silage acreage increases by 3 million acres because of the projected growth in demand for beef by 1980.

Total output of the model's commodities under Alternative A increases significantly from the 1971-73 level. Again, this alternative supposes that most of the United States, increased grain production is exported to poor countries to upgrade the diets of hungry people. Expressed in feed units, total production for Alternative A increases 74.8 million tons or 24 percent over 1971-73 levels (Figure 4). Wheat production increases sharply by 45 percent, while feed grains and soybeans increase by 22 and 13 percent, respectively. Although production of the latter two commodities rises significantly, their acreage expands by only 6 and 1 percent, respectively, mostly because projected yields increase by 14 and 12 percent. The model is specified to allow interregional shifts in crop production in line with the comparative advantage of each region for each crop. Cotton acreage declines by 18 percent, because cotton exports are held constant at 4.2 million bales per annum, and a 19 percent increase in yields results from regional shifts in production allowed in the model. Silage acreage increases 36 percent and production increases 40 percent. Silage yield does not increase greatly,

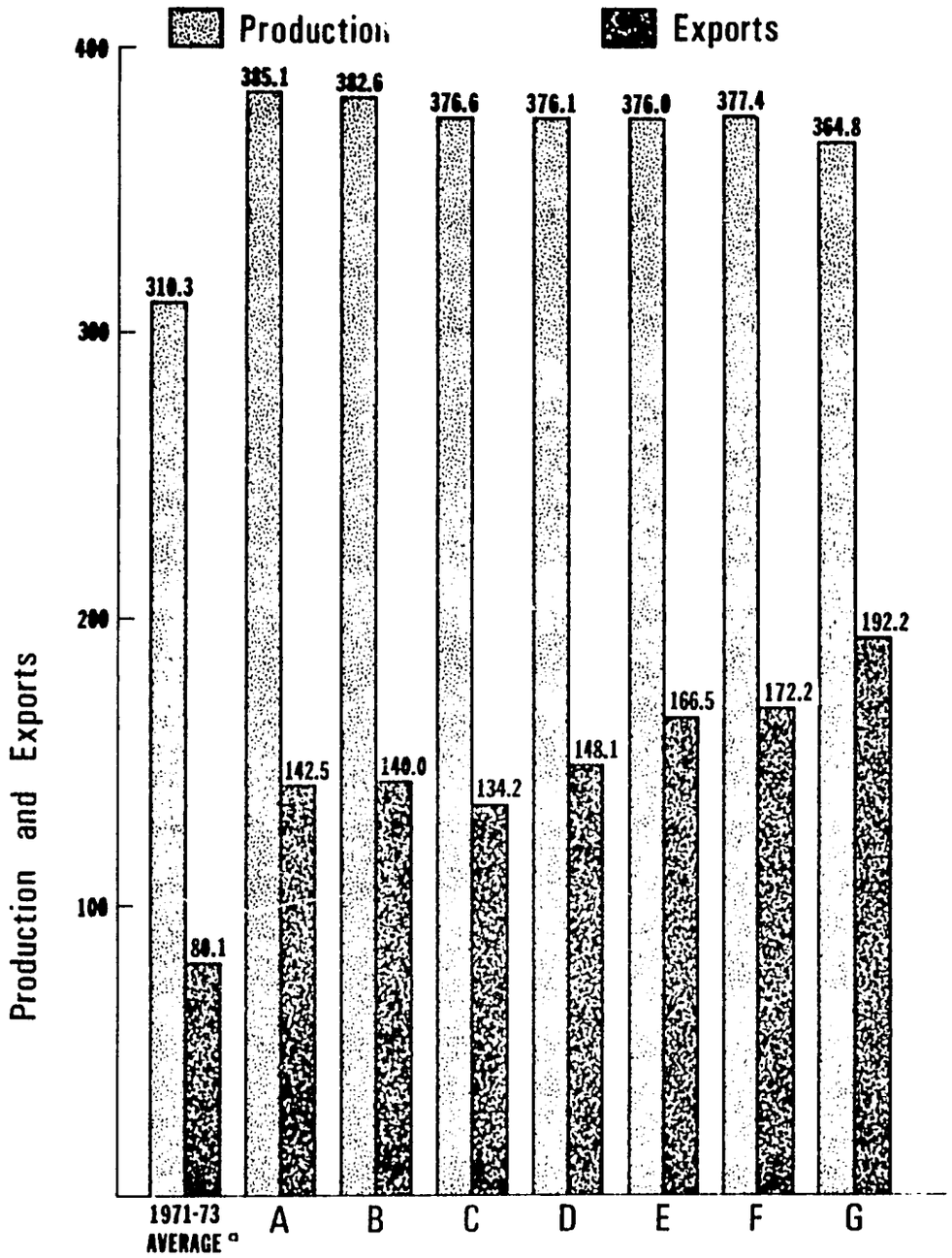

Figure 4. Estimated production and exports of wheat, feed grains, and soybeans for each model alternative (expressed in millions of tons of feed units).

[a]Statistical Reporting Service [29; 30; 31]. Economic Research Service [5].

because the location of silage production in the model is rather tightly bound in each region. The programming model does not allow major shifts in silage production to areas more compatible with higher yields, since silage is not an easily transportable commodity. The slight expansion in wheat yields noted for Alternative A may seem lower than expected. However, the model tends to allow wheat to be grown on lands available after the demand for feed grains and soybeans is satisfied.

Alternative B, emphasis on soybean and feed grain exports

Alternative B shows the effect of a world demand structure, which emphasizes feed grains and soybeans. Again, this alternative supposes increased U.S. grain production is mainly exported to affluent countries for greater meat production. Under this option, the export of wheat is held at its 1971-73 level, whereas soybean and feed grain exports are increased until the land base is nearly exhausted. Although total acreage stays rather constant relative to A, feed grain acreage increases by 11 percent and soybeans by 26 percent. Production increases by 4 and 20 percent respectively. Export levels of feed grains and soybeans can increase by 17 and 39 percent, respectively, under these circumstances. Obviously, wheat acreage declines from the previous alternative as production falls by 32 percent to 1.6 billion bushels. As a result of lower yields under Alternative B, cotton and silage acreage experience only a small change relative to A.

Because of the emphasis on feed grain and soybean production under Alternative B, yields for the two crops fall by 6 and 4 percent, respectively, compared to A. These two grains are now competing for the more marginal, lower yielding land areas. On the other hand, wheat now is grown on land

better adapted to its production and therefore wheat yield increases relative to Alternative A.

Alternative C, emphasis on wheat exports

Wheat exports increase sharply under Alternative C, a condition consistent with Gasser's proposal that there will be a relatively large increase in wheat exports in coming years [10]. Gasser notes that there are indications "that most of the developing countries will tend to import more wheat rather than feed grains because of limited foreign exchange and because their people cannot afford to consume large quantities of livestock products". Under this circumstance, export levels of feed grains and soybeans are held constant at the 1971-73 levels. Therefore, wheat exports are able to increase by 175 percent under Alternative C over that actually exported in 1971-73.

Because of the expanded exports of wheat, production is more than doubled over 1971-73. However, wheat acreage at 97 million acres is less than double the acreage in the 71-73 period. Although wheat production increases drastically, yields still increase slightly over the A alternative. Yields increase as the additional production comes from producing regions which are well adapted to wheat production but formerly were devoted to feed grains and soybeans.

Relative to Alternative A, production of both feed grains and soybeans decline under Alternative C. Feed grain production drops by 10 percent to 227.2 million tons and soybeans fall by 23 percent to 1.2 billion bushels. The acreage required by these crops declines by 12 percent and 27 percent, respectively. Again, increased yields for both feed grains and soybeans,

as they are shifted among regions to best exploit comparative advantage, cause the acreage decrease to be greater than it would have been if the yields had stayed constant. An interesting aspect of Alternative C is that all yields except for cotton lint increase over those of Alternative A, thus indicating that the nation's capacity to produce wheat is very flexible. When the export demand for wheat is high relative to the other grains, wheat production can shift to areas formerly producing other grains but which have high wheat yields.

Alternative D, substitution of silage for grain in beef production

Alternative D examines the effect of silage substitution for grain in beef production. For this circumstance, and the three remaining ones to be discussed, export proportions for the three grains are the same as the 1971-73 average proportions (as in Alternative A). The model constrains the location of silage production rather tightly. Thus in the model, silage is not allowed to be transported across demand regions. This constraint assumes beef producing units are locationally fixed and does not allow a shift of beef production from its 1968-70 regional location. Consequently, the model solution does not capture completely the efficiencies of expanded silage production if beef production were to shift to producing areas which have a comparative advantage in silage production. The estimates of potential gains in grain exports through silage-grain substitution thus is somewhat underestimated because of these constraints.

Wheat production increases by 3 percent, to 2.4 billion bushels, under Alternative D with the entire increase devoted to expanded exports. Feed grain production falls by 5 percent to 239.7 million tons, down 12.3 million

tons from Alternative A, because the domestic demand for feed grains falls with the increase in silage feeding. This decrease in domestic demand more than offsets the increase in exports of feed grains. Soybean production on the other hand increases slightly to 1.5 billion bushels.

As a result of the forced silage substitution under Alternative D, production of this commodity increases by 29 percent over Alternative A to 214.5 million tons (Figure 5). With this greater production, the yield of silage drops 15 percent to 10.9 tons per acre. Consequently, the acreage in silage expands to 16.0 million acres, 25 percent over the base alternative's acreage and 70 percent over the 1971-73 acreage. However, the actual figure includes that acreage, contained in the model's White Areas. The White Area silage acreage, 15 percent of the national silage acreage in 1969, is not included in the model estimate because it is constant between the model alternatives.

In the circumstance of Alternative D, cotton acreage increases slightly with a 2 percent fall in yield. As is indicated in Table 12, both cotton exports and domestic consumption are held constant throughout the analysis. Therefore, any change in cotton acreage results from changes in yields as crops shift among areas on a comparative advantage basis.

