Chapter 11

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Nature, Magnitude and Physical Areas of Potentia[l] Supply-Demand Imbalanc[e]

THE TOPICS to be covered by this and the following chapter by Professor Bottum are: (1) An evaluation of surplus problems as an over-input of land and labor, (2) the (possible) effects of technological prospects on a relative supply of land and agriculture's capacity to produce, (3) the relative overcapacity of farming from 1960 to 1985 and (4) the acreages not needed in agriculture and where located. Obviously, this is a large order if one is to take the assignment literally. But the purpose of this book is: (1) To bring into analysis and technical discussion facts and ideas relevant for providing answers and (2) to suggest areas of further study necessary to an adequate understanding and amelioration of these problems. Hence, we take our cue from this statement and present what we believe to be some of the more relevant ideas for analysis of farm surplus problems, together with some partial facts — partial because they deal with only a part of the surplus problem. Scattered within these ideas and facts will be found a number of suggestions for more exhaustive research.

The plan of this chapter is to consider the topics mentioned in the order given. We consider first the surplus problems of agriculture as an over-input of land and labor.

SURPLUS OUTPUT AND SURPLUS RESOURCES IN AGGREGATE

We believe the majority opinion to be that there is surplus capacity in agriculture. There seems also to be greater

[1]The opinions expressed in this chapter are those of the authors and do not necessarily represent those of the Farm Economics Research Division, ARS, or the United States Department of Agriculture. The writers wish to acknowledge helpful comments received from Arnold Paulsen. Naturally, he is not responsible for any errors or omissions.

agreement that the surplus capacity and corollary-income problems are caused chiefly by excess labor in agriculture. Only recently has the magnitude of the land input become suspect. Yet while there is agreement among many that there is surplus capacity in agriculture and that surplus capacity is in terms of land and labor, there are those who remain unconvinced. Why is this so? First, some persons believe that potential demand has not been fully exploited. "Just give low-income families adequate incomes or promote farm products at home and abroad and farm surpluses will disappear," they say. This reason is in the minds of a majority of the dissenters. Second, others believe that more efficiently organized farms would permit farmers to cover all costs with total output marketed at lower prices.

The hope expressed by the first reason given by the "unconverted" has been adequately repudiated elsewhere.[2] Attention to the problem of what would happen to surplus production if farm organization were changed has been less adequate. A priori evidence, however, appears strong on this question, and we would now like to present what seems to us to be this a priori evidence. To do this, we shall first present our definition of surplus production, then relate this definition to the specification of surplus factors in agriculture.

We begin by considering national agriculture in the aggregate. To further simplify the analysis, we first use static concepts. Later, the analysis is modified to include some dynamic aspects of production and consumption and more than one product.

In aggregate, surplus production can be simply and perhaps adequately defined in this way: Given that all factors are priced at opportunity cost, agriculture is producing surplus output if the cost of producing a marginal unit exceeds its competitive market price. (Because crop yields vary so greatly, this definition implies that marginal output is based on expected or average response.) A simple diagram may help to explain this definition of surplus production. In Figure 11.1, aggregate demand and supply curves for the agricultural sector are shown for a single period of production.

The aggregate supply curve in Figure 11.1 is based on marginal unit costs as defined above and the aggregate demand curve is for a unit of time, say one year, and includes export as well as domestic demand. According to the definition, all units represented by $oq_2 - oq_1$ are "surplus" because for each of these units a price would be less than the unit cost. For the moment, let's

[2] See, for example, "Demand for farm products." CAA Report 2. The Center for Agricultural and Economic Adjustment, Iowa State University, Ames.

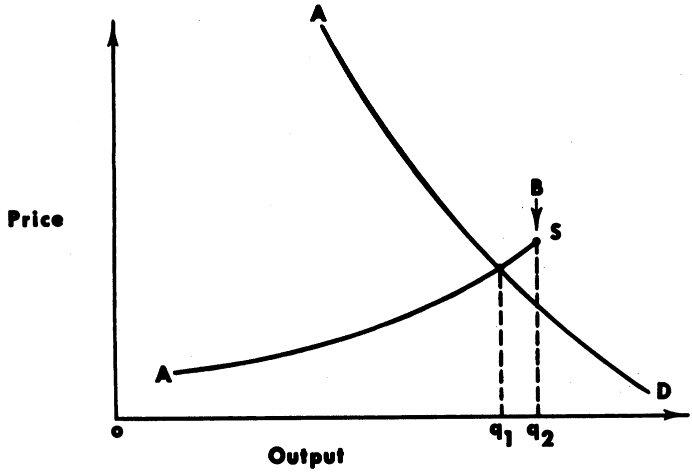

Fig. 11.1. Aggregate demand and supply curves for the agricultural sector for a single period of production.

call this quantity a "tentative" surplus. Only for the q_1-th unit does the price equal cost. Hence, the quantity oq_1 is the equilibrium output and represents nonsurplus production. Furthermore, given that the quantity $oq_2 - oq_1$ represents surplus production, then all factors used to produce these units are themselves surplus.

This statement can be illustrated by referring to the aggregate production function underlying the supply curve shown in Figure 11.1. This production function is shown in Figure 11.2.

In Figure 11.2, land — in acres or some other convenient unit — is plotted on the horizontal axis and is represented by the symbol x. Associated with each of these land units is the customary "bundle" of other resources including labor, machinery, operating capital and so on.

In Figure 11.2, the equilibrium quantity of factors is represented by ox_1. At this level of factor use, the factor/product price ratio represented by line bb′ is equal to the transformation ratio, $\frac{dq}{dx}$. At input level, ox_2, the factor/product price ratio represented by line cc′ is greater than $\frac{dq}{dx}$. (The slope of the factor price-product price line changes as output increases because we are dealing with aggregate demand and higher levels of production can be marketed only at lower prices.) Hence, all factors represented by $ox_2 - ox_1$ are surplus and these are the factors associated with output $oq_2 - oq_1$ in Figure 11.1.

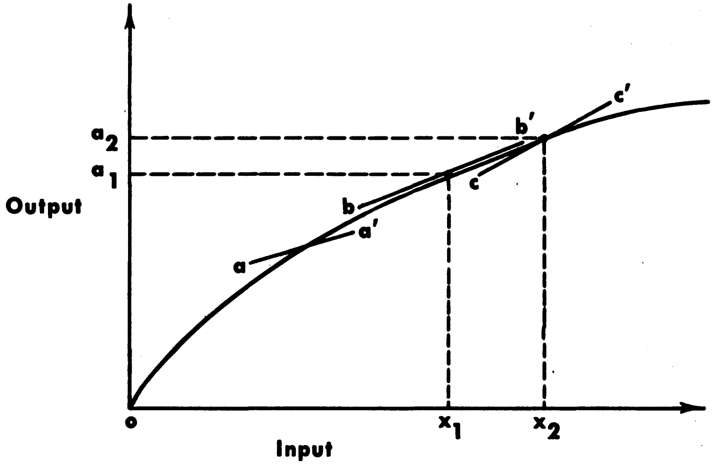

Fig. 11.2. Aggregate production function underlying the supply curve shown in Figure 11.1.

Figure 11.1 portrays total agriculture about as it exists today with a surplus output somewhere between 6 and 10 percent, depending on the "estimator."

Can anything be done to "remove" this so-called surplus? Conceptually, a number of possible alternatives are open.

The most desirable alternative seems to be that of increasing the demand for farm products, which would mean a shift of demand curve AD (Figure 11.1) to the right. This shift would need to be great enough so that demand curve AD would pass through point B (Figure 11.1). As noted earlier, results of research indicate that a shift of such magnitude is highly unlikely.

If we are willing to admit that demand expansion cannot take up the slack in agriculture, another alternative is to "remove" the surplus resources. Thus, with a given state of technology, if resources, ox_2 - ox_1 (Figure 11.2), were to be withdrawn from the agricultural sector, surplus output, oq_2 - oq_1 (Figure 11.1), would not be produced. Such a withdrawal implies not only a removal of land and labor from agriculture but also other resources including machinery, farm improvements and operating capital.

Apparently some persons believe that a third alternative that will bring supply into balance with demand is open to agriculture. This alternative is evidenced by the statement, "What farmers need to do is reduce cost of production." It is not quite clear just what this statement implies. Consequently, it opens up two possibilities. The statement can mean that farmers need either

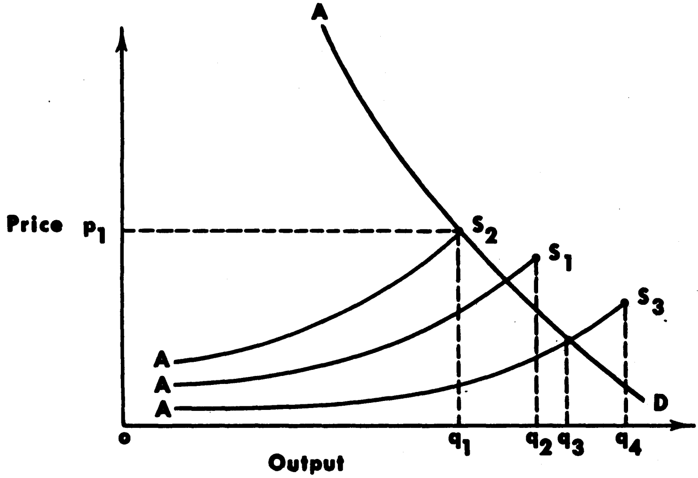

Fig. 11.3. Showing relationship of how drastic reduction in inputs could contract output to such a degree that supply and demand would be in balance.

