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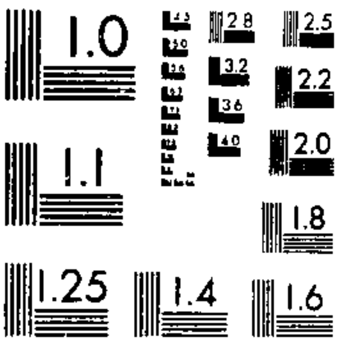

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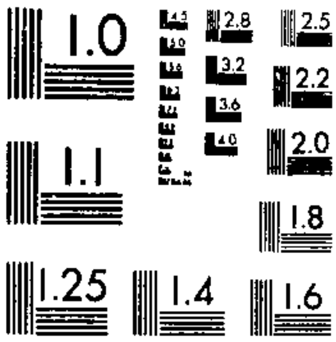

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UNITED STATES
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Soybeans in American Farming[1,2]

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Bureau of Agricultural Economics

CONTENTS

INTRODUCTION

Soybeans have become a major crop in the United States within the last 20 years. Until about 50 years ago they were rarely grown except at a few agricultural experiment stations. Beginning about that time many varieties were brought into this country and improvement was made through selection and breeding but it was not until the 1920's that the acreage was large enough to attract attention. In several States the production was noteworthy in the 1930's and then World War II brought the great expansion.

Multiple uses of soybeans had a part in the progress of the crop. They are used as beans, as hay, for grazing, and for plowing under. Local and general conditions usually determined the purpose for which the crop was used.

The expansion in acreage of soybeans harvested for beans to a figure three times that of the immediate prewar period was among the

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[2] The work represented by this publication was supported by the Bankhead-Jones special research fund.

[3] Assistance was received in this study from staff members of several of the State agricultural experiment stations and from many in the U. S. Department of Agriculture. The writer acknowledges especially information and suggestions from William J. Morse, of the Bureau of Plant Industry, Soils and Agricultural Engineering, and assistance throughout the study from Ronald L. Mighell and Edgar L. Burtis, of the Bureau of Agricultural Economics. Dorothy R. Owen did most of the statistical work.

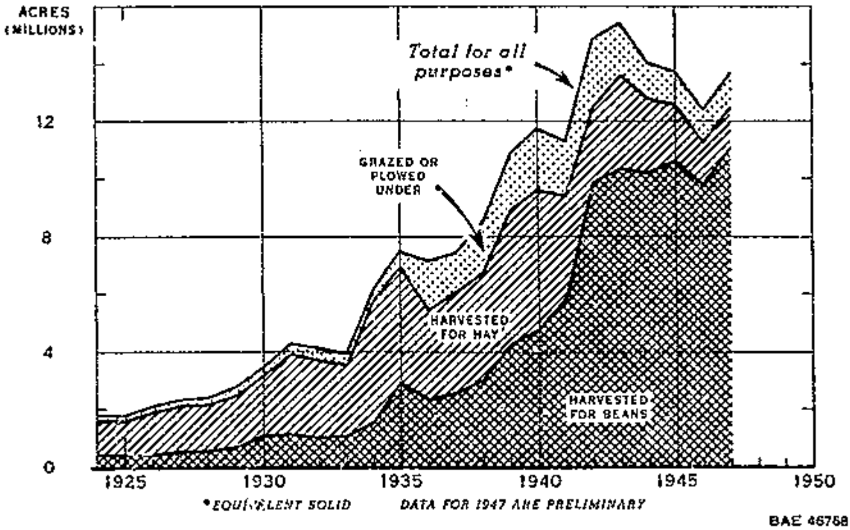

FIGURE 1.—Soybean acreage—total for all purposes: Harvested for beans, harvested for hay, and grazed or plowed under, United States, 1924–47.

most significant wartime changes in crop production (fig. 1). Since early in the war soybeans have been the source of more than half of all the oil meal, and nearly half of all the vegetable oils, produced in this country. In the prewar period less than one-fourth of all of our oil meal and vegetable oils came from soybeans.

What of the future of soybeans? Will further expansion be profitable or should growers look forward to some contraction in acreage? How will conditions in the different areas of production influence the adjustments that may be desirable?

Wartime demand for soybean oil was based on increased demand for fats and oils for domestic consumption and for the replacement of oils we formerly imported. Future developments relative to market outlets and prices of soybean oil will affect the acreage that can be grown with profit. Demand for soybean oil will depend upon supplies of other domestically produced vegetable oils and animal fats, supplies of foreign oils available for import, and the general level of economic conditions. As the protein meal obtained from soybeans has accounted for about half of the total value of soybeans, anything that affects the demand for high protein feeds will also influence soybean prices.

Advancing technology in production has been very effective in the expansion of soybean culture. Improved varieties adapted to different areas have increased the yields. Mechanized methods, particularly combines for harvesting, have reduced labor inputs. Better cultural methods have been adopted as growers have gained experience with the crop. These developments have lowered production costs and have given soybeans a stronger competitive position in the cropping system. The production would not otherwise have increased so greatly. Technological advances are still in progress. They can be expected to influence the level of production that will be most profitable for farmers in the future even if little change takes place in demand or prices for soybeans.

This report outlines the expansion of soybean production in this country, appraises the forces bringing it about, and evaluates the factors that may influence the future competitive position of soybeans in American farming.

In appraising the forces responsible for the expansion, the factors on the demand side fall in one category. They include not only prices but the whole development of the channels of marketing and processing which made it possible to market effectively much larger quantities of soybeans in recent years than ever before. On the supply side, the analysis considers the technological changes that would have increased production of soybeans even if there had been little expansion in demand. These include the effects of improved varieties, the adoption of more mechanized methods, and other practices.

Experience with soybeans under American conditions is so limited and the expansion has been so rapid that it is difficult to evaluate all of the factors that may affect the trend of future production. But the analysis of factors that caused the supply of soybeans to increase in the past together with an evaluation of the probable effects of technical developments still under way provides the basis for estimates of the future supply position of soybeans. Estimates are made of the production of soybeans that may be expected with each of three different sets of price relationships for soybeans, as compared with competing crops. These different price relationships represent alternative situations that could develop if demand were the same or higher or lower than in the recent past.

The future production of soybeans will depend, of course, upon the demand conditions that actually prevail. Therefore special attention is given to the longtime outlook for market outlets and prices. The demand for soybean oil will be greatly influenced by the supplies of fats and oils from competing sources, and information about them is drawn from other reports. This report is one of several in a general appraisal of the position of flaxseed, cottonseed, peanuts, and other fats and oils (*30, 40, 3, 12*).[3]

RISE OF SOYBEAN PRODUCTION

Early Developments

The soybean is one of the oldest crops grown by man. It has been cultivated widely in China since long before written records were kept. First importations of soybean seed into the United States probably were from eastern Asia. The soybean was first mentioned in our literature in 1804, as being "adapted to Pennsylvania," but its culture in the United States was limited to that of a rare garden plant until near the end of the nineteenth century. Before 1898 not more than 8 varieties, with a limited range of adaptation, were grown. In that year the United States Department of Agriculture began to introduce a great many varieties, and to experiment, in cooperation with several State agricultural experiment stations on a program of improvement through selection and breeding. By 1937 more than 10,000 soybean selections had been imported. The bulk of this material came from an extensive area of eastern Asia stretching from Manchuria to the

[3] Italic numbers in parentheses refer to Literature Cited, p. 64.

East Indies. It represented great variation in seed characteristics and in soil and climatic adaptation.

More than 100 varieties of soybeans, adapted to a wide range of soil and climate, are now grown or their production for seed is being increased in the United States. As improved varieties have been developed, inferior ones have been discarded. A large number of varieties is necessary if soybeans are to be grown successfully in different regions. A given variety is usually well adapted to a rather limited soil and climatic zone.

Production of soybeans increased rapidly during the first quarter of this century although the total acreage was small compared with many other crops. The acreage grown for all purposes increased from about 50,000 in 1907 to nearly 500,000 in 1917, and to nearly 2,000,000 in 1925. The crop was grown mainly for forage. Only one-fourth of the total acreage was harvested for beans in 1924; this was not much more than was necessary to provide seed for the expanding acreage.

Early expansion was mainly in the Southern and Eastern States. Cotton farmers in some parts of the South included soybeans along with lespedeza, oats, and corn in crop rotations to help control the cotton boll weevil. In 1919, the five leading States in soybean acreage were, in the order named, North Carolina, Virginia, Mississippi, Kentucky, and Alabama. By 1924, the more rapid expansion of the crop in the North Central region had brought Illinois into the leading position followed by Indiana, Tennessee, North Carolina, and Missouri.

Recent Trends

Total Acreage.—Expansion in soybean production during the last 25 years, and particularly since 1939, has been dramatic (fig. 1). The total acreage grown for all purposes increased from less than 2 million in 1925 to over 7 million in 1935, to nearly 12 million in 1940, and to over 15 million in 1943. It has averaged about 13.5 million in the last 4 years.

The earlier trend toward concentration of acreage in the North Central States has continued (table 1). In 1925, about 40 percent of the total acreage was located there; by 1930 the percentage exceeded one-half, and by 1940 it was more than two-thirds. In the war years about 75 percent of the acreage grown for all purposes was in that region, mostly in the Corn Belt. In the Lake States and Plains States north and west of the central Corn Belt area, although the crop was not so important from the standpoint of total acreage, percentage increases were even greater.

The total acreage planted for all purposes in areas outside the North Central States continued to increase until 1943, but it has declined since then. In the last 3 years, it has averaged about the same as in the immediate prewar period; but the percentage of the United States total declined from about 34 percent before the war to about 22 percent in the last 3 years.

Soybeans for Forage.—The total acreage of soybeans for hay and grazing or plowing under increased from 1.3 million in 1924 to 3 million in 1931–33, and then more sharply to 7 million in 1940. It has since declined gradually to an average of less than 3 million in 1945–47.

TABLE 1.—*Acreage of soybeans planted for all purposes, United States and selected groups of States, averages 1925–29, 1930–34, and 1935–39, and annual 1940–47*

Period or year	United States	Corn Belt [1]	Lake States [2]	Plains States [3]	Delta States [4]	Atlantic States [5]	All other States
	1,000 acres	*1,000 acres*	*1,000 acres*	*1,000 acres*	*1,000 acres*	*1,000 acres*	*1,000 acres*
1925–29	2, 302	1, 015	27	13	285	400	562
1930–34	4, 421	2, 577	141	48	449	522	684
1935–39	8, 331	5, 132	316	45	1, 096	711	1, 031
1940	11, 782	7, 534	653	102	1, 332	878	1, 283
1941	11, 345	6, 863	587	121	1, 483	908	1, 383
1942	14, 912	9, 656	842	369	1, 553	1, 060	1, 432
1943	15, 428	9, 954	585	435	1, 667	1, 184	1, 603
1944	14, 050	9, 905	595	243	1, 124	910	1, 273
1945	13, 777	9, 825	740	300	1, 015	840	1, 057
1946	12, 427	8, 450	854	279	1, 065	782	997
1947 [6]	13, 654	9, 302	1, 132	339	1, 085	816	980

[1] Illinois, Iowa, Indiana, Ohio, and Missouri.
[2] Minnesota, Wisconsin, and Michigan.
[3] Kansas, Nebraska, South Dakota, and North Dakota.
[4] Arkansas, Mississippi, and Louisiana.
[5] North Carolina, Virginia, Maryland, and Delaware.
[6] Preliminary.

Recurring drought accounted for much of the sharp increase in the middle 1930's. It ruined large acreages of corn, small grain, and tame hay, especially in the early part of the growing season. As soybeans can be planted later than most other crops, they were grown as an emergency forage crop. Programs of the Agricultural Adjustment Administration also contributed to the expansion. Restrictions on the acreage of corn made more land available for other crops. Payments were made to farmers for keeping a part of their cropland in crops classified as soil-conserving. Soybeans for hay were classified as soil-conserving, after 1936. Soybeans plowed under were considered soil-conserving throughout the period of these programs. This is the principal reason for the large increase in acreage plowed under in 1936.