Even though silage and cotton yields decline under Alternative D, yields for both feed grains and soybeans increase relative to Alternative A, even though grain exports for Alternative D are higher than under Alternative A. As the demand for feed grains is reduced, soybean and feed grain production can be shifted to regions which are better adapted to these activities and which have higher yields.

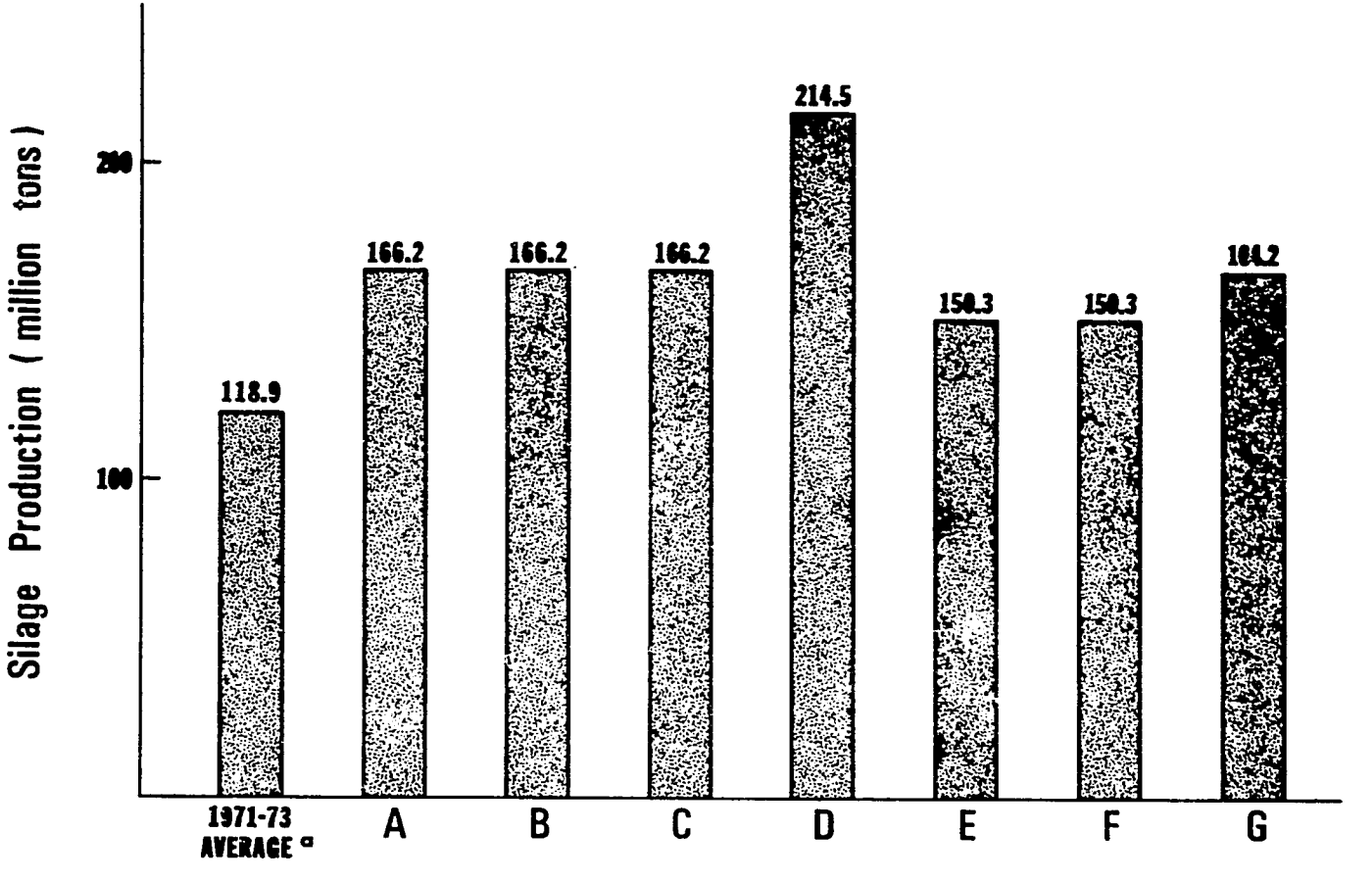

Figure 5. Estimated silage production for each model alternative (in million tons).
[a]Statistical Reporting Service [29; 30; 31].

The next three alternatives differ from the four discussed so far, in that they would require changes in the consumption pattern of the American public. These altered patterns occur through either reducing meat consumption or reducing meat consumption but substituting soybean protein for the reduced animal protein intake.

Alternative E, 25 percent substitution of vegetable for animal protein

Alternative E examines the implications of U.S. consumers reducing their meat consumption by 25 percent but substituting soy protein, in the form of isolates or concentrates, for the loss in animal protein. This reduction is a 25 percent decrease from the meat consumption levels projected for 1980 (as discussed in the parameter section of the study). As might be expected from such a change in consumer behavior, the reduced demand for meat results in a shift in the demand for feed grain and soybeans used in meat production. This shift in turn results in freeing land for additional exports, although some of this excess acreage now is required by an increased domestic demand for soybeans.

Under Alternative E, total wheat production increases by 13 percent over Alternative A. The wheat acreage requirements expand by 12 percent to 79 million acres. Feed grain production and acreage decline by 9 and 10 percent, respectively, because of the indirect decrease in demand for feed grains from reduced domestic meat consumption, not entirely offset by increased exports. However, soybean production increases by 9 percent to 1.7 billion bushels. This acreage increase is brought about by an increase in per capita demand for soybeans by U.S. consumers in the soy-meat substitution process and expanded soybean exports. In addition to the decrease in feed grain production, silage production and acreage experience a marked decline,

almost 10 percent. Because of the decrease in demand for beef specified under Alternative E, less silage now is fed.

Alternative F, 25 percent reduction in per capita meat consumption

Reduced meat consumption for Alternative F, without any substitution of soy products for the loss in protein, produces results somewhat analogous to those under Alternative E. In Alternative F, however, no additional domestic demand for soybeans is specified. All excess land generated by the reduction in demand for meat can be used to increase exports for the three grain commodities -- wheat, feed grains, and soybeans.

Again, wheat production and acreage increase as required to produce the 2.7 billion bushels of wheat. Production under Alternative F increases 15 percent and wheat acreage increases to 81 million acres, up 15 percent over Alternative A. Relative to Alternative A, feed grain production again decreases, as it did under Alternative E. This decline, however, is somewhat offset by higher feed grain exports. Feed grain production falls 9 percent, as American consumers are postulated to consume 25 percent less meat, down 21.6 million tons from the base alternative. Feed grain acreage also decreases by 9 percent.

Relative to Alternative E (substitution of soy products for meat) soybean production declines by 4 percent under F or 75.7 million bushels. This decline in production still allows an increase in exports of 4 percent over those specified under Alternative E because of the smaller amount of soybean meal used domestically in meat production. This follows because the decrease in domestic demand for soybeans, relative to Alternative E, releases production capactity for additional exports of all three grain commodities. Soy-

bean production under Alternative F, however, did increase slightly -- 4 percent over that of the base alternative. Silage production and acreage are the same as under the previous alternative, because the domestic demand for beef does not vary between these two situations.

Alternative G, simultaneous application of the previous variants

To obtain some "feel" for the impact of a combination of the previously analyzed alternatives on American agriculture, Alternative G illustrates the effects of a joint imposition of the conditions of the previous three variants, i.e., Alternatives D, E, and F. For the situation described in Alternative G, the consumer would first cut back his projected meat consumption by 25 percent. He then would substitute soy-protein for 25 percent of the residual meat consumption projected for 1980. Finally, silage would substitute for 25 percent of the feed grains used by beef. The demand for land, or the potential for additional exports, is drastically affected by this combination of conditions.

The production and acreage requirements of Alternative G illustrate some very interesting results, particularly if the emphasis shifts to more food for a hungry, food-short world. For this situation, it has been assumed that only the American consumer would make sacrifices, such as a reduction in meat consumption and substitution of soy protein. It is challenging to ponder what would happen to world food availability if not only the United States but all western world consumers were to adapt to the same consumption patterns.

Under Alternative G, wheat production increases by 26 percent to 3.0 billion bushels over Alternative A. Because of a slight increase in yield, the acreage requirement only increases by 24 percent to 88 million acres.

Feed grain production, on the other hand, decreases by 18 percent compared to the base alternative. Acreage requirements for feed grains decrease by 21 million acres from Alternative A. Under Alternative G, one facet which stands out is that American agriculture can export large additional quantities of feed grain, 140 percent in excess of 1971-73, and actually produce 1.4 million tons less. Soybean production increases to 1.7 billion bushels or 12 percent over Alternative A. Soybean acreage only increases 8 percent because of a 4 percent increase in soybean yield over the base alternative. Silage production and acreage both decrease by 2 percent, to 164.2 million tons and 12.5 million acres, respectively.

In the next section, regional distributions of production will be discussed. Regional production will vary among alternatives as new policies or scenarios are implemented and exports are increased.

Regional Distribution of Production

National production and acreage requirements for each alternative were discussed in previous sections. These statistics indicated the effect of each alternative on agricultural output. However, given the specification and nature of the model, it is also possible to compare acreage requirements for the 10 farm production regions under each alternative (or even each of the 150 regions of Figure 2, but for space limitations the latter is not done). The delineations of the ten farming regions are those used by the U.S. Department of Agriculture.[6] Although no land is taken out of production in this analysis, one may expect shifts in the regional production pattern

[6]The 10 production regions are those bounded by a heavy line in Figure 2; each contains many rural areas.

between alternatives because of the comparative advantage of some regions for different crops as demand or export mixes change. Such shifts in production can, of course, have great impacts on a region's economic base. For each of the model alternatives, Tables 6, 7, 8, 9, and 10 present acreage requirements for each commodity at the regional level.