(1) to reduce total production costs or (2) to reduce unit production costs. If farmers would reduce total production costs, this would mean that they probably would contract their expenditures for such things as fertilizer, hybrid seed, insecticides and other variable inputs. These are unit-cost-decreasing expenditures. Hence, if such action were taken, unit production costs would increase and, consequently, supply costs would increase. But if such a reduction in inputs were drastic enough, it might be possible to contract output to such a degree that supply and demand would be in balance. This relationship is depicted in Figure 11.3.

In this figure, curve AS_1 represents the supply curve as it presently exists, and AS_2 represents the supply curve that would result if farm expenditures were reduced. Given this adjustment, total capacity (oq_1) could be marketed and farm resources would receive opportunity cost returns. It seems obvious that such an equilibrium position would be highly unstable. This would be true because each farmer could improve his profit position (given the price level p_1, Figure 11.3) by increasing the variable expenses just contracted.

The other possibility — that of reducing unit costs — implies that expenditures for fertilizer, insecticides, hybrid seed, improved machinery and so on would be increased. Such changes would result in a shifting of the aggregate supply curve of agriculture. This shift could be represented by curve AS_3 (Figure 11.3).

As this curve is drawn, an output (oq_3) greater than present total capacity (oq_2) could be marketed and the resources used to produce this quantity could receive opportunity cost returns. (Again we note that factors are priced at their opportunity costs in Figure 11.3.) However, because resources would have been added to the agricultural "plant" (capital in the form of fertilizer and so on), output capacity exceeds equilibrium output. We have excess capacity equal to $oq_4 - oq_3$. This excess capacity may be greater than that existing before resource adjustments to reduce unit costs were made. Of course, Figure 11.3 shows only hypothetical situations and should not be interpreted as empirical evidence. However, such adjustments as that characterized by curve AS_3 are now occurring in agriculture. At the same time, the demand curve has been shifting along with shifts in supply. We shall discuss this dynamic aspect later, but first we shall relate Figure 11.3 to the aggregate production functions.

In Figure 11.4, oP_1 represents the aggregate production function of agriculture as it now is. The acreage of land and other resources in the agricultural "plant" is represented by ox_2. Output capacity, therefore, is oq_3 and the resources that produce this output are represented by ox_1. Production function oP_2 is the one underlying curve AS_2 (Figure 11.3). But ox_2 represents fewer total resources when associated with oP_2 than when associated with oP_1 because each acre of land is farmed less "intensively"; that is, less fertilizer, insecticides, livestock or other resources

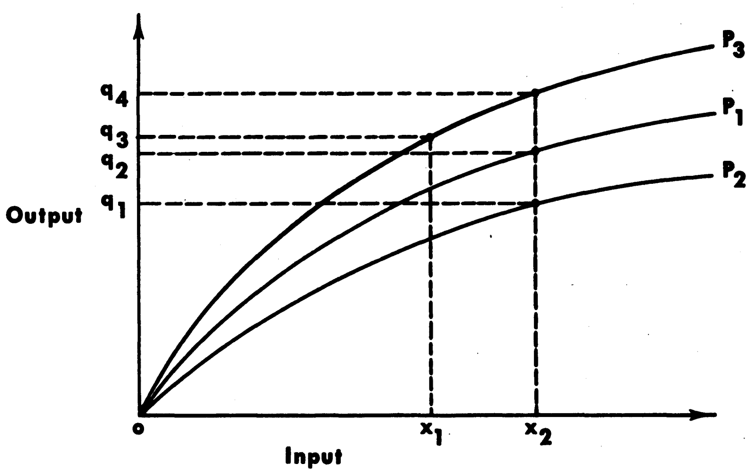

Fig. 11.4. Relationship of agricultural production functions to resources in the agricultural "plant" and output capacity.

are used per unit of land. Conversely, production function oP_3, which underlies curve AS_3, represents greater total resources for each level of output. Also, oP_2 represents less efficiently organized resources and oP_3 more efficiently organized resources as compared to oP_1 because unit production costs are higher and lower, respectively.

For production function oP_3, ox_2 - ox_3 represents the level of "surplus" land, that is, land not needed for the production of wheat and feed grains. But, as already noted, each acre of this land has a larger quantity of other resources "tied up with it" than does surplus land (see Figure 11.2) associated with function oP_1 because of intensive production practices. No surplus land and other resources are associated with function oP_2, as oq_1 is the equilibrium output.

A final note as to surplus output and resources should be added before we turn to some of the dynamic aspects of surplus production. Suppose that agriculture were organized to achieve absolute efficiency; that is, that total production costs were a minimum for each level of output. We could then ask the question, "Would there be surplus resources in agriculture?" The answer would be "yes." This answer would follow because, for efficient least-cost output, more labor would be available than could be efficiently employed on the available land. But also, with complete efficiency and assuming no change in the land base, very likely the total output forthcoming from this land could not be sold at a price that would cover the opportunity cost of the resources used. This would be a situation characterized by supply curve AS_3 and demand curve AD in Figure 11.3.

In discussing changes in output and consumption over time as related to surplus capacity, let us begin by assuming that agriculture is in equilibrium. As compared with the present situation, the agricultural plant is "brought up to date economically," so to speak, as shown by aggregate supply curve AS_1 and aggregate demand curve AD_1 in Figure 11.5. Again, we assume that factors are priced at their opportunity cost.

The equilibrium output in Figure 11.5 is oq_1, and for this output there are no surplus resources in agriculture. That is, the quantity of resources in agriculture is the amount that can produce quantity oq_1 and no more. In a following time period, time period 2, innovations are made (and assuming no changes in the general price level) and the supply curve appears as AS_2. New resources are brought into agriculture as a result of innovations or adopted technology, but all the resources of time period 1 that have not worn out are retained. (We assume that there is a normal shrinking of the agricultural labor force.) Consequently, the

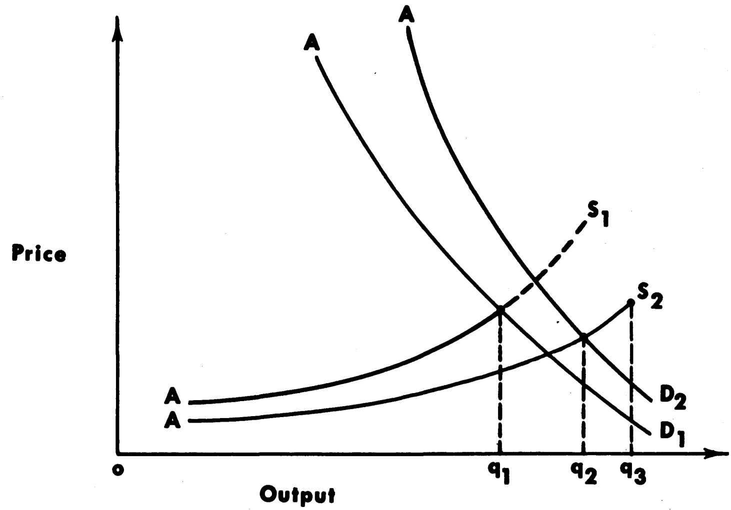

Fig. 11.5. Changes in agricultural output as shown by shifts in aggregate supply and demand.

maximum output of agriculture is oq_3, as shown in Figure 11.5. Although change in the aggregate supply of agriculture occurs over time, changes in aggregate demand occur also. The aggregate demand curve shifts, therefore, as is shown by curve AD_2 in Figure 11.5. Even though both aggregate demand and supply have shifted, relatively, the shift in supply is greater. Equilibrium output, consequently, is less than the capacity output. That is, oq_2 is less than oq_3 (Figure 11.5).

All the previous examples are hypothetical characterizations of the nature of surplus production in agriculture. The general conclusion was that surplus production implied a surplus of some or all factors used to produce agricultural commodities, not land and labor alone. But if the goal is that of production efficiency within agriculture, for any given point in time, some resources may not be surplus even though excess output exists. This may be the case for certain capital inputs, such as fertilizer. All the fertilizer used on "surplus" farm units could be shifted to non-surplus units and production efficiency would be increased; that is, each level of output would be produced at a lower total cost. But it is possible that this reallocation of fertilizer would increase the surplus of other factors above and beyond that existing in the absence of such reallocation. This might be true, even though all other surplus resources were removed from agriculture prior to the redistribution of fertilizer, because output would be greater than demand, as we have defined this condition.

Although the previous discussion dealt with a hypothetical example of surplus production, there is an element of fact in such an example and especially in the dynamic model. The level of capital in agriculture has increased significantly in the 1940's and 1950's, for example, plant nutrients and machinery. Thus, if demand is not expanding as fast as productive capacity, some of the resources are bound to be surplus. This is the situation that we observe today.