Soybeans were grown mainly for forage until 1941 when slightly more than half of the total planted acreage was harvested for beans (tables 16 and 17). Some soybeans were crushed for oil and meal beginning in the early 1920's, but it was not until 1935 that the quantity processed was larger than that used for seed and feed (table 18). The proportion of the total acreage harvested for beans has increased most in the North Central region. In the Delta States, soybeans were grown almost entirely for forage, green manure, and seed until 1942. In the Atlantic region, some have been grown for processing since the early 1920's, but the proportion of the total acreage used for this purpose has increased only moderately. During the last few years, soybeans have been grown almost entirely for harvest as beans in the North Central region, but forage and green manure has continued to be the main use in other regions.

SOYBEANS FOR BEANS.—The total acreage of soybeans harvested for beans expanded sharply from about 1 million in 1931–33 to nearly 5 million in 1940. The greatest single-year increase came in 1942 when the acreage was nearly 10 million, or about 4 million more than in 1941. Total acreage has averaged about 10 million in the years since then but it was slightly over 11 million in 1947.

A part of the 5-million-acre increase from 1940 to 1942 can be attributed to a reduction of 2 million acres for forage. The remaining 3 million acres was an extension of soybeans to additional land. Soybeans used for forage continued to decline and in 1945–47 averaged about 4 million acres less than in 1940. Only 1.5 million of the 5.7 million net increase in acreage of soybeans harvested for beans, between 1940 and 1945–47, was the result of extension of the crop to additional land.

The average yield of soybeans harvested for beans in the United States increased from 11 bushels per acre in 1924 to about 20 bushels in 1938 and 1939 (fig. 2). Yields have averaged a little less than 20

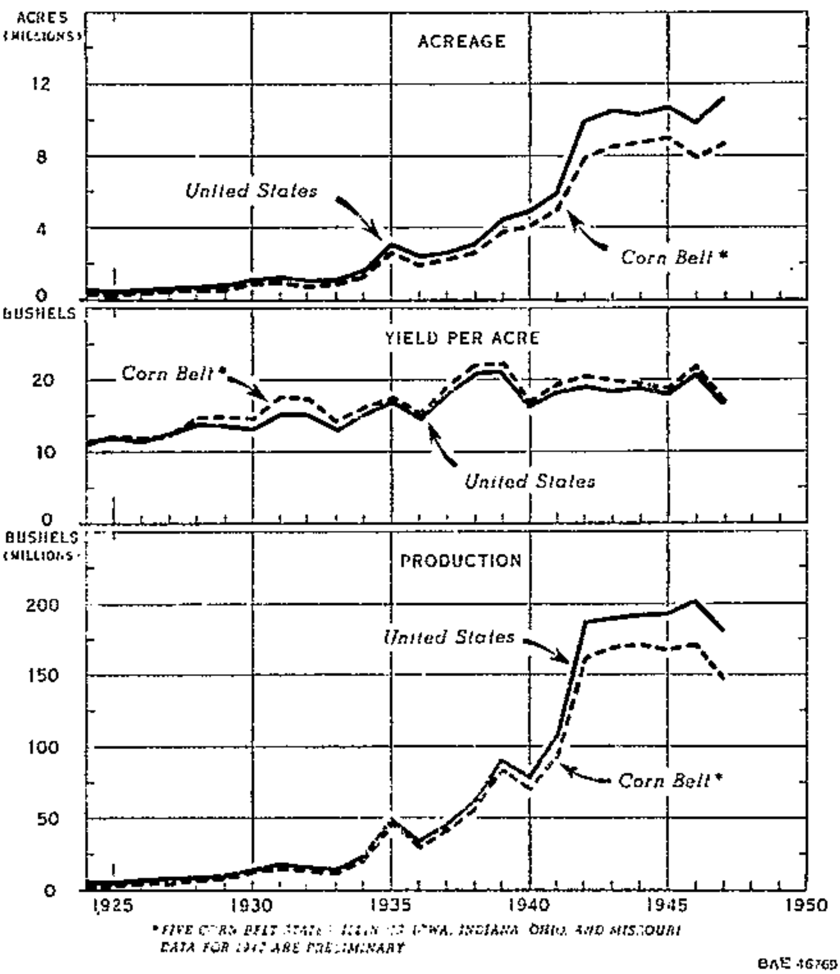

FIGURE 2. Acreage, yield per acre, and production of soybeans harvested for beans, United States and Corn Belt States, 1924–47.

bushels per acre in the years since 1939 but it is significant that they have been maintained on a high level, although total acreage has been greatly expanded. As the total acreage was increased, soybeans for beans probably were grown on land less well adapted for their production.

There are several reasons for the great expansion in production of soybeans during the last 20 years. Most of the increase from the early 1920's to the late 1930's resulted from the increase in acreage, although there were higher yields. The increase in production since 1940 also can be attributed mainly to the larger acreage, but it would not have been so large if improved varieties had not been developed so that yields could be maintained as production was extended to less suitable land (fig. 2).

Acreage of soybeans for harvest as beans has gradually become more concentrated in the North Central region (table 2). In 1946, 80 percent of the total acreage was located in the five Corn Belt States (Illinois, Iowa, Indiana, Ohio, and Missouri) compared with 58 percent in 1924. As yields are higher in this region than in others, production has become even more concentrated. The Corn Belt States supplied about 85 percent of the total United States production of soybeans in 1946, compared with 55 percent in 1924.

Noteworthy changes in the distribution of soybean production have taken place within the North Central region. Percentage increases in acreages since the immediate prewar period have been greatest in the Lake States and the Plains States (table 2). Altogether these States supplied 8 percent of the production of soybeans in this country in 1946, compared with less than 2 percent in 1924. Recent increases have been especially large in Minnesota. Within the five Corn Belt States, Illinois and Iowa have increased production the most.

TABLE 2.—*Acreage of soybeans harvested for beans, United States and selected groups of States,*[1] *averages 1925–29, 1930–34, and 1935–39, and annual 1940–47*

Period or year	United States	Corn Belt	Lake States	Plains States	Delta States	Atlantic States	All other States
	1,000 acres	*1,000 acres*	*1,000 acres*	*1,000 acres*	*1,000 acres*	*1,000 acres*	*1,000 acres*
1925–29	547	337	4	4	38	118	46
1930–34	1,163	877	9	10	45	160	62
1935–39	3,042	2,604	44	7	97	209	81
1940	1,807	1,097	155	31	117	283	124
1941	5,889	4,938	217	69	203	317	145
1942	9,894	7,898	484	269	480	470	293
1943	10,397	8,182	410	345	428	425	307
1944	10,232	8,697	412	217	332	333	241
1945	10,661	8,933	611	270	294	359	194
1946	9,806	7,863	729	246	392	344	232
1947[2]	11,125	8,674	1,022	310	402	432	285

[1] For States included in each regional group see footnotes to table 1.
[2] Preliminary.

Production of soybeans for processing is more concentrated in the North Central region than is indicated by the production data given above. In the last several years, from a fourth to a third of the soybeans harvested for beans in the eastern and southern States were used for seed. Additional quantities were used for feed on farms where grown. Official statistics are not available, but it appears that more than 95 percent of the soybeans used for processing are grown in the North Central States.

Soybeans were processed in the United States as early as 1910 or 1911, but the quantities were very small and operations were intermittent before the 1920's. Production in the Corn Belt was given encouragement in the 1920's when a few plants in that region undertook processing of soybeans for oil and meal as a regular business, and thus provided a more certain market for the crop. In 1928 three processing companies offered a guaranteed minimum price to growers in Illinois for soybeans delivered at their plants. The following year a guaranteed price was offered to growers in Indiana and Ohio as well. The number and capacity of processing plants continued to increase in the 1930's, and this expansion of the industry was greatly accelerated during World War II. In 1947 the total annual capacity of soybean-processing plants in the United States was about 180 million bushels.

Geographic Pattern

Soybeans are grown in three major regions of the United States. The largest and most intensive coincides generally with the Corn Belt type-of-farming region plus areas to the north and west. Another is the Mississippi Delta, which extends along the Mississippi River from the southeastern tip of Missouri into Louisiana. The third is located adjacent to the Atlantic coast from North Carolina to Delaware.

The North Central region greatly overshadows the other two in acreage of soybeans for beans (fig. 3). In 1946, it was the source of 92 percent of the crop grown in the United States. The Delta and the Atlantic Coast regions each contributed about 3 percent. The remaining 2 percent was scattered in other Southern and Eastern States. The proportion produced in the North Central States has remained at about 92 percent since the immediate prewar period although production has shifted north and west in recent years. The Plains and Lake States accounted for 8 percent of the national total in 1946, compared with 4 percent in 1940 and only 1 percent in 1935–39. The Mississippi Delta has increased in importance. But this has been offset almost exactly by a decline in the Atlantic region. (The States included in each region are listed in table 1.)

Nearly 391,000 farms reported soybeans harvested for beans in 1944, according to the United States Census of Agriculture. This is more farms than grow flaxseed, peanuts, barley, rye, spring wheat, or sorghums for grain. About 300,000 additional farms grew soybeans for other purposes (hay, grazing, or plowing under). Most of these farms were in Southern and Eastern States.

The heaviest concentration of farms growing soybeans for beans is in the North Central region where acreage also is greatest (fig. 4). In 120 counties in the North Central region and in 4 counties in North Carolina, 50 percent or more of all farms reported soybeans harvested

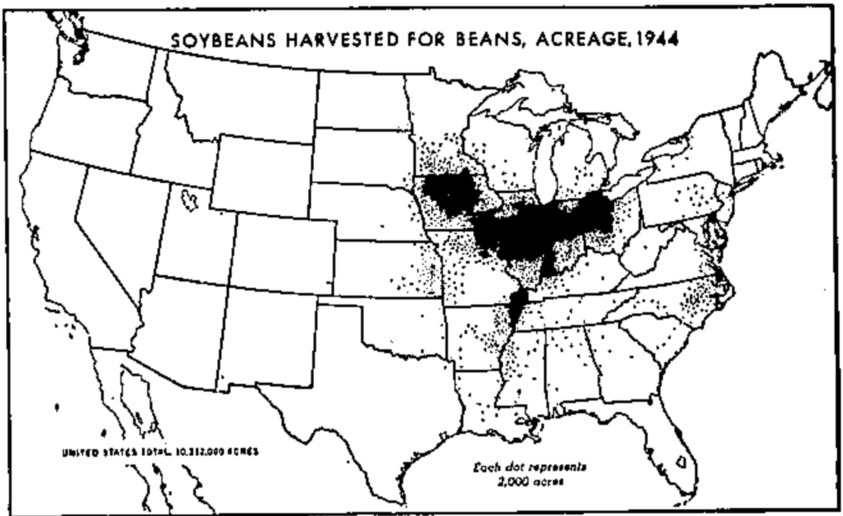

FIGURE 3.—Soybeans for beans are an important crop in three general regions—the North Central region, the Mississippi Delta, and the Atlantic Coast. The North Central region has about 90 percent of the acreage, and greatly overshadows the other regions.