Regional distributions under Alternative A

Because of 78 percent increase in exports, acreage requirements for all three crops increase rather drastically under Alternative A, as compared to the 1971-73 acreage. At the national level, wheat acreage increases 42 percent to 70 million acres. The Lake States region more than doubles its acreage in wheat, as do the Southeast and Delta States regions, under Alternative A. The Northern Plains region has the largest absolute increase in acreage, 8 million acres, over the actual 1971-73 acreage (see Table 6).

Nationally, under Alternative A, feed grains use only 6 percent more land, or 7 million more acres, than in the period 1971-73. The largest acreage increase occurs in the Corn Belt region, which now has 52 million acres in feed grains, an increase of 17 million acres over 1971-73. Except for the Southern Plains region, which now would harvest 10 million acres in feed grains, all other regions' feed grain acreage declines under Alternative A.

Soybean acreage under Alternative A is nearly equal to the 1971-73 actual acreage, although exports are increased by 78 percent between the two situations. Large increases in soybean acreage are estimated for the Northern and Southern Plains regions, up by 241 percent and 811 percent, respectively. In contrast, acreage decreases by 36 percent in the Corn Belt to 16 million acres.

Table 6.. Estimates of harvested acres for wheat for each of the model alternatives for the United States and for each of the ten farm production regions with 1971-73 figures for comparison.

Region	Model Alternatives							
	71-73[a]	A	B	C	D	E	F	G
	(Thousand acres)							
United States	49611.0	70659.4	47075.7	96919.5	72816.1	79098.1	81126.3	87783.3
Northeast	566.3	193.3	193.3	967.5	193.3	355.6	419.4	743.3
Corn Belt	3670.7	4010.1	2123.1	11242.2	4945.5	6445.4	6875.9	8060.1
Lake States	2257.0	4908.4	1691.1	10280.0	4744.9	6205.9	6221.6	7906.4
Appalachia	806.7	1508.2	899.4	2525.9	1536.8	1610.0	1635.4	2466.4
Southeast	422.7	1519.6	1164.2	2854.1	1482.3	1391.6	1158.6	1772.6
Delta States	385.0	3568.8	3274.1	4844.6	3497.0	3581.0	4379.4	4622.1
Southern Plains	6552.0	10289.2	5877.6	13447.1	10073.9	11514.8	11514.8	11508.8
Northern Plains	22810.0	30861.2	21168.9	35572.6	32054.4	33250.2	34172.6	35544.0
Mountain	8138.7	9397.5	6539.5	10675.7	9923.3	10275.6	10275.6	10681.4
Pacific	3977.7	4403.1	4144.5	4501.0	4364.7	4468.2	4472.9	4478.1

[a]Source: Statistical Reporting Service [29; 30; 31].

Table 7. Estimates of harvested acres for feed grains for each of the model alternatives for the United States and for each of the ten farm production regions with 1971-73 figures for comparison.

Region	Model Alternatives							
	71-73[a]	A	B	C	D	E	F	G
	(Thousand acres)							
United States	100876.3	107196.0	118602.9	94860.5	101596.5	96485.1	97143.6	86683.1
Northeast	3123.0	2508.4	2258.3	1904.1	2458.2	2518.1	2454.2	2137.3
Corn Belt	35388.7	52156.5	50287.6	49193.5	49063.6	47024.1	48259.6	42543.2
Lake States	14628.3	13690.4	14448.6	10006.3	12878.5	11725.0	11709.4	9890.7
Appalachia	4234.7	1719.1	1785.5	1517.0	1537.4	1516.9	1516.9	1516.9
Southeast	3300.7	1262.0	1390.9	1262.0	1262.0	1262.0	1262.0	1262.0
Delta States	721.0	222.8	222.8	222.8	222.8	222.8	222.8	222.8
Southern Plains	8394.0	10182.7	14066.0	9093.9	9992.9	10163.7	10163.7	10071.3
Northern Plains	23670.0	20191.8	25792.8	17678.9	19850.7	17589.6	17092.1	15138.1
Mountain	4971.7	4525.3	7383.4	3247.2	3594.4	3727.9	3727.9	3165.9
Pacific	2467.7	735.7	968.1	735.7	735.7	735.7	735.7	735.7

[a]Source: Statistical Reporting Service [29; 30; 31].

Table 8. Estimates of harvested acres for soybeans for each of the model alternatives for the United States and for each of the ten farm production regions with 1971-73 figures for comparison.

Region	Model Alternatives							
	71-73[a]	A	B	C	D	E	F	G
	(Thousand acres)							
United States	48271.7	48927.7	61525.3	35580.7	49533.6	52416.1	50091.7	52773.5
Northeast	524.3	468.1	718.2	337.8	468.1	468.1	468.1	543.3
Corn Belt	25384.7	16264.9	20025.6	12009.1	17383.4	19185.2	17520.3	21653.1
Lake States	4208.7	4421.4	6787.6	2768.8	5036.2	5375.3	5375.3	5501.6
Appalachia	3875.7	3382.9	3907.3	2180.4	3130.3	3458.2	3182.1	2215.1
Southeast	2896.0	4764.9	5066.7	3260.5	4744.4	4856.3	4873.7	4621.2
Delta States	8625.7	7803.7	8223.4	6740.1	7803.7	7803.7	7152.4	6733.1
Southern Plains	423.7	3861.4	4216.2	1881.8	3773.2	2641.8	2641.8	2560.1
Northern Plains	2333.0	7960.4	12580.2	6402.2	7194.2	8627.3	8878.1	8945.8
Mountain	0	-	-	-	-	-	-	-
Pacific	0	-	-	-	-	-	-	-

[a]Source: Statistical Reporting Service [29; 30; 31].

Table 9. Estimates of harvested acres for cotton for each of the model alternatives for the United States and for each of the ten farm production regions with 1971-73 figures for comparison.

Region	Model Alternatives							
	71-73[a]	A	B	C	D	E	F	G
	(Thousand acres)							
United States	12147.9	10023.3	10067.7	10106.0	10255.8	10047.6	10056.3	10157.3
Northeast	-	-	-	-	-	-	-	-
Corn Belt	300.0	148.6	148.6	148.6	148.6	148.6	148.6	148.6
Lake States	-	-	-	-	-	-	-	-
Appalachia	629.0	1135.2	1153.2	1519.6	1439.4	1258.7	1439.4	1519.6
Southeast	1274.5	885.2	844.0	1014.5	828.0	800.4	780.2	719.8
Delta States	3168.7	1495.8	1370.9	1283.8	1495.8	1495.8	1348.7	1495.8
Southern Plains	5474.0	4385.0	4558.5	4264.1	4646.7	4385.0	4385.0	4454.9
Northern Plains	-	-	-	-	-	-	-	-
Mountain	452.8	902.6	902.6	902.6	902.6	902.6	902.6	902.6
Pacific	848.0	1070.5	1090.0	972.8	795.0	1056.4	1051.7	915.8

[a]Source: Statistical Reporting Service [29; 30; 31].

Table 10. Estimates of harvested acres for silage for each of the model alternatives for the United States and for each of the ten farm production regions with 1971-73 figures for comparison.

Region	Model Alternatives							
	71-73[a]	A	B	C	D	E	F	G
	(Thousand acres)							
United States	504.3	12809.5	12908.0	12304.4	16026.7	11611.4	11610.2	12503.9
Northeast	1402.0	1202.3	1202.3	1141.4	1252.5	1030.4	1030.4	948.2
Corn Belt	2017.3	2475.0	2472.2	2463.6	3515.9	2253.7	2252.6	2652.0
Lake States	1449.0	3243.2	3336.2	3208.4	3603.8	2957.2	2957.2	2964.6
Appalachia	695.3	820.0	820.0	559.1	921.4	721.5	721.5	701.2
Southeast	231.4	314.7	316.2	314.7	429.6	288.7	288.7	330.2
Delta States	123.3	135.3	135.3	135.3	207.2	123.3	123.3	152.7
Southern Plains	157.7	285.1	285.1	285.1	516.7	266.5	266.5	376.8
Northern Plains	2517.0	2883.2	2883.2	2856.6	3410.2	2650.7	2650.7	2772.0
Mountain	582.4	962.8	962.8	962.8	1367.0	882.2	882.2	1038.3
Pacific	239.0	488.0	494.8	488.0	802.6	437.3	437.3	567.9

[a]Source: Statistical Reporting Service [29; 30; 31].

Cotton production was set at a fixed level, 12.1 million bales, for all seven alternatives. Since this is slightly lower than the actual level, 12.4 million bales, only minor adjustments in the location of cotton acreage take place in this analysis. The Corn Belt region would transfer half of its acreage in cotton in 1971-73 to feed grain production under Alternative A. The Delta States and Southern Plains regions also would decrease their cotton production. The Appalachian, Mountain, and Pacific regions, however, would increase their combined acreage by over a million acres. Under Alternative A, the location of silage production does not show any drastic changes, except for an increase of almost 2 million acres in the Lake States region. The reason for the minor changes is that silage production is rather tightly constrained to the 1971-73 production locations.

Regional distributions under Alternative B

Alternative B, emphasizing exports of feed grains and soybeans, shows a marked change in wheat acreage, down 33 percent, as compared to Alternative A. This acreage is taken up by both feed grain and soybean production to satisfy the expanded exports of this situation. At the national level, feed grain and soybean acreage increase by 11 percent and 26 percent, respectively. The biggest declines in wheat acreage, are estimated for the Corn Belt and Southern Plains regions, 47 and 42 percent, respectively. Decreases in wheat production also occur in the Lake States region, 3 million acres and the Northern Plains regions, 9 million acres. Again, the land released from wheat production is taken up by feed grain and soybean production. As may be expected, the Corn Belt, Northern Plains, and Southern Plains regions show a relative advantage in producing soybeans and feed grains.