The measurement or specification of these surpluses, however, is very difficult, even for agriculture as a whole. Specification becomes more difficult if we attempt to delimit surplus resources with respect to particular commodities. We may be able in some crude way to specify the level of resources committed to production of wheat, corn or cotton, but what can we say about agriculture as a whole? Would it be possible to shift surplus resources to other crops or livestock so they would be earning a rate equal to their opportunity cost? No doubt some such shifts are possible. But such possibilities further complicate the problem.

Although the measurement of the current level of surplus resources in agriculture is a significant problem, it is doubly difficult to make such specification for some future period in time. The more important variables involved in such a projection are changes in technology, population, income and export demand and geographical shifts in population.

We have seen that resources are usually added to agriculture as a result of changes in technology. These additional resources are substitutes for resources already in agriculture and primarily those arising in agriculture — land and labor. If the demand for agricultural products does not expand rapidly enough to absorb the additional output forthcoming from these additional resources, there will be additional excess resources. But just what will happen in the area of future technological innovations is difficult to predict. The rapidity by which presently available technology will be adopted is also difficult to predict. Probable increases in population and income also represent a knotty problem for the prognosticator. Thus, the only conclusion that one can come to is that the prediction of surplus production and, therefore, of surplus factors in agriculture can only be crude, even for agriculture as a whole.

REGIONAL SURPLUSES

If we want to "pin down" surplus output and resources to particular areas or regions, the problem is further complicated. If we want to move in the direction of greater production efficiency, the result could be that regions would be contracting at different rates or that some might be expanding while others would start contracting. For example, data in Table 11.1 show that there have been great differences in the increase in output among regions. The greatest expansion in output has been in the Northern Plains and Mountain States where the increases have been 64 and 57 percent, respectively. In contrast, the increases in output have been only 25 and 24 percent, respectively, in the Southern Plains and Delta States, the areas with the smallest increases in the nation.[3] Other data in Table 11.1 partly explain the differences in output changes. Cropland used for crops increased in the Northern Plains and Mountain States by 9 and 38 percent, respectively, while the acreages of cropland used in the Southern Plains and Delta States declined by 19 and 25 percent, respectively. The increased output in the face of reduced acreages is explained mainly by the use of additional commercial fertilizer. For example, as acreages declined from 25 percent in the Delta States from 1939 to 1958, fertilizer use increased 292 percent. Similar examples are shown in Table 11.1 for other regions. The data in this table imply that fertilizer was substituted for cropland during the period shown in a number of areas. Even in the areas where cropland has increased, this substitution is evident in a relative sense.

Table 11.1. Percentage Change in Total Farm Output and Use of Specified Resources, by Regions, 1939-58

Region	Total output	Cropland used for crops	Plant nutrients	Man-hours of labor
		(Increase or decrease - in percent)		
Northeast	34[a]	-20	115	-46
Lake States	40	-3	1,178	-43
Corn Belt	44	9	957	-42
Northern Plains	64	9	5,318	-38
Appalachian	29	-25	132	-46
Southeast	44	-34	136	-57
Delta	24	-25	292	-60
Southern Plains	25	-19	1,371	-51
Mountain	57	38	1,500	-35
Pacific	59	15	656	-33

[a] Based on averages for the periods 1939-41 and 1956-58.

Source: USDA Stat. Bul. No. 233. Revised Sept., 1959.

[3] The tacit assumption here, of course, is that these changes are the result of competitive pressures that augment resource efficiency.

Table 11.2. Percentage Change in Specified Farm Commodities, by Regions, 1939-58[a]

Product	Region									
	Northeast	Lake States	Corn Belt	Northern Plains	Appa-lachian	Southeast	Delta States	Southern Plains	Mountain	Pacific
All livestock and products	45	29	30	33	54	142	69	14	27	57
Meat animals	11	14	33	51	36	91	55	29	41	35
Dairy products	24	33	13	-15	35	34	12	-22	8	37
Poultry and eggs	99	66	42	17	120	432	194	40	25	139
All crops	7	31	39	61	7	8	-4	15	62	58
Feed grains	31	43	30	75	13	52	-20	40	112	164
Hay and forage	7	13	15	67	14	7	-11	-30	30	22
Food grains	-14	16	20	38	-15	53	91	45	71	42
Vegetables	17	6	-38	-9	-32	30	-30	8	54	84
Fruits and nuts	-13	15	-47	-76	-33	87	-38	-46	-13	14
Sugar crops	-33	16	-46	25	-63	-44	-4	-84	17	80
Cotton	--	--	-31	--	-33	-41	-19	14	246	231
Tobacco	-14	-41	-22	--	25	41	--	--	--	--
Oil crops	776	134	277	448	83	10	1,450	38	-44	-50

[a]Data derived from Supplement 1 to "Changes in farm production and efficiency, a summary report" USDA Stat. Bul. 233. Based on averages for the periods 1939-41 and 1956-58.

Data in Table 11.1 show further that while the number of man-hours of labor has declined in all areas, the decline is greatest in the area where the increase in output is lowest. For example, the Appalachian, Delta, and Southern Plains regions show the smallest increase in output and the largest decline in use of labor. Comparable data on machinery and equipment on farms in each of these regions would show large increases in number and value of machinery and equipment used. Unfortunately, these data are not available by regions. It seems evident then that machinery has provided a significant replacement for farm labor.

Obscured by these aggregate data are the changes occurring in the output of many products of agriculture, region by region. Even though the over-all output of agriculture in each of these 10 regions is expanding, this is not true of individual commodities. This fact is brought out by the data in Table 11.2. These data show that while certain regions are expanding output of some product sectors, others are being contracted. Furthermore, within each region, the rates of expansion or contraction are not the same for any commodity group. For example, in the Delta States, the over-all agricultural output increased by 24 percent. But the output of all crops decreased by 4 percent. Furthermore, while the output of all crops decreased in this region, output of food grains and of oil crops increased by 91 and 1,450 percent, respectively. In the main, the data in Table 11.2 point to increased regional specialization, which for the most part has been due to improved technology in both production and marketing. But these regional changes in production also result from population shifts. This influence is probably indicated by the relatively great increases in production of poultry and feed grains and vegetables in the Mountain and Pacific regions.

It should be remembered, however, that the data in Table 11.2 are based on aggregates, in terms of both commodities and land area. A more detailed disaggregation may reveal "islands" of a trend counter to that shown in Table 11.2. For example, the great increase in poultry and egg production in the Southeast is due chiefly to the great increase in broiler production in northern Georgia and South Carolina. Increased regional specialization is evidence of changes in comparative advantage. Technological advancement, population growths, income changes and shifts in population and consumer taste have great impact on the changes in the comparative advantages enjoyed by regions over time. The development of the combine assisted in the shift of comparative advantage in wheat production from the East to the Great Plains. Currently, development of the cottonpicker seems to have given the Southwest and West, where the topography and climate is more favorable to its use than in other regions, a comparative advantage in cotton production.

The important point here is that prospective regional changes in specialization and production patterns need to be taken into account if the level of resources required in agriculture at some point in the future is to be estimated with any degree of accuracy.

All of the factors mentioned will influence the quantities, kinds and location of resources that will be needed in agriculture during the next quarter century of 1960 to 1985. These things we know. What we do not know is the magnitude of these influences. Simple projections will not provide the answers. We need to take into account the complex of influences that operate in the economy, with the individual influences taken into account simultaneously. Otherwise, the estimates are likely to be greatly in error.

The preceding paragraphs may lead the reader to believe that we have given up on our assigned task because of the grossness of the admonitions. This is not the case, as we hope the rest of this chapter will reveal.

In a following section are shown the results of a method of analysis that seemed relevant for estimating the regional changes in resource use that will need to take place if one sector of agriculture — wheat and feed grains — is to keep in step with the demand. But first we would like to speculate about underlying factors, the probable direction of change in aggregate resource use and the prospective overcapacity in the wheat and feed grain sector in the next 25 years.

PROSPECTIVE OVERCAPACITY IN THE WHEAT AND FEED GRAIN SECTOR OF AGRICULTURE FROM 1960-85

The chief reason for the excess production of feed grains, wheat and other crops over demand has been the rapidly rising output since about 1940 — because of adoption of combinations of improved technology and management which have greatly increased output per acre.

In programming future adjustments in agriculture needed to balance the supply of and the demand for agricultural products, we need to estimate the rates of change in the years ahead. In this section, we attempt to estimate the aggregate production of feed grains and food wheat for the next 25 years, using available information.

POTENTIAL CHANGES IN PRODUCTION OF FEED GRAINS

Total production of the four feed grains — corn, oats, barley and grain sorghum — has increased greatly in the last few years mainly because of higher yields per acre and an expanded corn acreage in 1959. Regression of feed grain production by years for 1940-58 indicates that it increased at the rate of about 1.86 million tons per year during this time.[4] As corn represented 67.5 percent of the feed grains produced in 1958 and an estimated 74.2 percent in 1959,[5] major emphasis will be placed on potential changes in corn production.