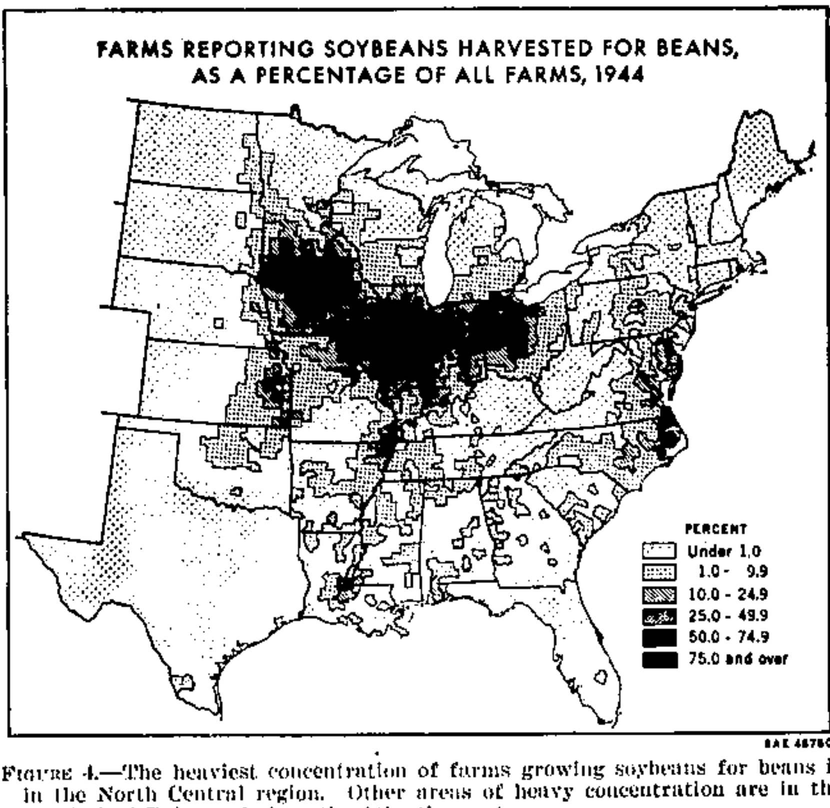

FIGURE 4.—The heaviest concentration of farms growing soybeans for beans is in the North Central region. Other areas of heavy concentration are in the Mississippi Delta and along the Atlantic coast.

for beans. The proportion was 75 percent or more in 15 of these counties. In 150 other counties, distributed in 13 States, the crop was grown on 25 to 49 percent of all farms. The three States with the largest percentages were Illinois with 42 percent, Iowa with 40 percent, and Indiana with 32 percent.

The total number of farms in the United States reporting soybeans harvested for beans in 1944 was 54 percent greater than in 1939. Of the 30 States that grew soybeans for beans, 23 reported increases, 5 decreases, and 2 no appreciable change. The decreases were in Southern and Eastern States whereas the increases were mainly in the North and West. Increases of more than 200 percent were reported in Missouri, Minnesota, North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and Arkansas.

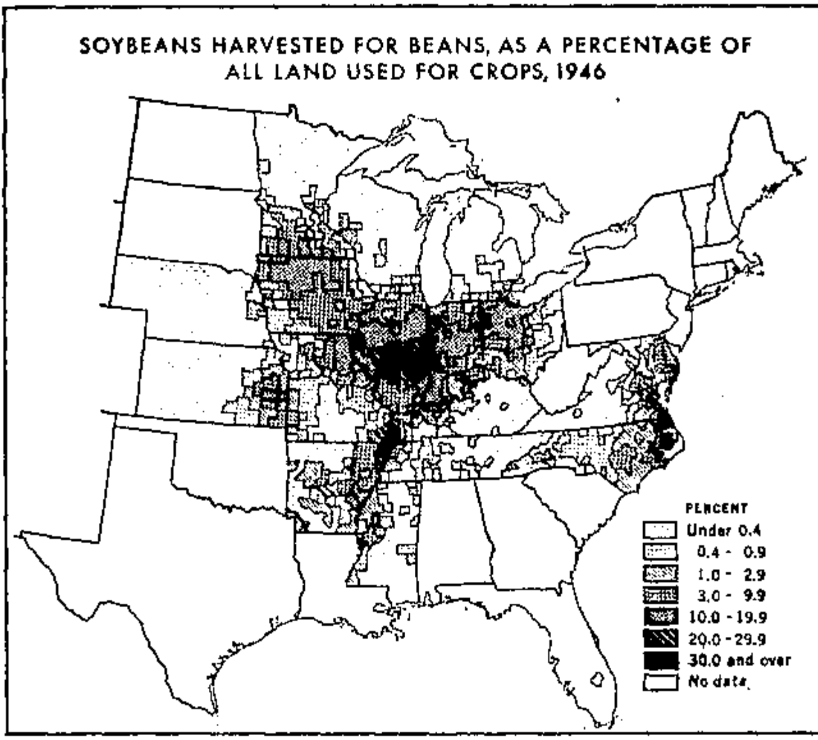

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FIGURE 5.—Soybeans for beans occupied 20 percent or more of the cropland in 52 counties in 1946. The heaviest concentrations were in central Illinois, in a few counties in the Mississippi Delta, and along the Atlantic coast.

Soybeans for beans occupy a substantial proportion of the land used for all crops in some areas (fig. 5). In 1946, the percentage was more than 30 in 21 counties—14 counties in Illinois, 2 in Missouri, and 5 in North Carolina. The largest percentage for a single county was 49 percent in Camden County, N. C. In 52 counties, soybeans were harvested from at least 20 percent of all the cropland. These figures also show that the heaviest concentration of soybeans for beans is in the North Central States, in the Corn Belt. This area roughly forms a crescent-shaped belt, with Illinois as its thickest or middle part.

FACTORS AFFECTING TRENDS

The rapid rise in soybean production in this country is one of the dramatic developments in the recent history of American agriculture. Other instances can be cited in which plant introductions led to vast changes, but the unusual thing about soybeans is that they represent the successful large-scale introduction of an entirely new cash crop into the well-established cropping systems of the mature farming economy of the Corn Belt. The story can be explained only in the terms of the unique conjuncture of several necessary factors. The absence of any one of the principal factors might have greatly retarded or even prevented the expansion.

By 1940, variety adaptation, mechanization, marketing, and processing technology, and slowly accumulating experience on the part of farmers, all had reached a critical stage. Then a sudden wartime increase in demand supplied the catalytic price and marketing conditions which touched off the principal expansion. To understand more fully we must look more closely at the record of the earlier years. We have seen in figure 2 the broad picture of the trends in acreage, yield, and production since 1924. This picture shows that acreage expansion was a larger element than yield in the upward trend in production for the whole period. But yield is one of the important causal factors in the acreage expansion.

To appraise the underlying factors that seem to explain the upward trends requires first, some consideration of developments on the demand side that made it possible to market much larger quantities of soybeans at prices relatively more favorable. It also involves a detailed examination of the physical conditions that have limited and channeled the expansion. To show how the supply position of soybeans has shifted, the effects of improvements in yield and of mechanization on costs and returns of soybean production, as compared with competing crops, must be analyzed.

Prices and Market Outlets

In the case of well-established commodities, the prices and the quantities sold usually reflect most of the demand factors. This is less true of a new and expanding commodity like soybeans, because the dynamics of building a marketing and processing mechanism cannot be fully reflected in available price series. But a look at the price situation is a useful starting point. Figure 6 shows the United States farm prices for soybeans, corn, and oats for the period 1924–47. Relative prices in the principal soybean areas differ only slightly from these national prices. This figure indicates clearly several phases in soybean price history. Prices for soybeans were high in the 1920's, then declined from 1929 to 1931, remained low during the 1930's, and with the war suddenly became considerably higher. The price data for the early period are not really comparable with those for later years, however, because a large proportion of the soybean sales were formerly for seed (*10*). This was a period in which a large

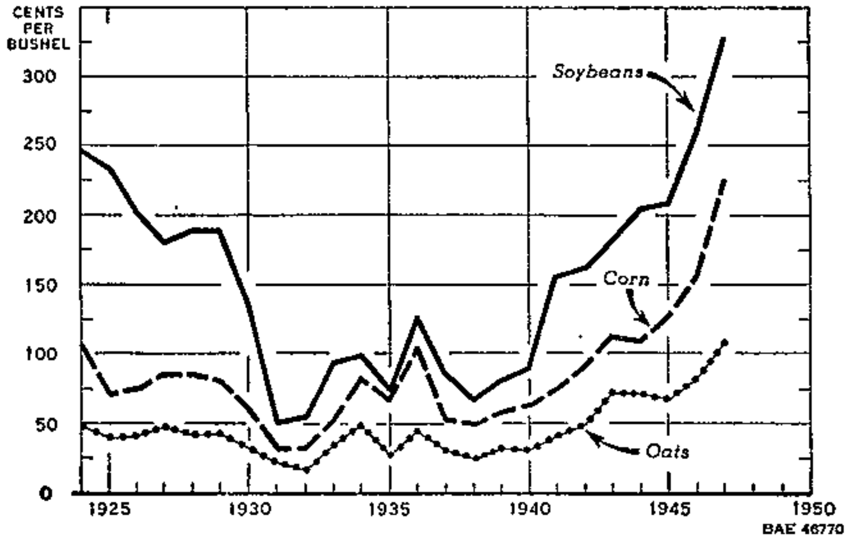

FIGURE 6.—Prices received by farmers for soybeans, corn, and oats, United States, season average, 1924–47.

proportion of the seed was used for growing soybeans for hay, for grazing, and for plowing under. With the present large production of soybeans the seed use makes up only a small part of the total crop, and published prices reflect mainly commercial uses.

Price relationships between soybeans, corn, and oats changed greatly from the immediate prewar to the wartime years. Soybean-corn price ratios that had been as low as 1.11 in 1935, rose to a high of 2.06 in 1941 and during the following years remained at a level that was consistently higher than prewar. The average ratio during the war was about 1.7, compared with 1.4 for the years 1935–39. The wartime level of soybean prices on a ratio basis was thus nearly 20 percent higher than prewar, as compared with corn. At the higher price level the absolute price spread between soybeans and corn became three and four times what it was before the war. As costs tend to lag, this meant that soybeans were more profitable than the relative prices would indicate.

This favorable price situation and the possibility for the sale of much larger quantities of soybeans came about because of the reduction in supplies of fats and oils from other sources and the general increase in demand resulting from the higher level of economic activity. Imports of fats and oils were reduced from about 2 billion pounds in the immediate prewar years to about 1 billion during the war. This would have been equivalent to a reduction of about 10 percent in total United States supplies. However, domestic production of animal fats and vegetable oils was expanded by more than enough to maintain total supplies at prewar levels. Among these, the expansion in production of soybean oil from about a half billion pounds before the war to about 1 billion pounds in 1942 and to 1.5 billion in 1946, contributed the most. Equally effective in the increase in demand for soybeans was the increase in demand for high-protein feed. Before the war about half of the value of soybeans was due to the value of the protein meal obtained from soybeans. This approximate relationship has been maintained by the expanding demand for protein feeds resulting from higher prices for livestock.

There seems little doubt that a major part of the wartime expansion was an immediate result of this whole favorable price situation for soybeans. The other favorable factors were already present and the demands of the time—working through prices, production goals, and the other motivating forces of wartime—brought about the great expansion (*43*). No doubt some expansion would have taken place with less favorable prices, because the full effects of the other forces had not been worked out. Also on the demand side, progress in the development of marketing and processing channels had been taking place all along the line. In the earlier years, small quantities of soybeans could not be handled efficiently at local receiving points, the pricing mechanism was not developed, and grading standards had not been worked out. In the processing plants, the prevailing processes were not at first efficient in extracting the oil, nor in working up the oil meal. Improved methods of processing both oil and oil meal were being developed gradually. Out of this advancing technology a wider market possibility was evolved, and by 1940 a market demand had been built up which had not been technically possible a few years earlier.

Before 1934 less than a fourth of the soybeans grown in the United States were used for processing. As markets expanded and production increased this proportion became consistently larger, while the proportions used for seed and feed became smaller. By 1937 about two-thirds of the crop was processed, and this proportion increased to more than 80 percent during the last few years (table 18). Of the soybean oil produced before 1935, more than half went into paint, varnish, soap, and other nonfood products. The proportion used for food rose from 42 percent in 1934 to 86 percent in 1939 and to 90 percent in 1944. The proportion has recently declined somewhat, with the increased use for industrial purposes (table 19). Practically all of the soybean-oil meal is used for feed. Other outlets, including exports, human food, and industrial uses, take less than 5 percent of the total supply of soybean-oil meal (table 20).