Regional distribution under Alternative C

When wheat exports are emphasized under Alternative C, production patterns shift drastically. Compared to the base alternative, the Corn Belt and Lake States regions more than double their wheat acreage at the expense of feed grains and soybeans. In both the Southern Plains and Northern Plains regions, wheat acreage increases by 31 and 15 percent, respectively, again at the expense of feed grains and soybeans.

Regional distribution under Alternative D

The 25 percent silage substitution assumed under Alternative D brings relatively few major changes in the location of production of crops. Compared to Alternative A, the increase in wheat acreage, 2 million acres, would be concentrated in the Northern Plains region. Feed grain acreage declines by about 6 million acres, and 50 percent of this is in the Corn Belt. This acreage can now be used for wheat and soybean production. Except for an increase of 1 million acres in the Northern Plains region, soybean and cotton acreages stay relatively constant between the base alternative and Alternative D. Naturally, the silage requirement increases by 25 percent to 16 million acres. The largest absolute increase, 1 million acres, is in the Corn Belt region, where land requirements go up by 42 percent over Alternative A. Though increasing in each region, the remainder of the changes in silage acreage are all of relatively small magnitude.

Regional distribution under Alternative E

Under Alternative E, 25 percent of the projected animal protein consumption is replaced by vegetable protein. For this alternative, wheat acreage requirements increase by 12 percent, compared to the base alternative,

because of increased exports allowed in the former situation. The Corn Belt region shifts an additional 2 million acres to wheat, using land released from feed grain production. The Lake States region follows the same pattern as the Corn Belt. In the former, wheat acreage is up 26 percent and feed grain land requirements are down 14 percent. The Northern Plains region shifts about 3 million acres or 13 percent of its feed grain acreage to wheat production. The major increase in soybean acreage under Alternative E occurs in the Corn Belt region, up 18 percent relative to the base Alternative A.

Regional distribution under Alternative F

Alternative F, which incorporates a 25 percent reduction in projected meat consumption, requires 15 percent more land in wheat nationally than in the base alternative. The Corn Belt and Lake State regions increase wheat and soybean acreage by 4 million and 2 million acres, respectively. The Southern Plains region, having lost some of its soybeans acreage, increases wheat acreage by over a million acres. Similarly, the Northern Plains region requires 3 million more acres for wheat production than under the base alternative. With a reduction in meat consumption, 10 million acres can be released from feed grain production, relative to Alternative A. Most of this reduction occurs in the Corn Belt, Lake States, and Northern Plains region. From the results of this analysis, it appears that as land is freed from feed grain production, the afore-mentioned regions, which had a comparative advantage in feed grains, can readily convert the idled land into use for both wheat and soybeans.

Regional distribution under Alternative G

Alternative G, simultaneously combining the previous three scenarios, shows the largest impact on acreage diverted from feed grain production into wheat and soybeans. Relative to the base alternative, over 20 million acres previously in feed grains are shifted to 17 million acres of wheat production and about 4 million acres of soybean production. In total, soybean acreage would occupy over 52 million acres. The Lake States, Corn Belt, and Northern Plains regions take up most of the slack in reduced feed grain land with both wheat and soybeans. The Southern Plains region reduces its soybeans acreage slightly, 1 million acres, exhibiting some comparative advantage in wheat production. The Corn Belt region releases 10 million acres from feed grain production and the Northern Plains region releases 3 million acres, compared to the base alternative. The silage acreage requirements for this situation decrease by 3 million acres, or 2 percent, from Alternative A.

Supply Prices

For each of the seven alternatives, the programming model estimates a national supply price for each commodity (although consuming region supply prices also are generated, they are not reported because of space limitations). These supply prices are given in Table 11. The supply price for a commodity can be defined as that price which brings forth the quantity of output needed to meet demands under a given set of conditions. Basically, the programming model selects the production cost of the last producing area contributing towards total supply as the supply price. Because of the perfect competitive framework in which this model is cast, the last rural area to enter would by definition be the highest cost area. The theory of the firm then tells us that production cost must just be equal to the supply price of that commodity.

Table 11. Supply prices for the seven alternatives in 1972 and 1974 dollars.

		1972[a]	Model Alternatives A	B	C	D	E	F	G
					1972 dollars				
Wheat	$/bu.	1.7[illegible]	2.53	2.66	2.36	2.55	2.38	2.34	2.40
Feed grain	$/bu.	1.32	1.75	2.00	1.51	1.76	1.60	1.56	1.56
Soybeans	$/bu.	[illegible].13	3.79	4.60	3.10	3.83	3.37	3.27	3.20
Cotton	$/lb.	0.267	0.378	0.365	0.370	0.384	0.369	0.368	0.375
Silage	$/ton	--[b]	12.56	13.82	11.20	12.[illegible]	11.87	11.71	11.42
					1974 dollars				
Wheat	$/bu.	2.[illegible]	3.57	3.75	3.3[illegible]	3.[illegible]	3.36	3.30	3.38
Feed grain	$/bu.	1.8[illegible]	2.47	2.82	2.13	2.[illegible]	2.2[illegible]	2.20	2.20
Soybeans	$/bu.	[illegible]	[illegible].34	[illegible].49	4.37	[illegible].0	4.75	4.61	4.51
Cotton	$/lb.	0.37[illegible]	[illegible].533	0.543	[illegible].522	[illegible].541	0.520	0.519	0.529
Silage	$/ton	--	17.71	19.48	15.7[illegible]	17.[illegible]	[illegible]. 3	16.51	16.10

[a]Source: Statistical Reporting Service [illegible].

[b]No farm price for silage could be obtained for the seven methods.

Returns to land, then, are computed to be the difference in the supply price and production cost in each rural area rather than being included in the estimate of production costs. In Table 11, actual 1972 prices received by farmers, as well as the prices estimated under the various alternatives are presented. Prices are reported in 1972 dollars and, for comparison, are also given in 1974 prices.

Alternative A prices

The farm prices estimated under Alternative A for all of the model commodities except silage are considerably higher than the actual 1972 prices. These higher prices result because exports are forced to increase by 78 percent over 1971-73. As marginal lands are brought into production to satisfy these additional export demands, supply prices must rise because of the higher production costs in these regions.

Alternative B prices

Supply prices increase even more under Alternative B, where the emphasis is on export of feed grains for greater meat production and consumption in the developed and affluent countries of the world. In this alternative higher export demands for soybeans and feed grains are specified while wheat exports are held constant. These greater farm price increases indicate the relative difficulty, through the model, the nation's agriculture has in filling the very large demands for feed grains and soybeans under Alternative B. Relative to Alternative A, this fact is also evidenced by the decrease in yields for these two crops as their acreage increases to meet enlarged exports.

Alternative C prices

The opposite effect prevails under Alternative C, where emphasis is on wheat exports as food to the poorer countries. As pointed out in the previous section, American agriculture is extremely well suited and flexible in producing wheat. Under Alternative C where a large quantity of wheat would be produced, farm prices for all commodities fall relative to the base alternative. Per unit price differentials between these two circumstances are 15 cents for wheat, 24 cents for feed grains, 59 cents for soybeans, 0.8 cents for cotton, and $1.32 for silage. Since supply prices reflect costs of production, the lower prices estimated under Alternative C reflect the suitability of a large segment of American agriculture for wheat production.

The remarkable stability of the estimated supply prices throughout the various scenarios is mainly due to the fact that total production (as expressed in total feed units produced, Figure 5) stays rather constant. Of course, this itself is a consequence of the stipulation that the land base be exhausted in each circumstance.

It is interesting to point out that for wheat and feed grains, the estimated prices are considerably above the target price levels of the Agricultural and Consumer Protection Act of 1973 -- $2.05 and $1.38 per bushel, respectively, for all of the alternatives. The cotton target price level of 38 cents is only met in Alternatives B and D, although the divergence from this level is never larger than 1.2 cents. These relatively high supply prices indicate that "all-out production" to help feed the world would require market prices higher than those of the 1973 Act, even when inflation from 1972 to present is ignored. These higher prices are necessary

if farmers are to find the added output to be profitable.

Prices of other alternatives

Although exports and production would be highest under Alternative G, the prices estimated for all commodities are less under this circumstance than under Alternative A. Exports under Alternative G increase by 140 percent over the actual 1971-73 level and by 35 percent over Alternative A for the three grain commodities. Relative to Alternative A, however, the following per unit price decreases are estimated: 13 cents for wheat, 19 cents for feed grains, 59 cents for soybeans, 3 cents for cotton, and $1.14 for silage. The fact that farm prices are lower relative to Alternative A therefore may serve as an indication that American agriculture is extremely capable and well suited for wheat production, as is also shown under Alternative C. Or viewed in another manner, the higher prices of Alternative A indicate the relatively high costs of feed grain production relative to wheat production if the United States went "all-out" to help feed the rest of the world.

To give the reader additional understanding for what these prices mean in terms of today's purchasing power of the dollar, the prices reported in Table 11 are inflated to 1974 dollars for comparison. The inflation factor used is derived from the index of prices paid by farmers [28]. It is appropriate to inflate these prices by this index, because the supply price concept is closely related to costs of production. For each of the seven alternatives, the prices of wheat, feed grains, and cotton are well above the target level prices set in the 1973 bill (referred to earlier). However, the proposed target level prices of $3.41 for wheat, $2.25 for corn, and 48 cents for cotton [40] are consistent with the adjusted 1974 prices presented in Table 11.

Export Capacity

The programming model constructed for this study attempts to measure America's capacity in producing its domestic food and maximize shipments of grain commodities to the rest of the world. In this section of the report, we present the changes in export capacity resulting as various alternatives, or policies, are implemented.