Changes in Product Mix

Production of feed grains (particularly corn and oats) is on the threshold of another technical revolution because of changes in rotations. In areas where high corn yields can be maintained in a continuous corn[6] or corn-soybean rotation and where erosion is not a problem, corn and soybeans are likely to replace much of the acreage now in oats and forage.

When acreage allotments for corn were discontinued in 1959, total harvested acreage increased from 73 million in 1958 to 84 million in 1959; but the total acreage of feed grains increased by only 7 million as the acreage of oats decreased by 3 million.[7] The national estimates for 1960 plantings are for a slight increase in corn acreage, a 6-percent increase in soybean acreage, and a 5-percent decrease in acreage of oats.[8]

For each acre of oats or hay shifted to corn, there will be an increase in feed production. Using feed unit conversions[9] and 1960 projected yields,[10] each acre of oats and hay shifted to corn will produce, on the average, 160 and 40 percent more feed units,

[4] L. M. Thompson, I. J. Johnson, J. T. Pesek, and R. H. Shaw. "Some causes of recent high yields of feed grains." Proceedings of the Iowa State Feed-Livestock Workshop, Ames, Feb. 16-18, 1959. Special Report 24.

[5] R. P. Christensen, S. E. Johnson, and R. V. Baumann. "Production prospects for wheat, feed and livestock, 1960-65. U.S. Agr. Res. Serv., ARS, 43-115. Dec., 1959.

[6] W. D. Shrader, J. Pesek, and W. D. Moldenhauer. "What about continuous corn?" Iowa Farm Sci. March, 1960.

[7] Christensen _et al._, _op. cit._

[8] "Federal-state crop and livestock reporting service." Report on a survey of prospective crop plantings in the U.S. Des Moines Register. Mar. 19, 1960.

[9] E. O. Heady, R. McAlexander, and W. D. Shrader. "Combinations of rotations and fertilization to maximize crop profits on farms in North-Central Iowa." Iowa Agr. Exp. Sta. Res. Bul. 439. 1956.

[10] Christensen _et al._, _op. cit._

respectively. The comparative value of corn over oats is likely to increase in the future since the rate of yield increase per year has been about three times higher for corn than for oats.[11]

Shrader and Riecken[12] in their chapter state that soils, climate and present status of technology favor increased production of corn on extensive areas in the Midland Feed Region. They estimate that continuous corn or row-crop rotations could be used on about 86 million acres of classes A and B land in this region. In the three sub-regions (Central Prairie, Eastern Forest and Southern Prairie-Forest) where the climate is most favorable and yields are highest, about 49 million acres could be planted to continuous corn or a corn-soybean rotation. The potential corn production in these sub-regions, using estimated acreages of classes A and B land and attainable corn yields estimated for different soil and land-capability situations, could approach about 3.3 billion bushels, they estimate. If present soybean acreage is maintained, the potential corn production then would be about 2.6 billion bushels. In contrast, corn production in 1955 was 1.4 billion bushels in these three sub-regions.

The substitution of soybean acreage for acreages of oats and forage will occur also in the above-mentioned areas. Soybean acreage will depend partly upon the relative prices of corn and soybeans. Soybeans will also be grown with corn to decrease weather risks and income variations.

With the reduction of wheat acreage in 1954, when acreage allotments went into effect, much of this land was diverted to feed grains. The two Plains regions and the Mountain Region had the largest diversion of wheatland to feed grains. Grain sorghum was substituted for wheat and forage sorghums in the Great Plains. Barley has been planted on some of the diverted wheat acreage in the Mountain Region and Pacific Region.

Changes in Capital Inputs

Fertilizer. The three most important factors that have affected yield increases of corn since 1940 have been (1) adoption of hybrid corn, (2) use of more fertilizer (particularly nitrogen) and (3) concentration of corn on more favorable soils in a more favorable climate. Of the estimated 17.5-bushel increase in yield from 1940 to 1958, about 6 bushels have been attributed to fertilizers, with most of the influence of nitrogen occurring since

[11] Thompson et al., op. cit.

[12] W. D. Shrader and F. F. Riecken. "Potentials for increasing production in the Corn Belt," Chapter 5, this volume.

1950.[13] Increased fertilizer usage will be the dominant factor in further increases in yields of corn.

The tonnage of fertilizer for all crops has increased linearly with time since 1940. The annual increase was 1.032 million tons; if this trend is projected to 1965, the estimated tonnage will be 34 million tons.[14] The tonnage of plant nutrients (N, P_2O_5 and K_2O) has increased at an average rate of 257,000 tons per year. A projection of the 1940-57 trend estimates that 8.2 million tons will be used in 1965; the tonnage of N, P_2O_5 and K_2O will be about 3.0, 2.6 and 2.5 million tons, respectively, in 1965.[15] The more rapid increase in nitrogen usage than of P and K usage is likely to continue beyond 1965, particularly if corn is grown more intensively on increased acreages and if prices of corn remain high in relation to N fertilizer.

Since World War II, fertilizer use has been increasing throughout the country, with a larger percentage of total nutrients (25 percent) and nitrogen (19 percent) applied in the Corn Belt than in any other region. A report shows that 35.3 percent of the nitrogen used in 1954 was applied to corn and 7.1 percent to oats and barley.[16] The study showed also that 60 percent of the corn and 30 percent of the acreages of oats and barley were fertilized in 1954.

The percentage of the corn fertilized and the rates of nutrients applied vary widely among the states in the Midland Feed Region.[17] Generally, a higher percentage of the corn is fertilized in states east of the Mississippi River than in those west of the river. Higher rates of P and K fertilizer generally are used in the eastern part of the area, but the patterns of nitrogen usage are less distinct. The rates of N fertilizer in the various states are affected by soils, rotations, manure applications, precipitation and irrigation. Fertilizer usage also varies widely among soil association areas within a state. In Iowa, for example, the percentage of fields fertilized and average rates of the nutrients vary widely among the soil association areas.[18] It is obvious, however, that corn yields in Iowa can be increased considerably as more farmers fertilize corn, as rates are increased and as other associated high-level management practices are adopted.

About 8.4 percent of the total nutrients were applied to oats and barley in 1954, with 31 percent of the acreage fertilized;

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[13] Thompson et al., op. cit.

[14] Ibid.

[15] Ibid.

[16] J. R. Adams, L. B. Nelson, and D. B. Ibach. "Crop use patterns of fertilizer in the United States." Croplife. Aug. 18 to Oct. 13, 1958.

[17] Ibid.

[18] Ibid.

average nutrient application was estimated at 15, 31 and 24 pounds of N, P_2O_5 and K_2O, respectively, per fertilized acre.[19] The percentage of the total fertilizer used on oats and barley will decrease in the future.

Fertilizers have accounted for very little of the increase in sorghum production, although, under adequate moisture, sorghum responds to fertilizers much the same as does corn. Since much of the grain sorghum acreage is in the Great Plains area of uncertain and variable rainfall, fertilizer usage for sorghums is not likely to increase rapidly.

Other management practices. A large increase in corn yields occurred from 1940 to 1950 with the development and adoption of hybrid corn. Hybrids have increased corn yields an estimated 25 percent over open-pollinated corn; about 7 of the 17.5-bushel increase from 1940 to 1958 has been estimated to be due to corn improvement.[20] In recent years, yields have been increased about 1 percent per year because of improved hybrid varieties.[21] A somewhat lower rate of increase is expected to continue in the future with adoption of the best present varieties and development of varieties resistant to corn borer and diseases, varieties better adapted to high stand and fertility levels and varieties that can utilize moisture more efficiently.

Variety improvements in oats and barley from 1940-60 have been made largely to overcome potential yield losses from new races of rust and from new diseases. No appreciable gains in yields per acre from variety improvement are expected in the future.

Sorghum yields increased slightly from 1940 to 1956 but the marked upward trend in 1957 and 1958 reflects the initial use of hybrid sorghums and favorable weather. The new hybrids yield about 25 to 30 percent more than the older varieties. About two-thirds of the grain sorghum in 1958 was planted to hybrids. Yields are expected to increase in future years because of improvements in hybrid varieties.

Increased use of insecticides to control soil insects will be particularly important as the intensity of corn in the rotation increases. At present, the level of adoption of soil insecticide treatment is very low to moderate among different counties in Iowa.[22] Insecticides for control of corn borer have not been

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[19] Ibid.

[20] Thompson et al., op. cit.

[21] Ibid.

[22] Unpublished data, Project 1377, CAEE and Iowa Agr. Exp. Sta., Iowa State University.

widely used, although research has shown that application at the proper time often is profitable.

The use of herbicides for weed control in row crops may be both a cost-decreasing and a yield-increasing practice. Application of 2,4-D for controlling broadleaf weeds in corn has been widely accepted in Iowa, although its use has not reduced noticeably the number of cultivations. The use of pre-emergence herbicides to control grassy weeds, now in the trial stage by a few farmers, is expected to increase. Tillage operations and production costs can be reduced with the pre-emergence herbicides, and farmers will depend less on timely cultivations or rotary hoeing for effective weed control in the row crops.