In general, price increases were about the same in all regions. Although a few minor regional differences in price relationships appeared, it is clear that prices were not a cause of differences in production trends between regions. To explain them, it is necessary to gain an understanding of how physical factors and changes in cost and returns from soybeans and competing crops favored expansion of soybeans in particular areas.

Adaptation to Climate and Soils

Soybeans can be grown under a wide range of climatic and soil conditions. They are found in eastern Asia from latitudes of 8° south in Java to 48° north in Manchuria. A great many different localized varieties have resulted, each with a rather limited range of adaptation. They differ in time required for maturity from 75 to 200 or more days, in soil requirements, and in various plant characteristics.

The introduction of seed from many different Asiatic sources has provided the basis for the development of varieties that are adapted to the wide range of soil and climatic conditions in this country.

Climatic requirements of soybeans are about the same as those of corn. Like corn, lack of rainfall west of the ninety-eighth meridian limits their production in large areas of the West. But rainfall is adequate in most parts of the eastern half of the United States. Length of growing season has been an important factor affecting areas of adaptation for soybeans in the past, but different varieties that are well adapted to different latitudes have been developed gradually and this has extended the range of successful production.

Soil requirements of soybeans also are similar to those of corn. Both crops can be grown on widely different soil types although both give the highest yields on mellow and fertile silt or sandy loams. Variations in yields between soils classified as good and poor usually are much less for soybeans than for corn. Soybeans are vigorous foragers and so can frequently be grown successfully on soils that are not fertile enough for other crops. Of course, for best results such soils should be limed and fertilized with elements in which they are deficient. Soybeans will tolerate more strongly acid soil conditions than will red clover or alfalfa, although not so well as do cowpeas and lespedeza. They withstand short periods of drought better than do most other crops (*25*).

The adaptability of soybeans to soil conditions that are unfavorable for other crops has influenced their production in some areas. For example, they have become an important crop in the claypan area of Illinois because yields are more dependable than the yields of corn or small grain in both wet and dry years. Soils in this area dry out slowly in the spring, frequently making it difficult to plant oats or corn early enough to obtain satisfactory yields (*15*). In other parts of the North Central States, soybeans have been grown successfully on heavy clay or wet muck soils that were previously idle or not productive. In the Delta States, farmers have found soybeans to be a good cash crop on land not well adapted for cotton. In the Atlantic Coast States, they are grown successfully on soils that have inadequate drainage for tobacco, cotton, or peanuts.

Evidently it can be concluded that soybeans are adapted to a wider range of soil and climatic conditions than are most other crops. This is especially true if varieties well adapted to local climatic conditions are available. Natural physical conditions have not confined soybeans to their present areas of concentration. Their great adaptability to widely different conditions has meant that production is much more widespread than otherwise would be true.

Regional and national trends in production have been definitely influenced by the limitations imposed by climate and soil. But these factors have operated in different ways. The climatic limitations are gradually being modified by the work of the plant breeders, which is developing varieties better suited to adverse conditions. What at first appeared to handicap soybeans in competition with other crops may yet come to be a special advantage.

With respect to soil erosion, soil depletion, and the whole complex of relationships between soils and the cropping system, much is still to be learned by growers and scientific workers. When the crop has been fully fitted into the permanent economy of the Corn Belt and other areas there are likely to be further changes in its acreage and production. To gain a better understanding of the forces involved it is well to consider briefly what is known of some of the characteristic interactions between soils and soybeans. Soil erosion is considered first because this appears to be the physical factor that has had most to do with influencing geographic trends.

Soil Erosion.—The extent of soil erosion on a particular piece of land is determined largely by the slope, the condition of the soil, the nature of the crop cover, and the distribution of the rainfall. Heavy rains during periods when the land lacks vegetative cover will cause more erosion than rains when the land is well covered with growing plants or crop residues.

There are wide differences between crops in their influence on erosion losses. Intertilled crops are least effective in controlling soil losses, small grain crops are intermediate, and sod crops are most effective. Soybeans are classified as an intertilled crop if grown in rows, or as close-grown, like small grains, if drilled closely.

The root-growth habits of soybeans have a loosening effect on the soil. This does not appear to lead to more erosion during the growing season than takes place with corn or other intertilled crops. But after the crop is harvested, the looser soil structure and the smaller quantity of plant residues may lead to considerably more erosion on sloping soils unless cover crops are quickly grown. This special hazard is generally recognized by farmers and so soybeans have been confined mainly to the more level land.

Intertilled crops grown in wide rows allow more erosion than those in narrow rows. When soybeans are drilled in 8-inch rows the erosion losses average about half as much as when they are planted in wide rows. Tests by the Missouri Agricultural Experiment Station in 1924–31 showed soil losses with soybeans in 8-inch rows to be 46 percent of those in wide rows; tests in 1932–39 showed such losses to be 62 percent of those in 42-inch rows (*21, 34*).

Loosening of the soil by soybeans is usually beneficial on level land. The erosive effects on sloping land are most noticeable if the soil is underlaid with a relatively impervious subsoil, as the surface layer is then more vulnerable to saturation and washing. Most of the soybean roots extend deeply into the soil, but those in the topsoil decompose rapidly upon maturity or after harvest, leaving this layer without much durable fiber to hold it in place. When soybeans are grown in rows on rolling land, considerable soil erosion may occur. Erosion losses may be greatly reduced by solid planting on the contour and by following other recommended conservation practices (*17*).

Part of the soil erosion associated with soybeans is the result of the physical condition of the soil before planting. Soybeans commonly follow corn, or some other intertilled crop. Intensive cultivation breaks down the granular structure of the soil and increases its erosiveness. Susceptibility to erosion is also increased by leaving the ground bare and unprotected for several months before it is plowed for soybeans. Experiments have shown that soybeans following meadow are no more conducive to erosion than is corn following meadow. After corn, soybeans in rows may be no more erosive during the growing season than second-year corn, and when planted solid

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they are considerably less so (*34*). Erosion losses from land in corn a second year are usually about twice as large as those from first-year corn after sod (*35*).

When soybeans follow a row crop on sloping land the soil is highly susceptible to erosion before planting takes place and for 3 or 4 weeks thereafter, until the plants are large enough to give some protection. However, the soil is no more susceptible to erosion during the period of seedbed preparation and early growth of soybeans than it is during the like period for corn, sorghum, cowpeas, cotton, and other late spring planted crops that require about the same type of seedbed preparation (*17*). The other period of high susceptibility to erosion of land in intertilled crops comes after harvest, especially if the land is left bare until planting time the next spring. At this postharvest season erosion losses following soybeans may be greater than after other crops. But if followed by fall-sown grain or other winter cover crops, erosion losses are usually not large.

The way in which soybeans are harvested also affects the degree of erosion that may take place. If they are cut for hay, or harvested with a binder, the land is left relatively bare of protective cover whereas if the combine is used, the leaves are allowed to fall on the ground during the ripening process and the straw may be scattered uniformly over the field. Combines and trucks may start gullies if the wheel tracks run up and down the slope. If the tracks run across the slope, gullies may be avoided.

The largest concentrations of soybean acreage for beans in this country are in areas of relatively level land—the Corn Belt prairies, the flat lands of the Mississippi Delta, and the Coastal Plain of North Carolina and Virginia. These are the areas in which soybean production has been most successful and in which production is likely to continue most important. So far as possible, soybeans should be grown only on level or fairly level land. In general, they are not recommended for lands that have a slope of more than 7 percent. If the crop is to be grown on lands with greater slopes than 3 percent they should be drilled solid on the contour, or at least across the slope, and special care should be taken to maintain soil fertility at a high level, to provide cover crops for winter and spring protection, and to have sod-forming crops at frequent intervals in the rotation.

From the viewpoint of permanent agriculture it appears that the erosion hazard is serious enough to limit the expansion of soybeans outside of the more level areas. This will be a strong influence toward a greater concentration of soybean production in the more favored areas. It is a factor that is not reflected in intercrop comparisons of yields.

Soil Depletion and Soil Building.—All crops draw nutrient elements from the soil and soybeans are no exception, but under certain conditions soybeans may make net contributions, particularly of nitrogen. Nitrogen is the most expensive of the nutrients to add to the soil in the form of commercial fertilizer.

Soybeans, like other legumes, are able to obtain a large part of their nitrogen requirements from the air through the aid of root-nodule bacteria. But to do this the plants must be inoculated, either by appropriate bacteria present in the soil or by bacteria in cultures applied to the seed. Soybean plants with an abundance of nodules can obtain about two-thirds of their nitrogen from the air and the remainder from the soil. If the soil is richly supplied with nitrates, the plant will obtain most of its nitrogen from the soil and relatively little from the air (*24*, *26*).

When well-nodulated soybeans are plowed under for green manure, they add nitrogen to the soil. The additions of nitrogen may range from 60 to 100 pounds an acre, depending on the productivity of the soil. Although they do not add any minerals, soybeans plowed under increase the supply of readily available mineral nutrients in the soil as a result of their assimilation of these minerals during the growing process (*32*). If the crop is harvested for beans and the straw is left on the field there will be a net addition of nitrogen, but some mineral elements will be removed with the beans. If harvested for hay there will be a net removal of nitrogen as well as of other nutrients from the soil. As the portion of a soybean plant above ground makes up about nine-tenths of the total plant its disposition mainly determines the effect of the crop on the supply of nutrients in the soil.

Data on the quantities of the principal nutrient elements added to or removed from the soil by soybeans and other selected crops are shown in table 3. They show that for the indicated yields corn removes the most nitrogen. Soybeans harvested for beans, with the straw left on the ground, add 16 pounds of nitrogen per acre but soybean hay removes 30 pounds. Alfalfa and clover cut for hay add about as much nitrogen as they take away; their advantage over soybeans in this respect is explained by the larger proportion of roots to stems and leaves and by the aftermath growth. Soybeans harvested for beans remove more potassium and calcium than corn, oats, or wheat, but less than alfalfa or clover harvested for hay. In the removal of phosphorus, soybeans are about equal to corn. If the manure obtained from feeding soybean, alfalfa, or clover hay is carefully returned to the land there can be a substantial addition of nitrogen to the soil and a partial replenishment of the mineral elements that had been removed.

TABLE 3.—*Plant-food elements added or removed by selected crops* [1]

Crop	Acre yield	Nutrient elements per acre					
		Added	Removed				
		N	N	P	K	Ca	Mg
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Corn	50 bushels		50	8.8	10.0	0.5	3.5
Oats	40 bushels		26	4.5	6.5	.8	1.6
Wheat	25 bushels		36	6.0	7.5	.5	2.0
Soybeans for beans [2]	20 bushels	16		8.0	25.0	2.8	3.0
Soybeans for hay [3]	2½ tons		30	13.0	40.0	72.0	31.0
Alfalfa [3]	3 tons			13.0	96.0	120.0	24.0
Red clover [3]	2 tons			10.0	60.0	64.0	18.0

[1] Based on data published by Ill. Agr. Expt. Sta. (*32*, p. 554).
[2] Soybeans sold, straw returned.
[3] Hay removed, no manure returned.

Soil Tilth.—Soybeans tend to loosen the soil and to improve its granular structure. This is especially beneficial on heavy clay or silty clay loam soils. By improving the soil structure, better aeration is promoted, and this creates a favorable environment for the roots of growing plants. The improved aeration and the increase in available nitrogen in the soil also have a stimulating effect on the number of micro-organisms which assist in the decay of plant residues. Other legumes also improve the soil structure, but soybeans seem to be most effective (*32*).

Soybeans leave compact soils in much better physical condition than do corn and small grains. The improved tilth is most pronounced immediately after the soybeans are harvested, but on heavy soils it is still apparent the following spring or even later. Soybeans harvested for beans leave the ground in excellent condition for seeding winter grains with little or no seedbed preparation. If soybeans are harvested for hay before August 1 the stubble ground provides a very good seedbed for alfalfa seeded in the summer.