To facilitate comparisons between the alternatives, Figure 6 presents the estimated exports of wheat, feed grains, and soybeans (expressed in feed units)[7] available under each alternative. Those which are most successful in increasing national exports of the grain commodities are readily apparent.

Alternative A exports

Under Alternative A, exports are increased in historic proportions to 178 percent of the actual 1971-73 level (Table 12). This increase in exports is possible because of the larger land base associated with the programming model, 29 million acres more than in 1971-73, and higher per acre yields projected for 1980. By incorporating the same export mix as in 1971-73, Alternative A assumes that nothing will change with respect to importing nations' preferences for each of the three grain commodities. Neither does it assume that wheat production is emphasized more to feed the hungry of poor countries or that feed grains are emphasized for more meat in the developed countries. Cotton lint exports are held at 4.2 million bales for all seven alternatives.

---

[7]A feed unit is understood to be the ratio of the feed value of a unit weight of a given grain to the feed value of an identical weight of corn.

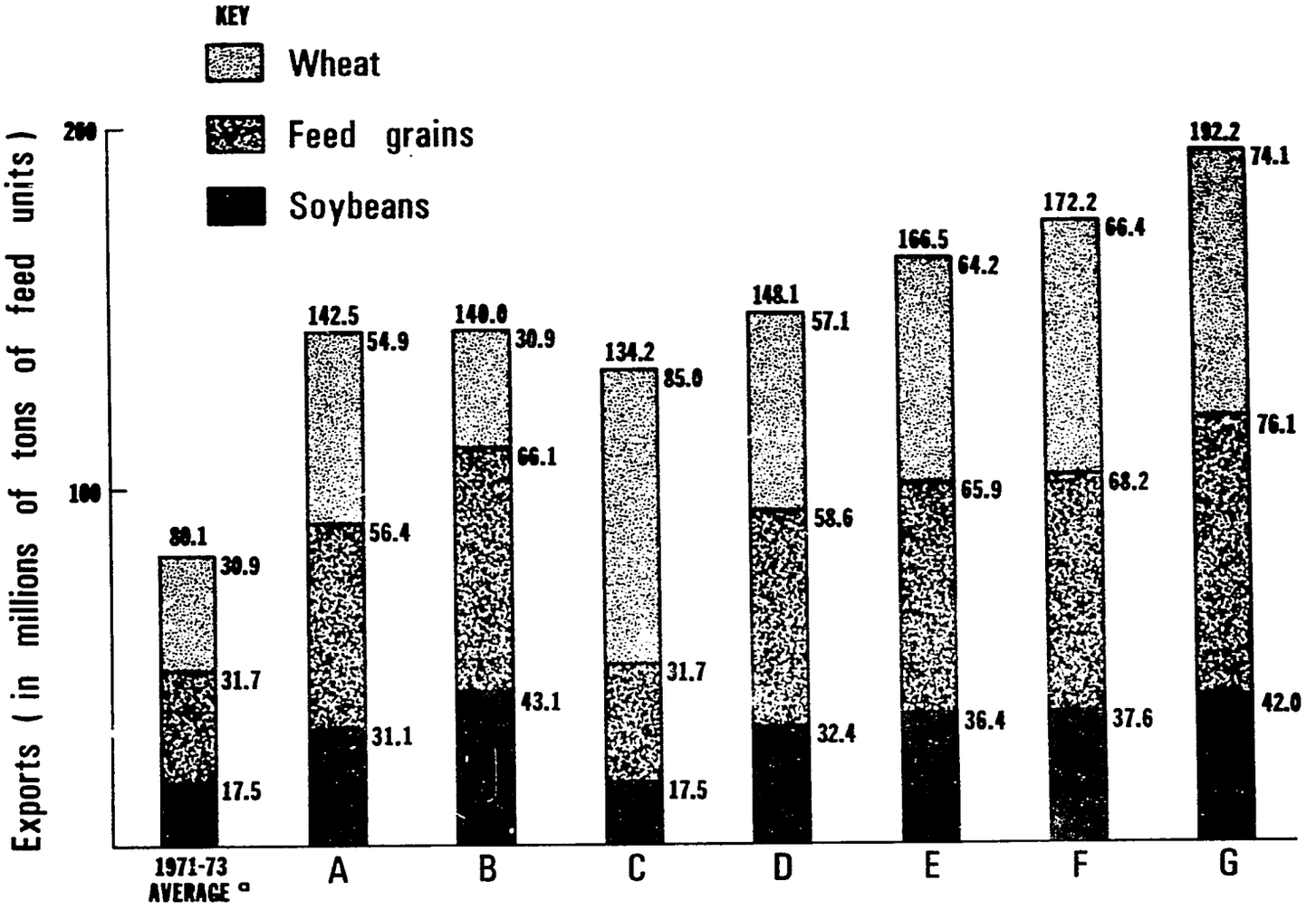

Figure 6. Estimates of wheat, feed grain, and soybean exports for each model alternative (in millions of tons of feed units).

[a]Economic Research Service [5].

Table 12. Estimated exports for each model alternative with 1971-73 average exports for comparison.

	Actual[a] 1971-73	Model Alternatives						
		A	B	C	D	E	F	G
Wheat (million bu.)	979.8	1744.1	979.8	2698.4	1812.6	2038.0	2106.6	2351.5
Feed grains (million tons)	31.7	56.4	66.1	31.7	58.6	65.9	68.2	76.1
Soybeans (million bu.)	450.2	801.3	1109.4	450.2	832.9	936.4	967.9	1080.5
Cotton (million bales)	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
Silage - -	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[a]Source: U. S. Dept. Agr. [34].

Alternative B exports

Under Alternative B, however, it is assumed that feed grain and soybean exports are expanded while wheat exports stay at the 71-73 level. This shift in "preference" leads to an increase of feed grain and soybean exports of 108 and 146 percent, respectively, over the actual 1971-73 level. Quantities exported under Alternative B are 980 million bushels of wheat, 66 million tons of feed grains and 1.1 billion bushels of soybeans.

Alternative C exports

Instead of emphasizing soybean and feed grain exports, emphasis can be placed on wheat exports -- a very reasonable emphasis in the face of present world food scarcities as suggested by the World Food Conference in Rome in November 1974. Under Alternative C, then, feed grains and soybeans are held at the 1971-73 level of exports and wheat exports are now increased to the limit permissable by the land base in this model with the requirement that U.S. domestic demands be met. This shift allows wheat exports to increase by 175 percent to 2.7 billion bushels. This quantity is 1.7 billion bushels more than the average quantity exported during 1971-73.

Alternative D exports

Under Alternative D, and for that matter all alternatives hereafter, exports are forced to increase in historic proportions. Alternative D embraces the shift from "beef on grain" to "beef on silage." As is indicated by results of experiments at Iowa State University and elsewhere beef can profitably be fed and fattened on silage [9; 11]. This situation also addresses the proposal of some segments of the public and of world food experts who suggest that, in a food-short world, beef fed on grain is a

waste of resources, both in terms of grain as well as land, e.g., Peterson [22]. A 25 percent substitution of silage for grain allows exports to increase by 85 percent over the actual 1971-73 level and 4 percent over those of Alternative A. Wheat exports now are 800 million bushels higher than the 1971-73 average at 1.8 billion bushels and are 70 million bushels over Alternative A. Feed grain exports increase 2 million tons compared to Alternative A, to 59 million tons. Soybean exports now increase to 833 million bushels, 32 million bushels up from Alternative A.

Alternative E exports

Wheat exports increase to more than 2 billion bushels under Alternative E, where 25 percent of the animal protein in the human diet is substituted for soy protein. Exports of all three grain commodities increase 108 percent over the 1971-73 actual level and 17 percent more than Alternative A. Feed grain exports now reach almost 66 million tons, and soybean exports are 936 million bushels, up 135 million bushels from Alternative A.

Alternative F exports

Exports under Alternative F, where meat consumption is reduced by 25 percent from levels projected for 1980, increase slightly over those of the Alternative E. With a reduction in meat consumption and no replacement with vegetable protein, exports can increase 21 percent over Alternative A. Wheat exports now total 2.1 billion bushels; feed grain exports, 68 million tons; and soybean exports, 968 million bushels. Note that although feed grain exports are greater, total feed grain production is 32 million tons lower under Alternative F than under Alternative A.

Alternative G exports

Finally, grain exports under Alternative G are considerably higher than under any of the previous alternatives. This situation incorporates a 25 percent reduction in meat consumption by U.S. consumers, substitution of soy protein for animal protein for 25 percent of the meat consumed in the United States, and a 25 percent substitution of silage for grain fed to beef. This combination of shifts allows exports to increase 140 percent over the actual 1971-73 average level, which were by far the highest in history, and 35 percent more than Alternative A. Soybean exports now increase to over 1 billion bushels, more than double the actual exports in 1971-73. Feed grain exports increase 20 million tons over Alternative A, and wheat exports now reach their second highest level of the seven alternatives, 2.4 billion bushels. With the same land base and with changes in food consumption patterns, animal rations, and spatial distribution of agricultural production through comparative advantage of crops by regions, this nation could export and additional 600 million bushels of wheat, 20 million tons of feed grains, and 179 million bushels of soybeans above the very high levels projected for Alternative A.

Price and program caution

Other changes also could be made wich would extend U.S. food production and export capacities. These possibilities are being analyzed by the Center for Agricultural and Rural Development (CARD) in conjunction with certain aspects of environmental quality and protection of water and land supplies. However, even the greater output and exports posed under the few changes in consumption, substitution, and location in this study have important implications with respect to domestic and world prices and storage and market

programs. If the outputs of the seven alternatives, especially G, were to be produced under export demands of the 1970 level, prices and incomes of U.S. farmers would be extremely depressed. It is reasonable for U.S. farmers to expect that if either this nation or the world is going to call on them to produce large outputs for the hungry people of other countries, they should receive prices, through market mechanisms or price programs, which guarantee them market returns on the resources they use.