One of the dominant factors limiting corn yields in Iowa has been inadequate stand levels.[23]

Although stand levels may be nearer the optima in the eastern part of the Corn Belt than in Iowa, increased stand levels will contribute to higher average corn yields in the future and will allow fertilizers and other practices to be used more efficiently.

Improved and larger machinery has been an important factor in increased production of feed grains. Increased mechanization has given the areas with large, level to gently sloping fields an increased comparative advantage in crop production over areas with small, irregular-shaped fields and those with the steeper slopes on which conservation practices should be used. Further improvements in mechanization will decrease production costs and increase harvested yields somewhat.

The effects on feed grain yields of the management practices discussed here, as well as others, such as irrigation, drainage, soil conservation and conservation and efficient use of water are discussed in more detail by Nelson.[24]

Projected Yields to 1985

Corn. Christensen et al.[25] reported corn-yield projections from 1960 to 1965 (Table 11.3) made by a committee of ARS scientists who assumed 1959 acres for harvest and continued adoption of known practices that result in yield increases. The predicted annual rate of increase (0.4 bushel per year) is lower for this period than the rate of increase that occurred from 1940 to 1959.

[23] Ibid.
[24] L. B. Nelson. "Physical potentials for crop production," Chapter 8, this volume.
[25] Christensen et al., op. cit.

Table 11.3. Projected Average Corn Yields Per Acre Based on Various Sources, United States

Year	ARS	1940-58 trend[a]
	(Bushels per acre)	
1960	49.0[b]	48.3
1965	51.0[b]	53.2
1970	52.0[c]	58.0
1975	53.0[d]	62.9
1980	57.0[e]	67.7
1985	60.8[c]	72.6
2000	72.0[e]	----

[a] Thompson *et al., op. cit.*
[b] Christensen *et al., op. cit.*
[c] Interpolated from linear trend.
[d] R. O. Rogers and G. T. Barton. Unpublished data. FERD, ARS, USDA.
[e] USDA. "Land and water potentials and future requirements." Report to the Senate Select Committee on National Water Resources. 1959.

Christensen et al.[26] stated that the continuation of the 1940-58 yield trend to 1965 is possible. They cited Ibach and Lindberg,[27] who estimated that if fertilizer applications on corn were increased to give a marginal return of $2 at present prices and 75 percent of the corn acreage were fertilized at this rate, the national average yield might be about 59 bushels in 1965. Required rates of plant nutrients per acre fertilized were estimated to be 60, 50 and 60 pounds of N, P_2O_5 and K_2O, respectively. It is unlikely, however, that these average rates will be reached by 1965, although 75 percent of the corn acreage is likely to be fertilized by them. In 1958, 65 percent of the corn acreage was fertilized, but only 32 pounds of nitrogen was applied to each fertilized acre.[28]

An economic, attainable average corn yield for 1975 has been projected by Rogers and Barton[29] (Table 11.3). This projected yield appears to be lower than ARS projections for earlier or later years. The ARS corn yield projections for 1980 and 2000[30] (Table 11.3) indicate an upturn in the average rate of yield

[26] Ibid.
[27] D. B. Ibach and R. C. Lindberg. "The economic position of fertilizer use in the U.S. USDA Info. Bul. 202. 1958.
[28] Christensen et al., loc. cit.
[29] Rogers and Barton, op. cit.
[30] USDA. Land and Water Potentials and Future Requirements, op. cit.

increase. For these projections, the major assumptions were: (1) There would be a greater use of technology presently known by research workers; (2) future rate of adoption by farmers of improved practices would be consistent with current educational efforts and technical assistance; (3) price-cost relationships for farm products would be consistent with a high-employment economy; and (4) average weather would prevail in the projected period. It was emphasized in the report that the yield projections are based chiefly on past rates of research and rates of adoption of technology by farmers.

Thompson et al.[31] assumed that the regression of corn yields per acre on years from 1940 to 1958 was the best estimate of the yield trend during this period. They pointed out that the effect of fertilizer was greatest since 1950, but that of crop breeding was greatest before 1950. The major deviations from the regression line probably were due to weather.

Many consider that the slope of the 1940-58 yield trend line is not a good estimator for projected corn yields in the future. The yield trend during this period does include three technical developments in corn production — mechanization, hybrid varieties and markedly increased fertilization. The adoption of the first two is nearly 100 percent, but the most efficient use of the last one is still in the future. Another technical development in corn production — continuous corn — is beginning with the probable concentration of corn production in the areas where soils and climate are most favorable for higher yields. If a major breakthrough occurs in moisture utilization, which has tremendous and exciting possibilities in the Midwest according to Nelson,[32] corn yields may be increased markedly. These scientific advances and others are expected to keep increasing average corn yields.

Some also have thought that the slope of the 1940-58 yield trend line is biased upward by the higher yields in 1956 to 1958, particularly in 1958 owing to favorable weather. However, they seem to ignore the 1950, 1951 and 1953-55 yields, which, mainly because of unfavorable weather, were lower than the trend line. The best evidence that the yields are increasing at about the rate given by the trend line is that the line fitted through the points for corn yields in 1942, 1948 and 1958 (excellent growing seasons for corn in most of the major producing areas) is almost straight and closely parallels the regression fitted to the yields of all years.

The regression equation[33] for the 1940-58 yield trend line is:

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[31] Thompson et al., op. cit.
[32] Nelson, op. cit.
[33] Thompson et al., op. cit.

$\hat{Y} = 27.92 + 0.971X$, where X is years (1940=1). The projected corn yields up to 1985 from this regression are given in Table 11.3. Although these projections may be closer to economic maximum yields than to economic attainable yields, they may be reasonable under the following assumptions: (1) fertilizer, particularly nitrogen, usage increases at the rate indicated by recent trends; (2) rapid technological advances in corn growing continue to be made; (3) rate of adoption of new technology increases more rapidly in the future than it has in the past because of better prediction of the production functions for specific conditions; (4) corn acreage shifts are accelerated into the higher-yielding areas that Shrader and Riecken[34] indicated; and (5) there are no institutional restraints on the shifts in the corn acreage to the areas which have the greatest comparative advantages.

Of more importance than the projections for the average U.S. corn yields are the projected yields for the economic areas or broad regions of similar soils, states and soil association areas within the states. From these projections, a more precise analysis can be made of the future corn production, where shifts in acreages can be made for most efficient production, how many acres need to be taken out of feed-grain production and where these acreages would be located.[35]

Oats and barley. Yield projections for oats and barley were made by the ARS scientists, previously cited, for the years 1960 to 1965, 1975, 1980 and 2000 (Table 11.4). The projected yields from the 1940-58 trend lines are also given in Table 11.4. The regression equations[36] are: $\hat{Y} = 31.08 + 0.34X$ for oats and $\hat{Y} = 22.53 + 0.386X$ for barley, where X is years (1940=1).

There is little difference between the two estimates of projected oats and barley yields. Barley production can be estimated with more confidence than oat production, as barley acreage is expected to remain fairly constant, but the rate of decrease of oat acreage in the future is difficult to estimate.

Grain sorghum. The ARS scientists have projected grain sorghum yields of 30, 32, 35, 37 and 46 bushels per acre for the years of 1960, 1965, 1975, 1980 and 2000, respectively. The interpolated yield for 1985 is about 39.2 bushels per acre. Acreage is expected to be about 14.5 million acres in the next several years unless the Conservation Reserve is expanded more rapidly.

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[34] Shrader and Riecken, op. cit.

[35] E. O. Heady and A. C. Egbert. "Programming regional adjustments in grain production to eliminate surpluses." Jour. Farm Econ. 41:718-33. Nov., 1959.

[36] Thompson et al., op. cit.

Table 11.4. Projected Average Yields of Oats and Barley, United States

Year	Oats		Barley	
	ARS[a]	1940-58 trend[b]	ARS[a]	1940-58 trend[b]
	(Bushels)		(Bushels)	
1960	37.5	38.2	30.0	30.6
1965	39.0	39.9	32.0	32.6
1970	40.5[c]	41.6	33.5[c]	34.5
1975	42.0	43.3	35.0	36.4
1980	44.0	45.0	37.0	38.4
1985	46.0[c]	46.7	38.8[c]	40.3
2000	52.0	----	44.0	----

[a] 1960, 1965 – Christensen *et al., op. cit.*
1975 – Rogers and Barton, *op. cit.*
1980, 2000 – USDA, "Land and water potentials and future requirements," *op. cit.*
[b] Thompson *et al., op. cit.*
[c] Interpolated from linear trend.

The 1940-58 regression line of grain sorghum yields on years is not a good estimate of future yields.[37] High yields in 1957 and 1958 resulting from introduction of hybrid varieties and favorable weather have increased the slope of the regression higher than would be expected for the long-term trend.

Feed grains. Projections of feed-grain production from 1960 to 1985 based on constant harvested acreages of corn, barley and grain sorghum, a decreasing harvested acreage of oats, and ARS-yield projections are given in Table 11.5.