Soybeans improve the soil tilth by shading and protecting the soil and by root action. The dense canopy of leaves formed by the plants shades the ground and prevents the soil from baking and forming a crust and the leaves break the force and retard the packing action of heavy rains. If drilled solid or in narrow rows soybeans are more effective in this respect than if grown in wide rows. The roots often extend to a depth of 4 or 5 feet. This is deeper than the root penetration of small grains, although not nearly so deep as that of alfalfa and clover. The roots and the bacterial action they foster tend to break up and loosen the soil mass, making it more crumbly, better aerated, more easily worked by tillage implements, and more easily penetrated by the roots of following crops.

The loosening effect of soybeans on the soil may be a disadvantage under some conditions on certain types of soils, especially if the soil is not properly managed. Some heavy types, if plowed in the fall after soybeans are likely to "run together" badly after fall and spring rains. The chief reason for this seems to be that fine-textured soil on which soybeans have been grown is very easily pulverized by plowing and becomes tightly packed and crusted after long exposure to rains (*32*). This difficulty can be avoided by not plowing or thoroughly stirring the soil in the fall. Leaving the soybean straw scattered over the field gives additional protection. A winter cover crop drilled directly behind the combine with the straw falling evenly on the newly seeded ground helps considerably in protecting the soil from the leaching, packing, and erosive action of rains.

Effect on Subsequent Crops.—Experiments in several States have shown that soybeans have a beneficial effect on the yields of the crops that follow. Tests at the Ohio Agricultural Experiment Station over a period of 14 years showed that yields of wheat following soybeans for beans averaged 3.4 bushels higher than yields of wheat following oats. Following soybeans harvested for hay, wheat yields averaged 3.9 bushels higher than when grown after oats (*29*).

Tests at the Indiana Agricultural Experiment Station, covering 19 years, showed that yields of corn, oats, and wheat were all higher following soybeans than after any other crop except clover (table 4). In these experiments the top growth of all crops except second-growth clover was removed from the fields. Yields of oats after soybeans were almost as large as those after clover, and were substantially larger than after any other crop. Yields of wheat and corn showed less variation than oats when following crops other than clover. Soybeans showed the least variation in yields for all positions in the rotation (*45*). In other Indiana experiments, yields of wheat have averaged 6.6 more bushels per acre following soybeans than following standing corn (*5*).

Comparisons of the yields of corn following soybeans and following corn have been made for several recent years by the Iowa Agricultural Experiment Station. Data from these tests in 1942 show an average difference in favor of corn following soybeans of 8.3 bushels per acre on Webster silty clay loam and loam, and of 9.5 bushels on Clarion loam. Yields of corn after soybeans were higher on every one of the fields in the test, ranging from 3.5 to 18.8 bushels higher on the Webster soils and from 4.6 to 14.4 bushels higher on the Clarion loam (table 5). Similar results were obtained in 1943, 1944, and 1945 (*28*, *9*, *27*). The larger yields of corn following soybeans probably result from a greater supply of available nitrogen in the soil. On the finer textured soils the favorable effect of soybeans on soil structure may be another factor.

TABLE 4.—*Average yields of corn, soybeans, oats, and wheat in the first year after soybeans and other specified crops, Indiana experiments, 19 years, 1922–1940* [1]

Preceding crop	Average yields per acre			
	Corn	Soybeans	Oats	Wheat
	Bushels	*Bushels*	*Bushels*	*Bushels*
Soybeans	52. 6	23. 8	51. 4	24. 0
Corn	50. 1	24. 9	47. 9	23. 0
Oats	49. 8	24. 4	40. 9	22. 1
Wheat	50. 0	23. 4	42. 4	20. 3
Clover	57. 7	24. 8	51. 8	31. 2
Timothy	51. 6	23. 4	40. 7	22. 4

[1] Data from Ind. Agr. Expt. Sta. (*45*, p. 11).

TABLE 5.—*Yields per acre of corn following corn and following soybeans, Iowa experiments, 1942* [1]

Sequence	Webster soils		Clarion loam	
	Average [2]	Range [2]	Average [3]	Range [3]
	Bushels	*Bushels*	*Bushels*	*Bushels*
Corn following corn	63. 4	48. 5–95. 8	64. 6	50. 8–78. 4
Corn following soybeans	71. 7	52. 0–114. 6	74. 1	59. 8–85. 2
Difference	8. 3		9. 5	

[1] Data from tests on fields in Story and Hamilton Counties by the Iowa Agr. Expt. Sta. (*28*).
[2] 7 fields.
[3] 8 fields.

Replying to an inquiry mailed in 1945, 178 soybean growers in Illinois and Iowa answered the question: "How do soybeans affect the yields of crops grown on the land the following year?" Their answers were distributed as follows:

	Percent
Corn yield after soybeans:	
Increased	56
Decreased	23
No difference noted	21
Oats yield after soybeans:	
Increased	42
Decreased	38
No difference noted	20

Higher yields following soybeans, like those shown in table 5 for corn, are very significant when it comes to estimating the real net returns from competing crops, especially as soybeans most frequently follow corn in many parts of the Corn Belt.

Beneficial effects of soybeans on yields of subsequent crops have been reported in many other States. In southern Minnesota it has been observed that corn, sugar beets, small grains, and flax do very well following soybeans, especially if the soil is cultipacked or rolled after the seeding (2). Higher yields of crops after soybeans than after nonlegumes have been reported also from experiments in Kansas, Virginia, and New Jersey (24).

Soybeans used for green manure have a favorable effect on yields of most succeeding crops (24, 32). Because of their higher cost of production compared with sweetclover and other deep-rooted legumes, however, they are less practical in most northern areas except under certain conditions. In the Delta and other parts of the South, where soils are very low in humus and in nitrogen, soybeans are one of the most productive green-manure crops and they fit well in crop sequences.

Many farmers in the Corn Belt have reported difficulty in growing wheat successfully, following soybeans. The most common handicaps are delayed seeding and a large quantity of soybean straw on the field. In many cases these problems can be overcome by seeding wheat directly behind the combine. In some cases it may pay to use earlier maturing varieties of soybeans, considering the returns from both the soybean and wheat crops. Best results are obtained when the seedbed is worked as little as possible—only enough to cover the wheat seed. It frequently pays to apply a complete fertilizer at the time of seeding, as this gets the wheat off to a faster start and supplies nutrients needed before those from the decomposing soybean plants are available (5).

Some farmers have found that clover often fails when seeded with small grain following a crop of soybeans. Other farmers have obtained their best clover stands after soybeans. Possible reasons for clover failures are numerous. In some instances soil acidity may be the principal obstacle; in others a lack of available phosphorus or potassium may be responsible. These conditions may be corrected by proper applications of lime and fertilizers. If the soil is loose and the weather is dry at the time of seeding, failures may occur unless the field is rolled to compact the ground after seeding. Because soybeans leave the soil in good tilth and with more available nitrogen than is found after nonlegumes, small grains, particularly oats, usually grow more vigorously, compete more strongly with the clover for moisture and plant nutrients, and make too much shade. This suggests that on fertile soils clover, that is to follow soybeans, may do better when seeded with wheat than with oats. Correction of soil acidity and mineral deficiencies when necessary, shallow planting of inoculated seed, and cultipacking the ground if it is loose contribute greatly to improved stands of clover.

Tests by the Ohio Agricultural Experiment Station in 1944–46 showed little significant difference in stands of red clover following soybeans and corn (*49*). In Indiana, a quarter-century of rotation tests on fertile soil showed clover failures in wheat after soybeans to be no more frequent than in wheat following corn (*5*).

It can be concluded that when good cultural practices are followed and when they are grown on land that is fairly level, soybeans have a beneficial effect on the soil and on the yields of subsequent crops. On the other hand, if they are grown on steeply sloping land and if improper cultural methods are used, soybeans, like many other crops, may have a detrimental effect on the soil.

Variety Improvement

The plant scientists who carry on the work of plant exploration, selection, and breeding have taken a leading part in the development of soybeans. In a comparatively short span of years they have done for soybeans the job that took three centuries to accomplish by the slow processes of trial and error in the case of open-pollinated corn.

A quick review of the question of varieties at this point helps toward an understanding of what has been accomplished and what effect further improvement of varieties may have on future trends. Very briefly, the most vital accomplishment with soybean varieties up to this time has been the discovery and selection of varieties adapted to the different climatic and soil conditions in various parts of the Corn Belt and other soybean growing areas.

The varieties first selected and developed seemed best adapted to the central Corn Belt. The wartime expansion of soybeans to the north and west was apparently brought about by the timely development of varieties better suited to those areas. The notable increase in soybean production in Iowa, for example, might not have been possible with the varieties available a decade earlier. From now on the contribution of new varieties is likely to move more in terms of improving yields and characteristics for areas in which the crop is already well established. The work of plant breeders may now be somewhat more important to our farmers than the work of plant explorers.

Few crops include as many varieties as the soybean. Varieties differ widely in time of maturity, height of plant, quality of forage, and character and yield of seed, and resistance to lodging, shattering, and disease. Varieties differ in color, shape, size, and chemical composition of seed. Protein content runs from 28 to 56 percent, oil content from 12 to 26 percent, iodine number of oil from 118 to 141, and lecithin content of oil from $1\frac{1}{2}$ to 3 percent. A very important difference between varieties is in their adaptation to local conditions. There are wide differences also in the combination of characteristics present in a single variety.

During the period, 1898–1932, thousands of selections of soybean seed were brought into the United States (mostly from the Orient) for testing and experimental work by the Department of Agriculture and by many of the State agricultural experiment stations. A few of these selections proved outstanding, were increased for seed, and became popular varieties. Relatively few of the original introductions were selected for increase but many of the others have since been found useful in breeding work. From 1932 through 1946 only about 300 samples were received from foreign countries, but these included some early-maturing types that appear to be promising. Additional introductions from abroad are still desirable. For example, relatively few varieties have been obtained from South China, and it is anticipated that future introductions from that region may provide valuable material for developing improved varieties for the Southern States.

Extensive research aimed at variety improvement and more economical utilization of soybeans has been carried on in this country. A soybean oil and protein laboratory was established in 1929 at Holgate, Ohio, by the United States Department of Agriculture to conduct research toward development of high-oil and high-protein varieties. The United States Regional Soybean Laboratory was organized and began operations at Urbana, Ill., in 1936. In cooperation with State agricultural experiment stations this laboratory has studied the agronomic behavior of many thousands of soybean introductions and selections, and has developed several improved varieties. In 1942 that part of the laboratory work that was devoted to development of new industrial uses for soybeans was transferred from Urbana to the Northern Regional Research Laboratory at Peoria, Ill. At the same time the territory served by the laboratory at Urbana was expanded to include 12 of the Southern States, in addition to the 12 North Central States originally served. Development of higher-yielding varieties for the South as well as for the North Central States has progressed considerably with this decade (*8*).

The primary characteristics of a good variety of soybeans are: High yield of seed; resistance to lodging, shattering, and disease; maturity adapted to the area; and high content of oil and protein. A high iodine number is another quality sometimes desired. Selection and breeding work is constantly directed toward obtaining better performance of these characteristics. Until recent years the development of improved varieties was brought about mainly through selection. Now, planned hybridization has a larger part. As the desirable characteristics are usually found separated in different varieties, the plant breeder's problem is to bring them together into one variety. Soybeans are naturally self-fertilized. Crossing, to develop new combinations, is a painstaking process, but it greatly speeds up variety improvement.