III. SUMMARY AND POLICY REQUIREMENTS

American agricultrual exports have reached record levels, both in quantitative and value terms, in recent years. The American farmer in general fared well during this period, although the high grain prices eventually burdened livestock producers. Conversely, American consumers were affected adversely by the highly inflated food prices.

It is useful, though, to look at this situation from another point of view. Is U.S. agriculture able to continue to make such large contributions in "feeding the world" given the high birth rates in the LDC's as well as the small increases in per capita production experienced during the last decade? To put the U.S. agricultural exports in perspective over the last decade, a large part of the agricultural grain commodities (especially wheat) were actually shipped through PL 480, food for peace, and other government programs, rather than commercially, up to 1972. A considerable public subsidy went into these exports under PL 480, the United States international food aid program, begun in the 1960's. However, the amounts so subsidized have declined drastically during the last two calendar years as the commercial market has been strong enough to divert the government from buying large quantities of grains [5]. Consequently, less U.S. grain has been shipped to countries that can least afford to buy it at recent high price levels.

Many U.S. and world leaders have suggested the need for an improved organization of world food producing resources, greater food output, and expecially greater marketings by the grain exporting countries to the poorer or developing countries.

The world food situation may be regarded as being in a period of transition. Nations are becoming more aware of their food producing possibilities and limitations. The LDC's became aware that they need no longer "consider starvation by masses to be a necessary condition of either God or nature" [13, p. 10]. Planning in these countries improves over time, and therefore as disaster may strike, the LDC's will purchase in the international market to make up for the deficit supply. Consequently, U.S. agriculture may also in the future experience fluctuating exports because of its important place in the export market for grains. Also the growing inability or unwillingness of importing countries to "tighten the belt" in times of disaster, as well as the increasing affluence of the developed countries which will now spend a smaller proportion of their total budget on food items, also can contribute to this "yo-yo" effect. The "yo-yo" effect would come about as U.S. farmers produce "all out" in years of normal weather over the world and experience low prices. Then, in years of crop shortfalls over the world, and in the absence of grain reserves, other countries would step into the U.S. market for grain and send prices skyward again as in 1973-74.

The developed countries, with emphasis on the role of the United States because of its prominent place in grain production, can contribute towards an increase in world food production and food reserves through several means. Changes could be made in dietary habits and techniques of production.

It has recently been suggested, for example, at the Rome World Food Conference, that the citizens of the western world should sacrifice some of

their affluence in terms of consuming less meat.[8] This suggestion of course finds its roots in the partial misconception that grain fed to beef is an entirely wasteful method of transforming grain into human nutrients. It is true that beef animals are not very efficient in converting grains into animal proteins, as compared to conversion of elements to protein by plants. However, Zmolek suggests that the conversion of grain and protein supplement to the total weight of beef cattle is about 3:1, contrary to the usually quoted 7:1, the difference being that feeders have gained most of their weight on forage before they enter a feedlot [22, p. F1].

Also changes may come about on the consumption side. Consumers could change their dietary habits, through decreasing the level of animal protein intake or substitute soy protein for animal protein or some combination of the two.

If indeed, a situation came about where one of the above alternatives had to be accepted, how would it be accomplished? Would such changes be adopted voluntarily or would they have to be implemented by mechanisms or by government decree? It appears unlikely that such changes would come about voluntarily on a mass scale unless the price of meat were extremely high in the United States. However, there is some evidence with regard to the "substitution" alternative, i.e., changes through the market system. During the 1972 price freeze on beef, a marked shift occurred in the demand for soy substitute as a replacement in such products as ground meat.[9] People quickly readjusted their tastes and consumed texturized vegetable protein as

---

[8]Note that the assumption of a reduced meat consumption presupposes that such action will provide the consumer with a diet that is nutritionally sound.

[9]Personal communication with Dr. Agnes F. Carlin, Professor of Food and Nutrition, Iowa State University, Ames, Iowa.

a replacement for animal protein. Thus, it appears that if the price ratio is right, i.e., the price of soybean substitutes is low relative to the price of meat, the consumer will voluntarily alter the composition of his food basket.

A third possibility for expanding U.S. grain exports, one which has come up many times recently as an alternative to grain feeding, is the feeding of more corn silage to beef cattle as a substitute for corn grain. Also, there is revived interest in grazing and feeding cattle on pasture. Beef farmers may be forced more to such alternatives if grain prices stay as high as they have been recently.

In this study, a linear programming model is used to analyze the impact of seven possible scenarios on quantity and location of crop production, crop yields, supply prices, and export quantities at the national and regional levels. The model includes 150 producing regions, 31 demand regions, a transportation submodel, and domestic demand constraints projected to 1980 levels. In addition, cropland constraints are imposed in each producing region. The endogenous commodities included in the model are wheat, soybeans, cotton, silage, and feed grains (consisting of corn, sorghum, oats and barley).

This study analyzes seven alternative situations for 1980. All assume that American agriculture produces at full capacity. Here, full capacity is assumed to be attained when the land base of 251 million acres used in the programming model is fully utilized. In each circumstance, therefore, exports of the three grain commodities (wheat, feed grains and soybeans)

are maximized subject to the assumptions underlying each alternative and subject to attainment of all domestic food demands.

For the seven alternatives, estimated supply prices of the crops are at levels comparable to the target level prices of the 1973 Agricultural and Consumer Protection Act. However, they are in general lower than actual prices of the last few years, even if the estimated prices are inflated to reflect 1974 costs. Even though under all seven alternatives American agriculture produces at full capacity, the estimated supply prices (which reflect per unit production costs) do not skyrocket. This relatively stable set of supply prices indicates that American agriculture is extremely efficient and flexible in producing wheat, the production of which can increase sharply as the demand for feed grains and soybeans declines relative to the base alternative, A. These price results do not imply that farmer prices should never rise above these levels. Instead they indicate the minimum price levels necessary to draw forth the desired quantity of production and exports in a perfectly competitive market industry. U.S. farmers could not be expected to "produce food for the world" unless they were guaranteed price levels which give them market levels of return on their resources. The market price in any year is determined largely by the quantity available and the demand for the commodity in that year, and not by the cost of producing the commodity in the particular years.

The seven hypothesized situations for this study can be divided into two subsets. In the first subset, containing Alternatives A, B, and C, domestic demands are held constant, but the proportion of total grain exports attributed to each grain commodity (wheat, feed grains, and soybeans) is forced to vary. Alternative A, which represents the base situation for the

analysis, allows the increase in exports of the three commodities to be in historic proportions. Export quantities would be higher under this alternative than the export level reached in 1973 and 78 percent higher than the 1971-73 average quantity. Wheat production takes up most of the land drawn into production to meet the increased export demand. Relative to 1971-73, the location of wheat production shifts towards the Northern and Southern Plains regions, while the Corn Belt and Southern Plains regions pick up the increase in feed grain production. Soybean production increases in both the Northern Plains and Corn Belt regions. For Alternative A, supply prices at the farm level are estimated to be well above 1972 average prices except for soybeans.

Under Alternative B, the composition of grain exports is shifted. This circumstance considers the impact on production, exports, and prices if wheat exports are held at their 1971-73 level, while feed grain and soybean exports are increased to the limit of the model's land base. This alternative would suppose that world organizations or the United States emphasize greater feed grain production and exports so that the more affluent consumers of the world could eat more meat. With this stipulation, exports of feed grains and soybeans increase by 108 and 146 percent, respectively, over 1971-73 levels. The Corn Belt, Southern Plains, and Northern Plains regions account for the increase in production of feed grains, while the Northern Plains region is responsible for the increase in soybean production.

Supply prices are somewhat higher in this alternative than under Alternative A. As production of feed grains and soybeans are expanded into more marginal, higher cost areas, higher supply prices are generated to reflect the increased costs and lower yields of these regions.

A major objective of this analysis is to examine the impacts of different policies on American export capacities. Since, in a world critically short of food for human consumption, food grains may be in very great demand, Alternative C examines the effects of a complete emphasis on wheat exports while feed grain and soybean exports are held at their 1971-73 level. Hence, more food grains would be produced to export to the poorer countries for direct consumption as food. Wheat exports could total 2.7 billion bushels, almost triple the 1971-73 average wheat exports under these conditions. Relative to Alternative A, the Corn Belt and Lake States regions increase their wheat production considerably. However, the Northern Plains and Southern Plains regions would increase their wheat acreage by the largest absolute amounts, 13 million and 7 million acres, respectively. The Corn Belt region also increases feed grain production.

The fact that the supply prices in this situation are low relative to the previous alternatives indicates the cost advantage that wheat production has over the other commodities in producing direct human food. Most regions can adapt well to wheat. Thus, there are no sharp increases in wheat supply prices as wheat output is increased and other grain is held at the 1971-73 level. Another indication of American agriculture's capacity to produce wheat is the estimated increase in yield for all commodities, except for a slight decrease in cotton, relative to the previous alternatives.

The second set of alternatives considers changes in production and (or) consumption patterns in the United States. Given the major objective of this analysis, each of the changes contributes towards an increased level of exports. For all four of the alternatives in this subset, the composition

of grain exports is the same as in Alternative A. Alternative D examines the impacts of a 25 percent substitution of silage for feed grains in feedlot production of beef. With this relatively minor shift in production practices, grain exports can increase by 4 percent over Alternative A. Although wheat and soybean production can now increase relative to Alternative A, feed grain production falls as the increase in feed grain exports does not offset the decrease in the domestic demand for feed grains by beef. Silage production increases to 214 million tons, up 30 percent relative to Alternative A. Because of the rather tightly constrained location bounds assumed for silage, major shifts do not occur in the production of this crop. (The model thus does not fully capitalize on the comparative advantage some regions may have in raising corn or sorghum silage.) Relative to Alternative A, most of the reduction in feed grain acreage would be located in the Corn Belt region. This acreage is then shifted to soybean and silage production.