The regression of total feed-grain production on the years 1940-58 does not appear to be a good estimate of future feed-grain production because of (1) the large increase in corn acreage in 1959 and expected acreage equally as high in the near future and (2) the decrease in oat acreage in recent years. The projected production based on the 1940-58 trend line,[38] $\hat{Y}$ (million tons) = 102.2 + 1.86X, where X is years (1940=1), appears to underestimate future production, particularly during the 1960's and 1970's.

Projections of feed-grain production are considerably higher (Table 11.5) if they are based on yields of corn, oats and barley projected from the 1940-58 trend lines rather than on ARS yield

[37] Ibid.
[38] Thompson et al., loc. cit.

Table 11.5. Projected Feed Grain Production, United States, 1960-85

Year	ARS[a]	1940-58 trend[b]	Based on 1960 acreages and 1940-58 yield trends[c]
		(Million tons)	
1960	154.4	141.3	153.3
1965	160.0	150.6	165.8
1970	162.8	159.9	177.7
1975	165.5	169.2	189.6
1980	175.7	178.5	201.7
1985	185.3	187.8	213.8

[a] Assumptions: (1) Constant harvested corn, barley and grain sorghum acreages of 84.0, 14.8 and 14.5 million acres, respectively, and a harvested oat acreage of 27.1 million acres in 1960 but decreasing 0.4 million acres per year thereafter and (2) yields based on ARS yield projections.

[b] Thompson *et al.*, *op. cit.*

[c] Assumptions: (1) Same acreages as given in footnote a and (2) projected yields of corn, oats and barley based on the 1940-58 trend lines of Thompson *et al.*, and projected yields of grain sorghum based on ARS estimates.

projections. For these projections, we assumed constant harvested acreages for corn, barley and sorghum grain of 84.0, 14.8 and 14.5 million acres, respectively, in 1960 and a harvested oat acreage of 27.1 million acres, which would decrease about 0.4 million acres per year thereafter. It is expected that soybeans will replace much of the acreage in oats.

POTENTIAL CHANGES IN PRODUCTION OF WHEAT

Changes in Product Mix

The number of harvested acres of wheat decreased from 71 million in 1952 to 53 million in 1959 because of the acreage allotment and marketing-quota programs that were put into effect in 1954 and still continued. Wheat is still concentrated in the Great Plains, Mountain and Pacific regions. These regions harvest 80 percent of the total wheat acreage. If acreage restrictions were removed, wheat acreage likely would increase in these regions; the increases would depend upon price and program relationships between wheat and feed grains.

Changes in Capital Inputs

The upward trends in wheat yields have been due to new varieties and increased use of fertilizer, chiefly nitrogen. The percentage of the wheat acreage fertilized in the United States increased from 18 percent in 1947 to 28 percent in 1954; the largest increase occurred in the Pacific Region and increases were moderate in the Northern Plains Region and Mountain Region.[39] From 1947 to 1954, the average rate of nitrogen per fertilized acre in the United States increased about 3.5 times; the average rate of P_2O_5 and K_2O increased in the Corn Belt and Lake States but in no region west of these.[40]

From the percentages of the acreages fertilized and the average rates of nutrient applications in the important wheat-producing states, it seems that more fertilizer can be used and that it will be an important factor in increased wheat yields in the future. Since the risk of drouth is high in most of the wheat-producing regions, fertilizer usage will be moderate. However, more efficient use of nitrogen is now being obtained by adjusting the rate to the amount of available moisture in the soil in the early spring.

In the regions that produce most of the wheat, production is highly mechanized; little gain in average yields is expected from increased mechanization.

Projected Yields to 1985

Projected wheat yields from 1960 to 2000 by ARS scientists are given in Table 11.6. The long-term upward yield trend from 1940-59 has been at the rate of 0.3 bushel per acre per year;[41] yield projections from the linear trend (Table 11.6) are somewhat higher than the ARS projections. With the increasing yields and a constant acreage, the production of wheat (Table 11.6) will continue to exceed market outlets.

POTENTIAL CHANGES IN UTILIZATION OF FEED GRAINS BY LIVESTOCK

Although in production of livestock products many advances, such as improved feeding methods, better equipment and trends

[39] Adams et al., op. cit.
[40] Adams et al., loc. cit.
[41] Christensen et al., op. cit.

Table 11.6. Projected Average Wheat Yields and Total Production, United States, 1960-2000

Year	Projected yields per acre		Projected production[c]	
	ARS[a]	1940-59 trend[b]	ARS	1940-59 trend
	(Bushels/acre)		(Million bushels)	
1960	21.0	22.0	1,108	1,160
1965	23.0	23.5	1,213	1,240
1970	23.5[d]	25.0	1,240	1,319
1975	24.0	26.5	1,266	1,398
1980	25.0	28.0	1,319	1,477
1985	26.5[d]	29.5	1,398	1,556
2000	31.0	34.0	1,635	1,793

[a] 1960, 1965 – Christensen *et al.*, *op. cit.*
1975 – Rogers and Barton, *op. cit.*
1980, 2000 – USDA, "Land and water potentials and future requirements," *op. cit.*
[b] Christensen *et al.*, *op. cit.*
[c] Assuming a constant harvested acreage of 52.745 million acres.
[d] Interpolated from linear trend.

trends toward more efficient breeds, have been made, the average amounts of livestock products produced per pound of concentrates have not changed greatly in recent years with the striking exception of broilers and turkeys. The trend has shown a higher amount of concentrates fed per unit of livestock product in all instances except those mentioned.[42] However, projections by the USDA have assumed a 10 percent increase in feeding efficiency by 1975.

The aggregate figures for the feeding efficiency of feed grains may be confounded with other factors. With lower prices for feed grains, probably there has been substitution of these for protein feeds in the rations. In addition, with the substitution of feed grains for forage, there has been more drylot feeding of hogs, and a trend toward substituting more feed grains for pasture and roughage for fattening beef cattle is evident.

POTENTIAL EXCESS ACREAGE IN WHEAT AND FEED GRAINS, 1985

Time did not permit detailed projections of wheat and feed-grain demand for 1985. However, linear extrapolation of

[42] Agricultural Marketing Service, ARS, USDA. Agricultural Outlook Charts, 1959 Nov., 1958.

available projected demands indicates that 182.4 million tons of feed grains and 1,120 million bushels of wheat will be required by that year.[43]

What do these projected outputs and requirements imply in terms of excess acreages? To answer this question, first we shall give acreage estimates based on ARS yield projections, then we shall give similar estimates based on 1960 acreages and 1940-58 yield trends. All these data are shown in Tables 11.5 and 11.6.

Taking the ARS projections given in these tables and the demand projections given above, the potential excess acreage for 1985 is 10.5 million acres of wheat and 2.1 million acres of feed grains. Because these estimates are based on harvested acreage, about 1.3 million acres need to be added to these figures to account for average abandonment. Finally, if the 17.0 million acres of wheat and feed-grain land currently in the Conservation Reserve Program were replanted to grains in 1985, the total excess acreage in wheat and feed grains would amount to 30.9 million acres.

Similar estimates of potential surplus acreages using 1940-59 yield trends and 1960 base acreages are 14.8 million acres of wheat and 19.1 million acres of feed grains. Adding the Conservation Reserve acreage and 2.2 million acres for average abandonment gives an estimated total excess of 53.1 million acres.

These two estimates of potential surplus acreages point out the range in estimates that occur under different sets of assumptions. We don't know which set of assumptions is more realistic, only time will answer that question. Too, a different set of assumptions for estimating requirements would change the surplus picture. These potential surpluses are subject to considerable error. Unfortunately, we are unable to set any confidence limits.

Finally, the estimates made are based on national averages. Analysis of the surplus land picture in terms of regional comparative advantage and adjustments in land use consistent with

[43]These values represent liberal extrapolations based on the work of: Rex Daly. "The long-run demand for farm products." Agr. Econ. Res. 8:73-91. 1956; and Statistical Data and Notes on the Long-run Demand for Farm Products. U.S. Agr. Market. Serv., Mimeographed. July, 1956. For example, if a population of 179 million and 230 million for 1960 and 1975 is assumed, and this implied linear rate of increase is extrapolated to 1985 (i.e., 257.2 million) and the trend in per capita consumption of wheat likewise is extrapolated, the indicated requirements of wheat for 1985 are 1,138 million bushels, or just 18 million bushels more than the estimate given above. A population of 230 million for 1975 is the upper limit of current population estimates. If Daly's highest rate of increase in feed grain requirements for 1975 is extrapolated linearly to 1985, the increase in feed grain consumption from 1952-53 to 1985 is 53 percent, whereas the 182.4 million tons of feed grains given above are 159 percent of the 1952-53 disappearance.

comparative advantage needed to balance production with consumption will give a different estimate of the surplus land potential. This is true because of the variation in yields from region to region. If comparative advantage dictated that acreages be withdrawn from corn production in areas outside the Corn Belt, the potential surplus acreage would be greater than if Corn Belt acreages were to be taken out.

We now proceed to an analysis that attempts to identify region by region the potential excess wheat and feed grain acreages when "restricted" comparative advantage, as measured by relative cost of production, is taken into account.