One of the outstanding varieties developed to date is the Lincoln. It is a midseason variety, particularly well adapted to a broad band extending from Ohio across the heart of the Corn Belt to eastern Nebraska. It originated from a natural cross made at the Illinois Experiment Station in 1934 and was developed by the Regional Soybean Laboratory at Urbana, in cooperation with Illinois Station. Several years of testing throughout the Corn Belt show that the Lincoln averages about 17 percent higher in yield and has a substantially higher percentage of oil than other leading midseason varieties. The Lincoln is also above average in resistance to lodging. It will grow successfully over a wider area than any other good midseason variety. The seed was not available for general sale until 1944, but in 1946 more than half the soybean acreage in Illinois and Indiana was of this variety (*8, 50*).

Some of the other outstanding varieties developed fairly recently are the Hawkeye, S–100, Ogden, Volstate, and Roanoke. Supplies of seed of the Hawkeye, adapted to the northern part of the Corn Belt, and of S–100, adapted to the upper South, are not yet available in large enough quantity for general release. The Ogden is adapted to the central and upper South, and Volstate and Roanoke are particularly adapted to the central South.

Many other varieties have shown good to outstanding performance. There are a number of advantages in having several varieties for each locality. Some varieties do better than others on certain soils. Varieties of different maturity help to avoid peak labor loads during harvest on farms that have large acreages, or where several farms use the same combine. Different varieties in a community reduce the risk of epidemics of disease. Numerous varieties are needed for breeding work.

Among the objectives of the present improvement work are the development of varieties that are early maturing and high yielding for the northern fringe of the Corn Belt; varieties that are more resistant to shattering, especially west of the Mississippi; and varieties that normally mature between September 15 and October 1 in the South. With the potential threat of diseases, investigations and breeding for disease resistance also have become important (*8, 14, 1*).

The effect of variety improvement on yields over the next decade cannot be estimated with any degree of precision, but it will surely be considerable. The Lincoln variety, for example, has not yet made its mark on the yield picture in the United States. The first year in which its distribution was general was 1946 and possibly some of the higher yields of the central Corn Belt in that year were caused by it. The second year, 1947, was troubled with unfavorable weather and yields were low anyway. On the basis of the widespread tests it would seem that the Lincoln may raise commercial yields 10 to 15 percent in the areas in which it seems best adapted.

Some of the other new varieties will have similar effects in adapted areas. Probably the progress will be less rapid and spectacular with soybeans than was the case with hybrid corn because of the difference in the breeding problem involved. The timetable furnished by the Lincoln will illustrate. It took a little over 10 years from the time this variety was originated until enough seed was available for general distribution. As the work of developing a successful variety is only well started with the original hybrid cross this time can scarcely be shortened. Successive generations coupled with rigorous selection are required to fix a strain that will truly reproduce itself. The end result is a pure variety. In the case of corn, hybrid seed remains hybrid—and the basic pure lines are maintained and the same crosses are repeated to make the seed. The breeding problems are thus somewhat different and, at least for the next decade, the possibilities of rapid change are mainly limited in the case of soybeans to new varieties and selections already known to show promise.

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Intercrop Competition

With limited land resources, an upward trend in any one crop must immediately affect others. The nature of the competition between soybeans and other crops is so complex as to require special consideration. The principal crops involved in the Corn Belt competition are shown in table 6 in terms of percentages of total cropland in 1947. Corn occupies about one-third of the cropland for the five States as a whole, followed by hay and oats. Soybeans take up only 9 percent of the total, although the percentages are higher in the strictly soybean areas, as the 15 percent for Illinois suggests. The percentages differ considerably from State to State. Beneath the broad averages shown in this table are a great many different situations in smaller areas and on special soils (fig. 5).

Some of the over-all shifts between crops from 1924 to 1947 are shown in figure 7, for Indiana, Illinois, and Iowa. For the period as

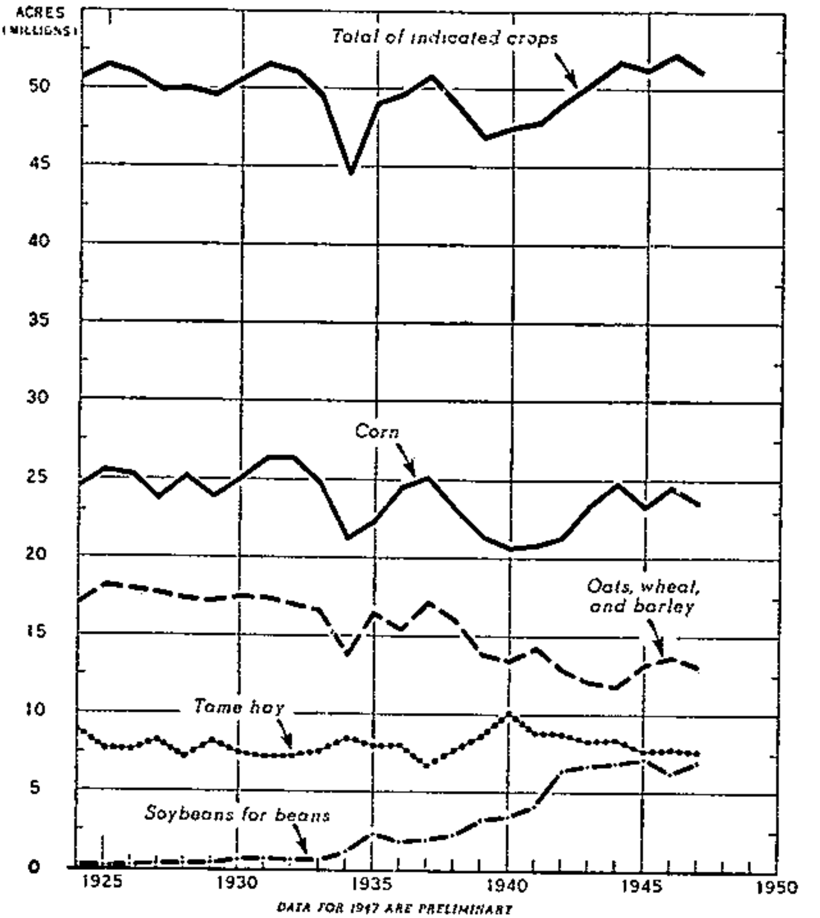

Figure 7.—Acreage of soybeans for beans and other specified crops harvested in Indiana, Illinois, and Iowa, 1924–47.

a whole, the expansion in soybeans was apparently offset mainly by contraction in the acreage in small grains, together with some shrinkage in the acreage of corn. It is known that some acreage came from rotation pasture also, although comparable data are not available. In Iowa, the change in the oats crop was the source of most of the small-grain contraction, and in the other two States winter wheat was more significant. The acreage released from corn during the 1930's was a considerable source of land for growing soybeans during that part of the period.

TABLE 6.—*Percentages of total cropland from which specified crops were harvested, and percentages in pasture and in other uses, 5 Corn Belt States, 1947*

Crop	Ohio	Indiana	Illinois	Iowa	Missouri	5 States
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Corn	26	33	37	42	24	34
Oats	6	8	14	22	8	13
Soybeans [1]	7	11	15	7	5	9
Wheat [2]	16	12	6	1	8	7
All Hay [3]	19	12	11	13	22	15
Pasture [4]	14	14	9	10	17	12
Other [5]	12	10	8	5	16	10
Total cropland [6]	100	100	100	100	100	100

[1] Soybeans harvested for beans.
[2] All wheat.
[3] Tame hay in all States plus small acreages of wild hay in Iowa and Missouri. Includes small acreages of soybeans harvested for hay in all States.
[4] Cropland used only for pasture, U. S. Census of Agriculture, 1945. (*39*)
[5] Minor crops, crop failure, and idle and fallow cropland.
[6] Land used for crops (harvested and failure) plus cropland used only for pasture plus idle and fallow cropland. From U. S. Census of Agriculture, 1945. (*39*)

The explanation for the crop shifts in wartime from the immediately preceding period appears to be rather different from the longer time story. Small grain and hay decreased slightly whereas corn and soybeans increased considerably. Most of the land for the wartime expansion of the latter crops apparently came from rotation pasture and idle cropland, so the total acreage used for crops expanded. In the competition for available cropland, soybeans were increased relatively more than corn.

Because soybeans are usually intertilled they have been classed with corn and other intertilled crops, and most discussions of intercrop relationships have centered around the soybean-corn competition. The history of crop shifts indicates clearly that this is only a partial and inadequate view of the matter. The competition lies with all of the crops in the cropping system rather than with any one.

Computations of "net profit" or "net return" from competing crops are beset with pitfalls because of the joint use of soils, labor, machinery, and other farm resources, and the difficulty of arriving at appropriate valuations for the separate costs and for the credits for contributions to other enterprises. Yet the fact remains that no crop would be grown very long unless it made a net contribution to the farm income, and a larger contribution than any alternative would.

To understand how shifts in crops occur it is desirable to keep in mind some of the general agronomic and farm-management framework involved in permanent cropping systems in the Corn Belt. In the first place there are few situations in which it pays to grow a single crop (especially if it is intertilled) continuously on the same land. To maintain fertility, to prevent erosion, to control weeds and pests, and for other agronomic reasons the crops must be changed. A second crop with even a low apparent value may have a high marginal value because of its contribution to the main crop. A third crop may also have a value above its nominal value for the same reason. In most crop sequences a sod crop is necessary, sooner or later, if fertility is to be maintained. Ordinarily the most economical way to seed down for hay or pasture is to use a companion or nurse crop. The small grains serve this purpose. If livestock is an important element in the type-of-farming the desirable acreage of sod crops may be still larger and along with it the acreage of small grains needed for nurse crops.

In addition to these circumstances, the seasonal distribution in the use of labor and equipment may make diversification desirable. Even a rather low return per hour for labor and other resources in slack seasons may represent a noteworthy addition to the net farm income for the year.

Considerations of the sort just mentioned furnish the familiar farm-management framework within which farm adjustments work themselves out. There is much flexibility within the framework, however, for far-reaching trends. In the end it is the influence of changes in relative cost and price relationships which will determine intercrop shifts, and the trend in soybean acreage and production. The farm-management and agronomic framework only condition and channel the adjustments and make them different in different locations.

Yield Per Acre

The broad picture of upward trend in yields of soybeans per acre shown in figure 2 suggests that the rising yield has been one of the most influential factors in the competition between crops and in soybean expansion. From some of the early years to the best recent ones, soybean yields have nearly doubled. These higher yields mean much lower unit costs and therefore more competitive advantage. As yields of other crops have also been rising, from the standpoint of intercrop competition the matter of relative trends in yield assumes significance.

In figure 8, the trends in yields for corn, oats, and winter wheat are compared with soybeans in terms of 5-year moving averages. Using 1925–29 as 100, it is apparent that yields of soybeans have risen considerably more than those of the other three crops. If a later base period, after soybeans were more widely grown, were used it would show that soybean yields have increased somewhat less than corn yields in recent years. The statistical difficulty involved in almost any yield comparison between soybeans and other crops is tied in with the rapid increase in acreage and its regional distribution. One cannot be sure that soybeans grown in identical areas would show the same trend in yield. The expansion in acreage has brought soybeans to new areas

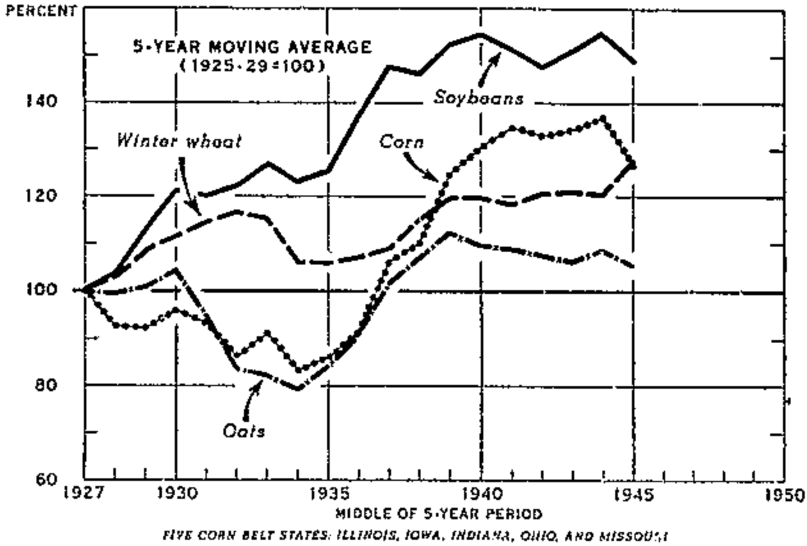

FIGURE 8.—Trends in yield per acre of soybeans for beans, corn, oats, and winter wheat, five Corn Belt States, 1925–47.

and to new land in old areas. Their yields were less depressed by the droughts of the 1930's than were those of the other crops but this is partly because soybeans had not yet expanded greatly into the areas most affected by drought.