Yields for all commodities, except for soybeans, decline under Alternative D. Soybean production expands onto some of the released feed grain land which has relatively low yield potential for soybeans. Estimated supply prices are almost the same as under Alternative A.

Alternatives E and F consider the effects of a change in consumption habits by the American public. Under Alternative E, the American consumer would substitute 25 percent of his projected animal protein intake by vegetable proteins in the form of soy concentrates or isolates. Although the source of protein is different, the consumer's total protein consumption does not change between Alternatives A and E. With a reduction in the demand for animal protein, wheat production again increases as exports rise by 17 percent over Alternative A. Feed grain production, however, would decrease

by 24 million tons to 228 million tons under Alternative E, as compared to A, as fewer animals are now fed. Because of increased export demands, soybean production would increase by 140 million bushels over Alternative A. Although the domestic demand for soybeans is reduced because of a decreased demand for soybeans by animals, this reduction is offset by the increased use of soybeans in human diets.

The Southern Plains, Northern Plains, and Corn Belt regions account for almost all of the increase in wheat production in Alternative E. The Northern Plains region now devotes over 34 million acres to wheat, compared to an average of 23 million acres during the 1971-73 period. Relative to Alternative A, most of this increase in wheat acreage in the Northern Plains region comes from a decline in feed grain acreage. The Corn Belt and Lake States regions also decrease in feed grain acreage. Under E the Corn Belt region now has 47 million acres feed grain, down 5 million acres compared to Alternative A. The Lake States region has a decline of 2 million acres as compared to A. These decreases in feed grain acreages are replaced by increases in wheat and soybean acreage.

Under Alternative E, estimated exports are more than double the 1971-73 average and 17 percent over the exports estimated under Alternative A. Wheat exports would reach over 2 billion bushels, while feed grain and soybean exports are 66 million tons and 936 million bushels, respectively. Supply prices of all commodities under this alternative fall relative to Alternative A. The price of soybeans declines most, 11 percent. Supply prices under this alternative are $2.38 for wheat, $1.60 for feed grains, $3.37 for soybeans, 36.9 cents for cotton, and $11.87 for silage.

Alternative F assumes a 25 percent cutback of meat consumption relative to Alternative A but does not allow for any soy protein substitution. Instead, it supposes that Americans simply reduce their consumption of protein from the projected levels. The results estimated under Alternative F are very similar to those of Alternative E. Production of wheat and feed grains increases over the levels estimated for Alternative E. However, soybean production falls, since now the reduced meat consumption is not offset by increased soy protein consumption. The decrease in soybean production caused by the reduced domestic demand, however, is partly offset by increased export demands. Grain exports are now 21 percent higher than under Alternative A. Wheat exports are 2.1 billion bushels; feed grains, 68 million tons; and soybeans, 968 million bushels under Alternative F.

Yields are slightly higher under Alternative F than under the previous alternative, E. Also they are higher than under the base alternative, indicating once more that as wheat production increases relative to feed grains and soybeans, yields can increase and farm supply prices tend to fall. American agriculture appears to have great potential in wheat production, a potential which may be of extreme importance given a burden in world food demand in the future and the supply-demand situation sketched in these alternatives.

The final scenario examined, Alternative G, combines the assumptions specified in Alternatives D, E, and F. Therefore, Alternative G incorporates a 25 percent reduction in meat consumption, a 25 percent substitution of soy protein for animal protein in the remaining meat consumption, and a 25 percent silage substitution for feed grains fed to beef. It also allows all crops to be distributed among regions according to their comparative advantage.

Wheat production would be almost 3 billion bushels under this alternative; soybean production, 1.7 billion bushels; and feed grain production, 205 million tons. Note that feed grain production falls 47 million tons relative to Alternative A. Exports of all three grain commodities under Alternative G increase by 140 percent over the 1971-73 level and 35 percent over the level estimated under Alternative A.

The Corn Belt, Lake States, Southern Plains, and Northern Plains regions increase wheat production by 600 million bushels compared to Alternative A, drawing into wheat production an additional 17 million acres of land. Almost all of this land would replace feed grain production in these regions. The Corn Belt increases soybean production by 5 million acres over Alternative A, up to 22 million acres.

Wheat exports are 2.4 billion bushels under Alternative G. Soybean exports are 1.0 billion bushels, more than double the record exports of 1974. Feed grain exports are 76.1 million tons under Alternative G, up 19.7 million tons over Alternative A. This increase in feed grain exports, however, does not nearly offset the drastic decrease in the domestic demand for feed grains associated with Alternative G.

Prices under Alternative G are consistently lower for all commodities than under Alternative A as per acre yields, except for cotton, are higher than under the base alternative. Generally, as wheat production increases proportionally to other grains in total production, grain supply prices fall and yields increase.

Policy Requirements

In this analysis, several alternatives in American agricultural production and consumption patterns have been examined. The results of the

study indicate that, even though these alternatives are constrained to modest levels, their implementation could allow great increases in U.S. grain production and exports. These production and export estimates provide support for the contention that shifts, such as the ones examined here, could contribute to solving the "world food problem." However, the supply price estimates of the study stress the need for strong market institutions and demand levels to insure that the American farmer can produce at "full capacity levels."

The authors wish to reemphasize that the production and consumption changes discussed in this report are not presented as prescriptions for the future of American agriculture. Rather they represent possible directions in which the U.S. farming industry could move, either because of market pressure or government action. The rather modest 25 percent changes hypothesized were chosen because they result in pronounced changes in grain production and export potentials. Of course, adjustments other than those examined in this study could also add to U.S. food production and exports.

The situations in this report that deal with a cutback in meat consumption allow sizeable increases in grain production. But these estimates probably underestimate the true export potential. This underestimation occurs because the model does not allow grassland freed from grazing to be converted to the production of grain. Although reductions in meat consumption are projected to allow sizeable increases in grain exports, they also imply a rather glum growth potential for the American livestock industry. And a cutback in the livestock sector would have a definite negative impact on some rural communities.

The results of this analysis indicate that U.S. agriculture has great capacity and flexibility in grain and food production. But these results

also stress that if national and world leaders are sincere about solving the world's food problems, and if they expect American agriculture to provide a large increment of increased world grain exports, they need to create conditions favorable to these developments. American agricultural capacity is so great that without "back up" programs of reserves, market guarantees, and price mechanisms, "all out" U.S. grain production would certainly depress farm prices and income. Hence, if world and national organizations are serious about improving the world's food situation, they must create policies as well as institutions, which will guarantee U.S. farmers prices that cover production costs and give market level returns to their resources.

APPENDIX: MATHEMATICAL STRUCTURE OF THE MODEL

The mathematical model used for this study is a linear programming model, which minimizes the cost of producing the five endogenous commodities in the 150 producing regions and the transportion of these commodities (except for silage) among the 31 demand regions.

The model consists of 307 equations and 2214 real variables. Land in the 150 rural areas and demands specified for the 31 consuming regions (plus national cotton lint demand) serve as constraints for the equations. The real variables include crop production and transportation activities.

In mathematical notation we may write the model as follows:

Find a set of x's such that

$$f(x) = C\ X \tag{A.1}$$

is minimized subject to

$$A\ x \leqq b \tag{A.2}$$

$$x \geqq 0 \tag{A.3}$$

where,

x is column vector of production and transportation activities;

C is row vector of unit costs for the activities;

A is a matrix of input-output coefficients; and

b is column vector of resource restraints and demand requirements.

The mathematical structure for all seven alternatives stays the same. The factors, which do vary between the alternatives, are the assumptions concerning the value of the model parameters (export levels for the endogenous commodities).

Equation A. 4 is the objective function to be minimized in the model:

$$f(c) = \sum_{i=1}^{150} \sum_{j=1}^{5} c_{ij}^{s} x_{ij} + \sum_{f=1}^{31} \sum_{l=1}^{31} \sum_{j=1}^{4} T_{flr} z_{mfr} \qquad (A.4)$$

where,

c_{ij}^{s} is the cost per acre of producing the j-th crop activity in the i-th rural area for farm-size structure s (j = 1,2,3,4,5 for wheat, feed grains, soybeans, cotton, and silage, respectively);

x_{ij} is the number of acres of the j-th crop activity in production in the i-th rural area;

T_{mfr} is the cost of transporting one ton of the r-th commodity to (from) the m-th demand region from (to) the f-th demand region ($m \neq f$; r = 1,2,3,4, for spring and winter wheat, feed grains, and oilmeals, respectively);

z_{mfr} is the tons of the r-th commodity transported from (to) the m-th demand region to (from) the f-th demand region.

Production of the crop commodities is restrained by the total cropland available in each rural area, Equation A.5:

$$L_i \geqq \sum_{j=1}^{5} x_{ij} \qquad (i = 1,2,\ldots,150) \qquad (A.5)$$

while the production of soybeans is additionally restrained by an agronomic restraint, Equation A.6

$$x_{i3} \leqq A_i L_i \qquad (i = 1,2,\ldots,150) \qquad (A.6)$$

where,

L_i is the total acreage of land available for the five crop commodities in the i-th rural area;

A_i is the proportion of the total amount of land available to soybean production in the i-th rural area (A_i = .5 for all rural areas except those in Arkansas, Louisana, and Mississippi where A_i = .7) and;

x_{ij} is defined as before.

In addition to the upper limits on production in Equations A.5 and A.6, minimum production restraints are imposed in each rural area as in Equation A.7:

$$x_{ij} \geqq B_{ij} \qquad (i = 1,2,\ldots,150;\ j = 1,2,3,4,5) \qquad (A.7)$$

where B_{ij} is 50 percent of the acreage of the j-th crop harvested in i-th rural area in 1969; and

x_{ij} is defined as before.