REGIONAL SURPLUS LAND AND OTHER RESOURCES IN THE WHEAT AND FEED-GRAIN INDUSTRY[44]

The analysis of regional surpluses in the wheat and feed industry presented here parallels many of the concepts outlined in the introductory part of this chapter. Because of the limited space, much of the procedure and supporting data cannot be presented here but they are available elsewhere.[45]

For this analysis, 104 programming regions in the United States were demarcated. These regions are shown in Figure 11.6. At attempt was made to include in each region areas that were homogeneous with respect to grain production. As may be seen in Figure 11.6, certain parts (the blank areas) of the United States were not included in these 104 programming regions. The reason for not including these areas was that less than 25 percent of the total cropland here was usually planted to wheat and feed grains. Hence, grains are of minor importance and as such represent supplementary enterprises that would be continued at present levels despite drastic changes in grain prices. Actually, on the average, these omitted areas produced less than 10 percent of all wheat and feed grains produced in the United States.

The 104 programming regions provided the basis for two linear programming analyses, one of an ex post[46] and the other of an ex ante nature. These might be called "backward-looking" and "forward-looking" models, respectively. The programming

[44] The data presented in this section are from results of cooperative research by A. C. Egbert, and E. O. Heady, Iowa Agr. Exp. Sta. and the Center for Agricultural and Economic Adjustment.

[45] Alvin C. Egbert. Programming Regional Adjustments in Resource Use for Grain Production. 1958. [Unpublished Ph.D. thesis. Iowa State University Library, Ames.] Heady and Egbert, op. cit.

[46] This is model C presented in Heady and Egbert, op. cit. It is presented here again for purposes of comparison.

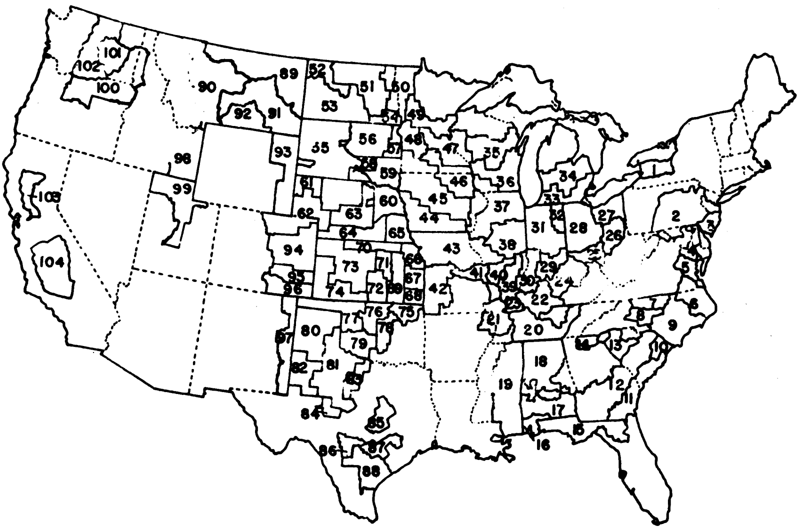

Fig. 11.6. Production regions.

activities considered for the programming regions were food wheat, feed wheat and a feed grain composite. The four feed grains – corn, oats, barley and grain sorghum – were weighted by the average relative acreage of each planted in 1952-54 in the particular region to form this composite. This feed-grain activity was constructed because of production problems of labor use and crop complementarity existing on farms.

Restrictions or restraints on production included the maximum acreages of these crops, plus two absolute constraints representing (1) the total United States food-wheat and feed-grain requirements and (2) net exports of each. The programming analysis used considered the least-cost comparative advantage of different regions in producing food and feed grains under the assumption of linear or constant input-output coefficients. A spatial production pattern and resource use thus determined differs from that which would be obtained by adding up "low per unit cost" regions until output of wheat and feed grain was balanced with requirements.

Programming Models

Ex post model. The formal or linear programming structure of the ex post model is as follows:

$$\text{(1)} \qquad \text{Max. } f(r) = \sum_i \sum_j x_{ij} r_{ij} \qquad \begin{array}{l} (j = 1, 2, 3) \\ (i = 1, 2, 3, \ldots, 104) \end{array}$$

in which x_{ij} is the output level of the j-th crop in the i-th region and r_{ij} is the net return from the j-th crop in the i-th region. Each r_{ij}, the net price, is the difference between the normal unit price and the unit cost. The unit cost for each activity included those that were due to labor, power, machinery, feed, fertilizer and related inputs. Land and overhead costs were not included in the estimates of unit costs.[47]

Objective function (1) is maximized subject to restraints (2), (3) and (4),

$$\text{(2)} \qquad \sum_j x_{ij} a_{ij} \leq A_i$$

in which x_{ij} has the same meaning as in function (1), a_{ij} is the per unit land input for the j-th activity in the i-th region and A_i is the maximum grain acreage in the i-th region. Each A_i is equal to the largest total acreage planted to wheat and feed grains. There were 104 inequalities of type (2) in the model. In addition, there were these two national-demand constraints:

$$\text{(3)} \qquad \sum_i \sum_{j=2}^{j=3} x_{ij} \geq D_1$$

$$\text{(4)} \qquad \sum_i X_{i1} \geq D_2$$

In each of these national-demand constraints, the coefficients of the x_{ij} are (1) because outputs are in terms of a bushel of wheat or of feed grain in corn equivalent. Likewise, the demand constraint for feed grain is in corn equivalent.

Ex ante model. The programming structure of this model is the same as that specified by functions (1) through (4) for the ex post model. Changes are made, however, in the activity net return, r_{ij}, the land-input coefficient, a_{ij} and the demand constraints, D_i. These changes result from these assumptions or

[47] A preferred objective function is one in which total costs are minimized rather than net returns maximized. In this case, transport costs to the regions of demand as well as production costs would be included in total unit cost. In the maximum net return formulation used here, it is assumed that net prices account for transport costs to the consuming regions. In effect, it is assumed that prices in each region are equal to those in a central market (or a series of interrelated markets) less the cost of transportation from the region. If this is the case and if markets absorb the programmed quantities at the implied prices, then solutions under either formulation will be the same.

modifications: (1) An optimum amount of fertilizer is applied on each crop; optimum fertilizer use is defined as the level beyond which net income could decline.[48] In other words, fertilizer is applied up to the point at which added cost is equal to added return.[49] (2) Mechanized production methods only are used. (3) Demand requirements are those projected for 1985.

The above changes that were made in formulating the ex ante model represent just a few of the possible changes pointed out earlier that probably will take place in the wheat and feed-grain industry, mainly on the supply side, between 1960 and 1985. These changes, however, are related to the factors that almost certainly will have some of the greatest impacts on the output potential of this industry in the future.

Before presenting the results of these models, we shall attempt to summarize the objectives visualized in formulating them and some of their more critical limitations. The answers to be obtained from the ex post model are these: Given the conditions (a) that production and consumption are in balance, (b) production occurs only in the region with the highest comparative cost advantage and (c) production relationships, prices and requirements are those of 1954: (1) What would be the production pattern of wheat and feed grain? (2) What would be the acreages of grainland left idle? (3) What are the levels of labor and other resources usually associated with these idled acreages? Stated another way, what would have been the structure of the wheat and feed-grain industry in 1954 if there had been no surplus production and if it had been organized on a least-cost basis?

The answers to be obtained from the ex ante model are the same as those for the ex post model when we suppose that the changes outlined above were to take place; that is, the changes in fertilizer application rates, production methods and demand requirements. We further suppose that price relationships and acreages and associated resources were similar to those existing in 1954. In essence, we are asking this question: What would be the surplus situation if certain variable inputs were increased with only small adjustments in the level of fixed resources and if the industry were organized on a least-cost basis?

Actually, the ex ante model does not surround the whole

[48] Formally, we find f_i such that $\frac{dy}{df} = \frac{p_f}{p_y}$ in which $\frac{dy}{df}$ is the derivative of crop output with respect to fertilizer inputs and p_f is the price of fertilizer and p_y is the price of the grain.

[49] The optimum fertilizer rates used were based on data presented in the USDA Handbook 68. The assistance of Professor John Pesek, Department of Agronomy, Iowa State University, in interpreting the data in the publication and working out the procedure for calculating the optimum fertilizer application is acknowledged.

Table 11.7. Estimated Wheat and Feed-Grain Requirements and Selected Data Derived by the Programming Models

Model	Requirements[a]		Acreage needed to produce requirements[b]	Grain acreage unused	Labor associated with unused acreage	Value of other resources associated with unused acreage
	Food wheat	Feed grains				
	(1 million bushels)		(1,000 acres)		(1,000 man-hours)	(1,000 dollars)
Ex post	757	3,887	202,254	28,855	290,397	481,548
Ex ante	880	5,888	190,554	40,555	171,337	838,088

[a] In addition to the quantities needed for seed, silage, and other forages.
[b] Includes acreage used for summer fallow.

problem of surplus production potential in the wheat and feed-grain industry, not only because it does not take into account the interrelationships of all agricultural commodities, as is also true of the ex post model, but also because it does not consider all the factors that are expected to influence this industry in the future: changes in technology other than those assumed, such as shifts to continuous corn; income changes; geographical shifts and growth in population; changes in export markets; and various institutional factors. Although the consideration of wheat and feed grains as the only crop alternatives may not represent a severe limitation in many regions, this may not be true in regions in which cotton and soybeans are important. For these reasons, the results are conditioned accordingly.