Another method of comparison is to compute yield ratios such as those shown for corn and soybeans in table 7 for each of the five Corn Belt States. These ratios show that there was a marked improvement for soybeans from 1925–29 to 1935–39. This has several causes, including differences in weather conditions which affected the crops differently and improvements in varieties and yields of soybeans. From 1935–39 to 1942–46 the yield ratios shifted in favor of corn except in Missouri, but they remained more favorable to soybeans than in 1925–29.

TABLE 7.—*Corn-soybean yield ratios in 5 Corn Belt States, averages 1925–29, 1935–39, 1942–46*

Period	Ohio	Indiana	Illinois	Iowa	Missouri
	Ratio	*Ratio*	*Ratio*	*Ratio*	*Ratio*
1925–29	2. 74	2. 73	2. 52	2. 70	3. 10
1935–39	2. 19	2. 29	2. 00	2. 20	2. 19
1942–46	2. 55	2. 63	2. 36	2. 66	2. 02

The principal factors influencing the upward trend in yield of soybeans appear to have been improvement of varieties and mechanization of harvesting operations. Additional factors were experience with the crop, better management of soils, more timely operations, and other improved practices including other phases of mechanization than harvesting alone. Because of joint relationships it is difficult to assign relative weights to each factor.

Variety improvement and mechanization have apparently operated in rather different ways. The work with varieties has resulted in some marked increases in yield but probably the chief influence has been felt through making available adapted varieties which enabled the crop to expand in new areas. In other words, variety improvement has widened the production areas within which competitive yields could be obtained. Mechanization, on the other hand, particularly of harvesting operations, has increased realized yields everywhere. The principal influence of mechanization on yields has been through the reduction of losses in harvesting. With the almost universal adoption of combine harvesters, this reduction of harvesting losses has raised yields in all areas. The influence of mechanization on timeliness of work performance and on better weed control has also had a general upward effect on yields. Other influences include such practices as the increased use of inoculation, row planting, and improved cropping systems.

VARIABILITY IN YIELDS.—An interesting characteristic of soybean yields is that year-to-year fluctuations are apparently less than is the case for other crops. A brief analysis of average yields for the five Corn Belt States for the period 1926–45 was made to measure variability by computing differences between each annual yield and the 5-year moving averages for each crop. The average percentage deviations were as follows:

	Percent
Soybeans	7.4
Corn	11.4
Oats	13.6
Wheat	10.4

RESPONSE TO FERTILIZATION.—The crop does not generally give large responses to current applications of fertilizers but it does show a definite response to variations in the level of soil fertility. Treatments that build up soils to a high level of productivity for other crops in the rotation also make for higher yields of soybeans. The soybean plant is a strong forager for nutrients in the soil. It makes good use of plant-food materials that remain in the soil after other crops are grown. Highest returns from fertilizers are therefore usually obtained when they are applied for corn, clover, or other crops in the rotation rather than directly for soybeans (*18*).

On some soils, however, direct applications of fertilizer to soybeans may be quite profitable. Experiments in North Carolina, for example, have shown marked increases in yields resulting from applications of lime, potash, and phosphate on soils deficient in these elements (*13*). Experiments in Iowa indicate that higher yields are obtained on soils containing a relative abundance of nitrogen than are obtained on soils low in nitrogen. The nodule mechanism of nitrogen fixation cannot make up entirely for a shortage of nitrogen in the soil, even though the soybeans are well nodulated. The most critical time of nitrogen need by the soybean plant is in the midseason period about the time of flowering. Management practices or fertilizer applications which result in an increase in available nitrogen at this stage are likely to bring larger yields (*27*).

Under some conditions, applications of fertilizer may result not only in more vigorous growth but also in earlier maturity of soybeans. Experiments in Indiana in 1943 showed that the moisture content of fertilized soybeans was significantly lower than that of unfertilized soybeans, early in October. These experiments also showed that applications of fertilizers high in phosphate and potash had a marked effect in increasing the number of pods per plant, the number of beans per pod, the size of seed, and the percentage of germination (*42*).

As the use of fertilizers is increased as a part of improved cropping practices, soybean yields may be expected to benefit from the higher level of fertility that will follow. But whether this will mean any competitive advantage seems doubtful, as competing crops will benefit to at least the same extent.

GEOGRAPHY OF SOYBEAN YIELDS.—The geographic pattern of soybean yields is shown in figure 9. Comparison with the earlier figures showing the distribution of soybean acreage indicates a considerable correlation between high yields and acreage concentration. The high-yield areas tend to have the most acreage and the highest proportion of the cropland in soybeans. The correlation is not complete, and a close

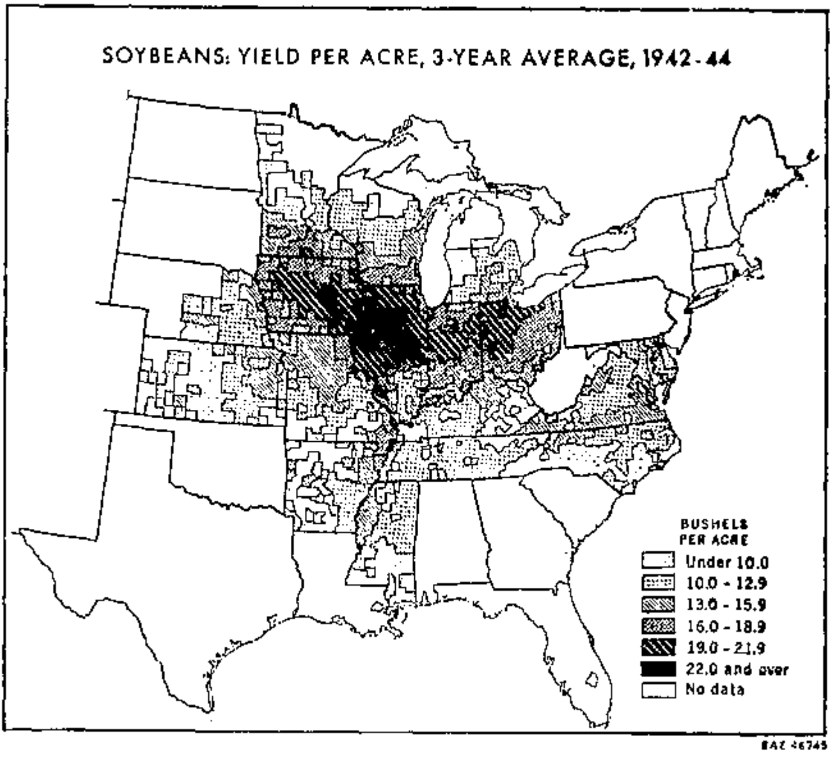

FIGURE 9.—The areas of highest yields of soybeans for beans coincide fairly closely with the areas of heaviest concentration of soybean acreage. There are some exceptions, however; for example, the highest yielding area in Illinois is somewhat north and west of the area of heaviest acreage concentration, and in Iowa the highest yielding area is to the southeast of the most concentrated acreage.

examination of the maps will reveal that in Iowa, for example, the acreage concentration is greater to the north and west of the areas of highest yield, and in Illinois some of the highest acreage appears a little to the east and south of the areas of highest yield.

The general conclusion from the yield map, however, is that natural factors have confined high soybean yields within relatively restricted climatic boundaries.

MECHANIZATION

Agricultural improvement in the United States in terms of mechanization and other forms of technology has affected all crop and livestock production. The shift from horse to tractor power and the increased mechanization of farm operations, especially marked in the Corn Belt, has influenced trends in soybeans in common with trends of other crops. But certain differential effects have been particularly striking. Of these by far the most outstanding resulted from the introduction of the small combine. The combine greatly decreased the labor of harvesting but, more significantly, was responsible for a considerable increase in harvested yields. Previous harvesting methods resulted in shattering and loss of as much as 30 percent of the beans produced, but using the combine reduced the loss to about 9 percent under average conditions (*19*). This would amount to a 30-percent increase in yield. This factor alone is probably more significant than anything else on the supply side in making possible the large expansion in soybean production. The other effects of mechanization in decreasing labor inputs and improving the returns are important but minor in comparison with the improvement in yields.

Soybeans came into a mature agriculture, in the Corn Belt and other areas, which was already provided with the machinery and equipment for producing a full line of crops. A shift to powered equipment merely happened to be underway at the time, and the expansion of soybeans did not greatly affect mechanization. The crop made use of the existing equipment for preparing land, planting, cultivating, and harvesting. The fact that Corn Belt farms became more highly mechanized in this period may have made it somewhat easier to include another crop in the cropping system because of the greater flexibility in farm operations.

The principal field operations involved in growing soybeans are similar to those for corn production, with the exception of harvesting. In the early stages of soybean expansion, the relatively small acreages of soybeans per farm may have sometimes involved inefficiencies, but present acreages per farm are large enough in most producing areas to avoid any difficulty of this sort. Probably few further increases in efficiency of field operations for soybeans are likely except those that will be shared by corn and other cultivated crops. Any further economies from mechanization that are likely to work to the special advantage of soybeans are those practices which may affect yields. To understand how these may develop, a brief discussion of current practices is pertinent at this point. These apply mainly to conditions in the Corn Belt where a greater part of the commercial crop is grown.

PREPARATION OF SEEDBED.—In preparing the seedbed for soybeans most growers follow about the same practices as used for corn. The land is usually plowed (frequently disked first) in the spring and is disked and harrowed several times before the planting takes place in order to kill weeds. Most soybeans are planted later than corn and there is usually time for an additional harrowing before the planting. A smooth, firm seedbed, with as few weeds as possible, even if this delays planting, is considered advisable. Disking alone, without plowing, is seldom effective in preparing a good seedbed except after potatoes or peas or on small-grain stubble where the soil works easily and is free of weeds.

PLANTING.—The method of planting soybeans in most areas has been determined largely by the equipment already available. Soybeans were first grown mainly for forage and were drilled or sometimes broadcast. At present, the most common planting machines in the Corn Belt are the corn planter and the grain drill. The cotton planter is used in the South and sugar-beet drills and bean planters are employed by some farmers. The corn planter is the favorite implement in the cash-grain areas of Illinois and Iowa, but the main reason appears to be simply that these farmers have corn planters and frequently do not have drills. Before the war, about three-fourths of the soybeans in the Corn Belt were seeded solid (drilled 6 to 8 inches apart). Row planting has increased rapidly since then, rising from 26 percent in 1940 to 54 percent in 1944 in Illinois, for example (*11*). A recent survey in Illinois, Indiana, and Ohio indicates further increases in row planting from 1944 to 1946 (*7*). Apparently about 80 percent of the 1946 crop in Iowa was in rows, compared with about 60 percent in Illinois and Indiana, and less than 20 percent in Ohio.

A considerable part of the wartime expansion in row planting came about because acreage increased in the areas that were equipped with corn planters. But it seems to be recognized that under most conditions row planting is advantageous from the viewpoint of weed control and higher yields. Rows fit in better with mechanized operations. On the other hand, solid planting has advantages in some situations. Where erosion is likely, solid planting retards run-off. Drilling on the contour is helpful on sloping land. On clean ground, solid planting reduces the labor in cultivation.