Equation A.4 is minimized subject to the following additional linear demand restraints:

$$D_{m1} \leqq \sum_{i=1}^{n} Y_{i1}\, x_{i1} \pm \sum_{f=1}^{31} z_{mf1} \qquad (A.8)$$

$$(m = 1,2,\ldots,31:\ f \neq m)$$

$$D_{m2} \leqq \sum_{i=1}^{n} Y_{i2}\, x_{i1} \pm \sum_{f=1}^{31} z_{mf2} \qquad (A.9)$$

$$(m = 1,2,\ldots,31;\ f \neq m)$$

$$D_{m3} \leqq \sum_{i=1}^{n} Y_{i3}\, x_{i2} \pm \sum_{f=1}^{31} z_{mf3} \tag{A.10}$$

$$(m = 1,2,\ldots,31;\ f \neq m)$$

$$D_{m4} \leqq \sum_{i=1}^{n} Y_{i4}\, x_{i3} + \sum_{i=1}^{n} Y_{i4}\, x_{i4} \pm \sum_{f=1}^{31} z_{mf4} \tag{A.11}$$

$$(m = 1,2,\ldots,31 \quad f \neq m)$$

$$D_5 \leqq \sum_{i=1}^{150} Y_{i5}\, x_{i4} \tag{A.12}$$

$$D_{m6} \leqq \sum_{i=1}^{n} Y_{i6}\, x_{i5} \tag{A.13}$$

where,

n is the number of rural areas in the m-th consuming region,

D_{mr} is the tons of the r-th commodity demanded in the m-th consuming region ($r = 1,2,3,4,6$ for spring wheat, winter wheat, feed grains, oilmeals, and silage, respectively);

D_5 is the national demand for cotton lint (in 480-lb. bales);

Y_{ir} is the yield in tons (except for cotton lint which is in 480-lb. bales) of the r-th commodity in the i-th rural area ($r = 1,2,3,4,5,6$ for spring wheat, winter wheat, feed grains, oilmeals, cotton lint, and silage);

x_{ij} and z_{mfr} are defined as before.

Finally we have the usual nonnegativity assumptions of linear programming:

$$x_{ij} \geqq 0.\ z_{flr} \geqq 0. \tag{A.14}$$

REFERENCES

1. Agricultural Stabilization and Conservation Service. 1972 set-aside programs--Annual report. U.S. Dept. Agr. ASCS. Feb. 1973.
2. Blakeslee, Leroy L., Earl O. Heady, and Charles F. Framingham. World food production, demand and trade. Center for Agricultural and Rural Development. Iowa State University Press. Ames. 1973.
3. Cows and calves can add profit on feed grain farms. Garst and Thomas Hybrid Corn Company. Coon Rapids, Iowa, July 1968.
4. Dvoskin, Dan, Kenneth J. Nicol, and Earl O. Heady. U.S. agricultural export capacities under varying prices, alternatives, regional adjustments, soil loss, and nitrogen restrictions. Iowa State University, Center for Agricultural and Rural Development. CARD Rpt.___. Forthcoming 1975.
5. Economic Research Service. Foreign agricultural trade. Statistical report 1973. U.S. Dept. Agr. Econ. Res. Serv. Supplement to: Foreign agricultural trade of the United States. May, 1974.
6. _____. Foreign agricultural trade of the United States. U.S. Dept. Agr. Econ. Res. Serv. Feb. 1975.
7. World food situation and prospects to 1985, The. U.S. Department of Agriculture. Foreign Agr. Econ. Rpt. 98. Dec. 1974.
8. Ewing, S. A. The beef industry - In a world of limited resources. Animal Science Department, Iowa State University, Ames. Paper presented at Annual Meeting of Beef Cattle Improvement Corporation at I.S.U. Jan. 1975.

9. Garst, Roswell. A brief history of corn and grain sorghum production in the U.S.A. by 5 years--periods 1930 through 1972--and some thoughts on the probable future production of the two crops. Garst and Thomas Hybrid Corn Company. Coon Rapids, Iowa. Feb. 1973.

10. Gasser, W. R. World food scarcity--Temporary or chronic? Paper presented and two seminars for Senior Congressional Staff, conducted by the Congressional Research Service and the Brookings Institution. Oct. 3, 1974.

11. Geasler, Mitchell, Everett G. Stoneberg, Steward Melvin, Minoru Amemiya, Regis D. Voss, and Louis E. Thompson. Iowa's opportunities with corn silage. Iowa State University Coop. Ext. Serv. AS-401. Ames. July 1974.

12. _____, Bill Zmolek, and Daryl Strohbehn. Feeding the beef cow. Iowa State University Coop. Ext. Serv. AS-404. Ames. Jan. 1975.

13. Heady, Earl O. What factors affect world food production? Mid-Am. Reporter, Mid-America Dairymen, Inc. Springfield, Mo. Jan. 1975.

14. _____, Howard C. Madsen, Kenneth J. Nicol, and Stanley H. Hargrove. Agricultural water policies and the environment. Iowa State University, Center for Agricultural and Rural Development. CARD Rpt. 40T. June 1972.

15. _____, and Dennis L. Thomas. Alternative crop exports, land use, production capacity, and programmed prices of U.S. agriculture for 1975. Iowa State University, Center for Agricultural and Rural Development. CARD Rpt. 50. Oct. 1974.

16. Mackie, A. B. International dimension of agricultural prices. Southern Journal of Economics, July 1974.

17. Morrison, Frank B. Feeds and feeding. Morrison Publishing Company. Clinton, Iowa. 1956.

18. Muhm, Don. See switch to cheaper feeds; more roughage, less grain. Des Moines Sunday Register. P. 1F. July 28, 1974.

19. Nagadevara, Vishnuprasad SSV, Earl O. Heady, and Kenneth J. Nicol. Implications of full application of soil conservancy and environmental regulations in Iowa with a national framework. Iowa State University, Center for Agricultural and Rural Development. CARD Rpt.___. Forthcoming 1975.

20. Nicol, Kenneth J. A modeling approach to the economic and regional impacts of sediment loss control. Ph.D. dissertation. Iowa State University, Ames. 1974.

21. _____, Earl O. Heady, and Howard C. Madsen. Models of soil loss, land and water use, spatial agricultural structure, and the environment. Iowa State University, Center for Agricultural and Rural Development. CARD Rpt. 49T. July 1974.

22. Peterson, George. A farm on the prairie. The Minneapolis Tribune. Feb. 16, 1975.

23. Production yearbook, 1972. Food and Agricultural Organization of the United Nations. Rome. 1973.

24. Silages in cattle feeding. Area Cattle Feeders, Short Course. Iowa State University Coop. Ext. Serv. AS-309. Ames. 1969.

25. Sonka, Steven T. Income and structure of American agriculture under future alternatives of farm size, policies and exports. Ph.D. dissertation. Iowa State University. Ames. 1974.

26. Sonka, Steven T., and Earl O. Heady. Income and structure of American agriculture under future alternatives of farm size, policies and exports. Iowa State University, Center for Agricultural and Rural Development. CARD Rpt. 53. Feb. 1975.

27. Statistical Reporting Service. Agricultural prices annual summary 1972. U.S.Dept. Agr. Stat. Rpt. Serv. Pr 1-3 (73). June 1973.

28. _____. Agricultural prices annual summary 1974. U.S. Dept. Agr. Stat. Rpt. Serv. Pr 1-3 (74). June 1975.

29. _____. Crop production 1971 annual summary. U.S. Dept. Agr. Stat. Rpt. Serv. CrPr 2-1 (73). Jan. 1973.

30. _____. Crop production 1972 annual summary. U.S. Dept. Agr. Stat. Rpt. Serv. CrPr 2-1 (74). Jan. 16, 1974.

31. _____. Crop production 1973 annual summary. U.S. Dept. Agr. Stat. Rpt. Serv. CrPr 2-1 (75). Jan. 1975.

32. Stoneberg, Evertt G., Frank W. Schaller, Dale O. Hull, Vernon M. Meyer, Norval J. Wardle, Nelson Gay, and Donald E. Voelker. Silage production and use. Iowa State University Coop. Ext. Serv. Pm 417. Ames. Feb. 1968.

33. Use of cron cobs, corn stalks and grain sorghum stubble for cattle feed, The. Garst and Thomas Hybrid Corn Company, Bul. No. 5. Coon Rapids, Iowa. July 1954.

34. U.S. Department of Agriculture Outlook and Situation Board. Agricultural supply and demand estimates. U.S. Dept. Agr. No. 8, Jan. 1974.

35. U.S. Department of Commerce, Bureau of the Census. Population estimates and projections. Current Population Rpt. Ser. No. 477. U.S. Gov. Print. Off. Washington, D.C. March 1972.

36. U.S. Department of Commerce, Bureau of the Census. U.S. census of agriculture, 1969. Vol. I: Statistics for the states and counties. U.S. Gov. Print. Off. Washington, D.C. 1971.

37. _____, Bureau of Economic Analysis. The economic base of selected geographic areas, historical and projected, 1929 to 2020. Preliminary report to the Water Resources Council. Washington, D.C. 1968.

38. Van Horn, H.H., and Nelson Gay. Urea-Corn silage for beef and dairy cattle. Iowa State University Coop. Ext. Serv. Pam. 316. Ames. July 1965.

39. Waugh, Frederick V. Demand and price analysis. U.S. Dept. of Agr., Econ. and Stat. Anal. Div. Tech. Bul. No. 1316. Nov. 1964.

40. Wall Street Journal. April 7, 1975. p. 16.

ADDITIONAL COPIES of this publication can be ordered from the Center for Agricultural and Rural Development, 578 East Hall, Iowa State University, Ames, Iowa 50011. Price is $2 each. A complete listing of all Center publications is available free upon request.