Programming Results

Surplus resources. Results of the two models are represented in Table 11.7. The ex post model provides for production of 755 million bushels of food wheat and 3,887 million bushels of corn equivalent. For the ex ante model, the quantities provided are 880 million bushels of food wheat and 5,888 million bushels of corn equivalent.[50]

As shown in Table 11.7, the 1954 wheat and feed-grain requirements could have been met while leaving 28.9 million acres idle. (This acreage includes summer fallow.) Associated with these acres in 1954 were 290.4 million man-hours of labor. In addition, the value of other inputs and services is calculated at $481.5 million. These inputs and services include those of machinery, fertilizer, lime, insecticides, irrigation water and others. These surplus levels are premised on the condition that the total 230 million acres of land had remained in grain production in 1954, as they probably would have done had production controls not been in effect.

For the ex ante model (Table 11.7), 40.6 million acres (including summer fallow) of the 1953 base acreage would have been unused despite increased requirements of 16 percent in food wheat and 51 percent in feed grains. The 171 million hours of labor associated with the 40.6 million acres is less than that of

[50]The requirements for the ex post model are at the 1954 level but are adjusted for normal livestock production, exports and given food uses. The ex ante requirements are the national estimates previously cited less residual production, seed and silage (see footnote 44). The residual production — that produced in the "plain" areas (Figure 11.1) — and silage are exogenous to the model. Seed is accounted for within the model by using net yields.

the ex post model. The reason, as suggested before, is that fewer man-hours are associated with each acre when mechanized production methods are used, as was assumed for this model. The value of other inputs and services associated with this unused acreage amounts to $838.1 million, which is much greater than for the ex post model.

The reader should recognize that these results imply that the acreage planted in grain would remain at the level of 1953, but that fertilizer rates would increase to the "optimum" level and a complete shift to mechanization would occur. This model was deliberately structured in this way to show how persistent surplus grain production could be without acreage adjustments, and also to show how the above-mentioned interfirm adjustments could affect regional production patterns in the future if production and consumption were in balance.

Regional-production patterns. The regional-production patterns resulting from the two models are shown in Figures 11.7 and 11.8. The cross-hatched areas in Figure 11.7 show the regions in which wheat and feed grains would have been produced if the average production had been equal to requirements and if

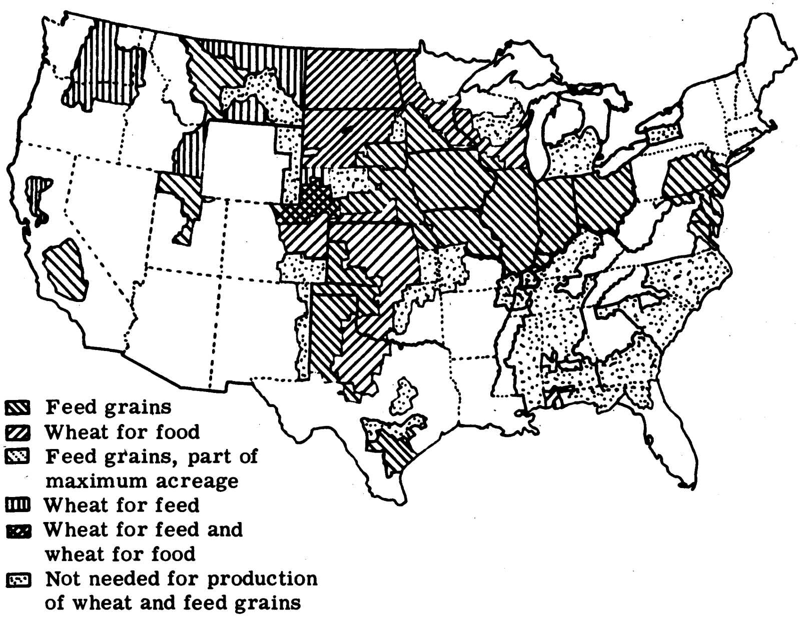

Fig. 11.7. Programmed production location of wheat and feed grains with production practices, resource use and requirements of 1954.

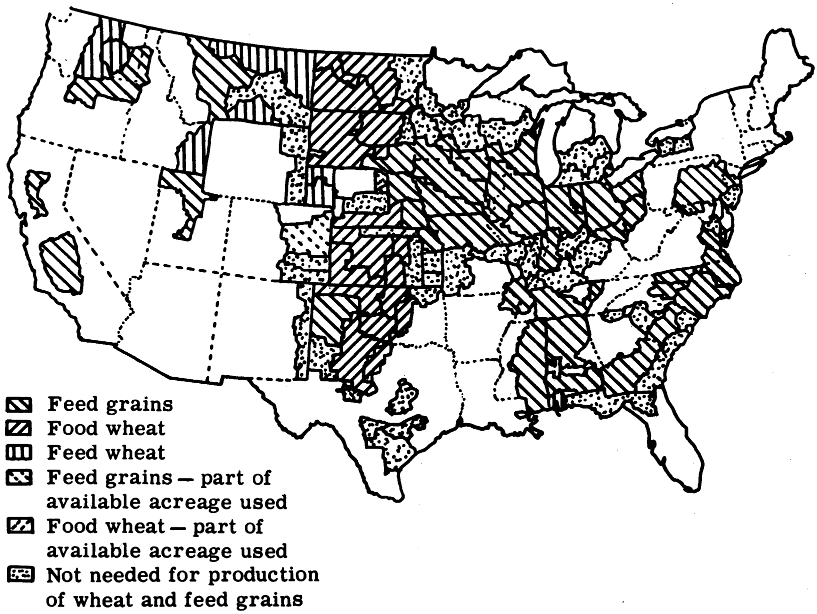

Fig. 11.8. Programmed production location of wheat and feed grains to meet projected requirements of 1985 with optimum fertilizer use and all production mechanized.

production patterns had been consistent with minimum costs by regions in 1954. The stippled areas designate the regions that would not have been needed to produce the specified grain requirements under the assumptions of the model. These regions are in the Southeast, in upper New York, Michigan, northern Wisconsin, eastern Kansas and Oklahoma, western Missouri, southeastern Colorado, eastern New Mexico, south-central Montana, eastern Wyoming and a few other scattered areas.

The regional-production pattern resulting from the ex ante model as shown in Figure 11.8, differs from that of the ex post model in these respects. Production would be shifted to regions in Virginia, North Carolina, South Carolina, Georgia, Mississippi, Tennessee and Alabama. Producing regions shown in Figure 11.7 but not in Figure 11.8 are in southern Indiana, southern Illinois, central Minnesota, eastern North Dakota, eastern Kansas and southwestern Texas.

These changes in the regional production pattern from the ex post to the ex ante model bring out this point, which was emphasized previously. Changes in technology can have a significant impact on the location of least-cost production. Because the location of production may vary over time and these locational shifts influence the level of resources required in each area, simple projections to specify the level of the quantity of resources in prospect, region by region, are not adequate. Consequently, policies based on simple projections could very well lead to very undesirable results from the public viewpoint.

In interpreting these results for regions, it must be remembered (1) that spatial production patterns were computed under the assumption of techniques (that is, production coefficients) equal to the average of the entire region, (2) that the coefficients are constant within the defined areas, (3) that price relatives remained the same as in 1954 and (4) for the ex ante model, that fertilizer was used at the "optimum" rates. Variations in the production coefficients within regions would mean that parts of the stippled areas in Figures 11.7 and 11.8 would be designated as producing areas. Conversely, part of the cross-hatched areas would be nonproducing areas. Computational limitations restricted the amount of detail that could be included in each of these models. Ample funds and computational resources are necessary to achieve an ideal degree of detail.

The primary objective in the formulation of these models was to answer the questions: "What might have been" and "what could be" the production pattern of a balanced grain industry, given the adjustment to least-cost areas?

CONCLUDING REMARKS

We have presented estimates of potential excess acreages in wheat and feed grains based on (1) national aggregates and (2) "restricted" regional comparative advantage. The latter is normative in nature but does illustrate the fundamental thesis of this chapter: Surplus estimates based on national aggregates (1) do not provide realistic estimates of surplus resources in agriculture and (2) do not aid in identifying, understanding and solving regional problems resulting from excess production.

We believe we have presented some evidence that shows that the surplus grain problem is not a spectre that will surely fade away if we sit back and wait for consumption to overtake production.

The results presented here are not meant as predictions, even in the loose sense of the term. The significant analysis limitations mentioned should not be overlooked. As was emphasized at the beginning, the specification of surplus resources in agriculture at present or in the future is fraught with difficulties and pitfalls. But analysis is needed and the results presented seem to us to be a step in the right direction.