Possibilities of future improvement in planting may be rather limited, although further increases in row planting in some areas may increase the yields. In other areas reverse adjustment from row to solid planting may bring in higher yields. Row planting is frequently carried out with the grain drill by covering designated feed cups. Hence, changing to row planting is not likely to be retarded by any lack of equipment.

CULTIVATION.—The seriousness of weeds in soybeans depends on the effectiveness with which they have been controlled in preceding crops and on the preparation of a clean seedbed before planting. Relatively late shallow planting on an early prepared clean seedbed gives soybeans a strong initial advantage over weeds. Well-timed cultivations with appropriate implements, properly used, assure maximum weed control after planting (*48*).

Nearly all row-planted soybeans in this country are cultivated one or more times with row-crop cultivators. On much of the row-planted acreage the spike-tooth harrow, or rotary hoe, or weeder is used for the early cultivations, and row cultivators are used later. Much of

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the solid-planted acreage is not cultivated at all after planting.[5] On the solid-planted acreage that is cultivated, the spike-tooth harrow, rotary hoe, and weeder are the implements most commonly used. A fairly common practice is to go over the ground once with the harrow or rotary hoe before the plants are up, to kill small weeds and to break the crust on soils that have hardened, after rains.

Effective weed control pays off in higher yields, more uniform maturity, and lower moisture content of soybeans. Most agronomists agree that many growers could obtain materially higher yields by closer attention to seedbed preparation and to more timely cultivation. Harrowing during the time of sprouting and before the first true leaves are well out may severely damage the plants because at this stage they are tender and brittle. But after the plants are 4 inches high, and until they are 8 or 10 inches high, they will withstand the action of rotary hoe or harrow without appreciable injury, if the cultivation is done on sunny afternoons when the plants are limp and tough. Cultivation after flowering begins may injure blossoms and reduce the production of beans.

The use of 2, 4–D (a chemical mixture) in preemergence treatment of soybean ground to control weeds may have possibilities for the future, but it has not yet proved to be practicable. Soybeans are very susceptible to 2, 4–D. The most promising possibility is its use in corn preceding soybeans, to reduce the menace of field bindweed and other deep-rooted perennial weeds. Flame weeding is another new and interesting method of weed control. When used at the right time, and properly operated, the flame weeder can be very effective but it has not yet been demonstrated that flame weeding can compete economically with other weed-control methods for soybeans (*48*).

HARVESTING.—Harvesting operations had long constituted an almost insurmountable bottleneck in producing soybeans under American conditions. Various improvised methods were used, all of which were labor consuming and caused considerable losses of beans from shattering. Then the combine became one of the most important production factors in bringing about expansion.

Some farmers tell of their experience, about 1910, of cutting soybeans with a cane knife and beating them over a sheet of woven wire stretched across a wagon bed. A little later, many growers in the Southern States used mule-drawn row harvesters that beat the beans off the standing stalks into a box, saving from 50 to 75 percent of the beans under favorable conditions (*13*). Other early methods were to cut the soybeans with a mower or self-rake reaper and thresh them in pea and bean threshers or in grain threshers. In the 1920's and early 1930's grain binders were rather widely used, and the bundles were cured in shocks and sometimes stacked before being threshed (*23*). About 80 percent of the acreage harvested for beans in Iowa in the early 1930's was cut with the binder, shocked, and threshed (*20*). Even when harvested with binder and thresher—the most successful of the early methods—losses from shattering were large as a result of weathering and much handling.

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[5] A survey by a commercial company of 4,200 soybean growers in the eastern Corn Belt showed that 28 percent of the solid-planted soybeans in Illinois, 60 percent of those in Indiana, and 66 percent of those in Ohio were not cultivated (*6*).

A combine was first used for harvesting soybeans in Illinois in 1924. Eleven combines were sold in Illinois in 1925 and 52 in 1926 (*19*). Two years later (1928) there were 400 combines on farms in Illinois and a total of more than 700 in the five Corn Belt States. The number increased rapidly to more than 110,000 in these States in 1945. Combines began to appear on farms in the Delta before the war and then spread to the Atlantic Coast and Southern States.

Man labor required in harvesting with the combine is less than one-third of that with the binder and thresher method, and the total cost of harvesting is also less (*31*, *47*, *22*). Combining greatly reduces harvesting losses of soybeans as compared with other methods, and the loss of beans at harvest time may be further reduced by improvements in design and operation of combines as well as by the development and use of varieties that are more resistant to shattering and lodging and that bear their lower branches higher off the ground. In addition, the use of combines as contrasted with the binder and thresher method frequently results in beans of lower moisture content, better keeping quality, and higher germination. Soybeans harvested with the binder or mower were generally cut before entirely mature, to reduce shattering. Soybeans on the standing stalk dry out more quickly after rains than those in shocks.

The first combines sold in the Corn Belt were of the 8-foot to 12-foot sizes. The 5-foot and 6-foot cut combines were introduced in 1935 and a few years later the 3½-foot and 4-foot sizes were available.

The 5-foot and 6-foot machines are the most popular at present, as they are well adapted to the acreages commonly grown and to the size of power units most commonly found on farms in that region. Careful integration of size of power unit, size of machine, and row width can result in the most economical use of labor and fuel in growing and harvesting the crop (*19*).

There has been an increase in the number of improved self-propelling combines in recent years. These machines have the advantages of additional saving of labor, making it easier to open fields, and saving more grain in opening fields. Where large acreages are grown or where there is a demand for custom harvesting the relatively large investment involved in these machines may be justified.

The harvesting season usually begins somewhat before corn is ready to be picked, but a considerable part of the acreage is commonly harvested after the corn-picking season begins. In the Delta and Southern States the soybean harvest comes before and during the cotton-picking season. Because of the overlapping of harvesting seasons there is some competition between soybeans, corn, and cotton for labor at this period but the competition is not altogether direct. Picking corn with mechanical pickers works to best advantage in the mornings and on damp days. Soybean combining works best when the plants are dry, usually in the afternoons on dry days.

Some experiments have been conducted during the last few years on artificial defoliation with cyanamid dust as a means of speeding up the drying out of soybean plants at maturity, to make earlier combining possible. The technique is still in the experimental stage, not yet ready for recommendation. It is possible that artificial defoliation may become an economical practice under some conditions (*4*).

The major gains from the adoption of the combine have no doubt been realized, and the influence of further improvements in harvesting on the future trend of soybean production will be relatively minor. Nevertheless, further advantages may accrue in terms of additional combines in some areas, and improvements in machines and their use, which will still further reduce the estimated 9 percent of harvesting loss. A striking parallel may be drawn between the influence of the combine on the yield of soybeans and the influence of hybrid corn on the yield of corn. In each case the innovation has brought rapid and marked results in a short span of years and has been almost universally adopted in the major areas of production, although some additional gains will come as refinements are developed. The major effects are now evident.

Relative Costs and Returns

Some data drawn from farm-account records in Illinois may be used to illustrate the general relationships involved between corn, soybeans, and small grains, in terms of computed returns. In table 8, net returns for these crops are shown for selected years from 1937 to 1946. The returns vary with fluctuating yields and prices, but it is significant that corn always appears to be most profitable, followed by soybeans and then by oats or wheat.

Table 8.—*Soybeans, corn, oats, and winter wheat: Average net returns per acre on farms keeping farm-account records in Champaign and Piatt Counties, Ill., specified years, 1937–1946* [1]

Year	Soybeans	Corn	Oats	Winter wheat
	Dollars	*Dollars*	*Dollars*	*Dollars*
1937	3. 12	12. 94	2. 64	−0. 50
1939	7. 75	10. 22	−6. 54	2. 04
1941	25. 84	29. 09	−. 31	7. 14
1943	26. 69	44. 64	7. 62	9. 52
1945	24. 62	40. 66	16. 85	----------
1946	33. 21	66. 76	19. 41	----------

[1] Data from cost accounts supervised by Ill. Agr. Expt. Sta. (*46*). The number of farmers keeping records on the project varied from 30 in 1937 to 24 in 1946. Data are for all the farmers reporting each crop—at least 20 farms in each instance, except as follows: Oats—16 farms in 1939, 17 in 1943, and 18 in 1945; winter wheat—15 farms in 1937, 16 in 1939, 13 in 1941, 5 in 1943, 2 in 1946, and none in 1945.

With the prices prevailing during this period a similar relative net-return situation will be found in most parts of the Corn Belt where soybeans are grown. The precise relationships differ considerably, of course. It is evident that corn has first choice in putting together the most profitable farming system. The proportion of land devoted to soybeans and other crops is influenced in turn not only by the computed dollar return but also by the other management factors previously mentioned. Having once reached a general adjustment with respect to the management factors, however, shifts between crops are likely to be determined chiefly by changes in relative costs and returns.

Let us look at trends in the gross returns per acre from soybeans, corn, and oats, over the period 1925–47, using Illinois as an example (table 9). These values are simply the product of average yields and average prices. We have already examined the trend in the prices of these three commodities and noted that the prices of soybeans in the 1920's were high because the demand for seed use and other special purposes took up most of the limited supply of beans. As yields were low during the same period, the average acre values do not appear so high as the prices. During the war years, the acre returns for soybeans improved relative to the immediate prewar period, and also relative to corn. The gain relative to corn would have been greater had not the influence of hybrid seed and other factors increased yields of corn more rapidly in this period. As an average for the war years, the gross acre returns for soybeans were about 10 percent higher than were the returns for corn, compared with the 1935–39 base. As costs rose less rapidly, the change in net returns on the higher price level can be considered as even greater. Acre returns from oats rose percentagewise about as much as soybeans during the war but the much greater spread at the higher price level made them less attractive.

TABLE 9.—*Average value per acre for soybeans, corn, and oats, Illinois, 1925–29, 1930–34, 1935–39, and annual 1940–47 and index numbers (1935–39=100)*

Period or year	Average value per acre			Index numbers (1935-39=100)		
	Soybeans	Corn	Oats	Soybeans	Corn	Oats
	Dollars	*Dollars*	*Dollars*	*Percent*	*Percent*	*Percent*
1925–29	25.32	27.13	12.31	156	115	128
1930–34	12.55	13.13	6.54	77	56	68
1935–39	16.27	23.64	9.62	100	100	100
1940	14.88	26.23	14.40	91	111	150
1941	33.11	39.22	17.63	204	166	183
1942	33.60	48.60	19.11	207	206	199
1943	37.80	53.00	24.09	232	224	250
1944	43.66	47.67	22.51	268	202	234
1945	41.60	56.26	30.82	256	238	320
1946	59.22	86.07	34.80	364	364	362
1947 [1]	60.30	90.46	37.45	371	383	389

[1] Preliminary.

Information on trends in costs is rather fragmentary, especially if comparisons extending back to the earlier years are wanted. The information in table 10 was taken from the carefully kept cost records for Champaign and Piatt Counties in Illinois, in the heart of the soybean region. The acreage covered in the early 1924–26 period is small, but is probably sufficient to give a true picture of the change in that area. Between 1924–26 and 1937–39 the input of man labor was reduced from 12 to 4 hours per acre and the transition from horse to tractor and binder to combine was practically completed. Only a very slight change has occurred since 1937–39 in physical costs of operation. The timing of the transition has been different in different parts of the Corn Belt but not greatly so. Mechanization has also reduced man labor on corn and oats and other crops, but not to the extent that took place in the case of soybeans. The combine and its solution of the harvest-and-yield losses probably was the primary key to the problem of cost reduction for soybeans. The combine benefited small grain too, but the advantage gained over the binder and thresher was less and was offset for many farmers by the loss of straw needed for livestock.

TABLE 10.—*Labor and power inputs per acre for soybeans on farms keeping cost records in Champaign and Piatt Counties, Ill., averages 1924–26, 1937–39, and 1944–46* [1]

Period	Area covered	Average yield	Man	Horse	Tractor	Truck
	Acres	*Bushels*	*Hours*	*Hours*	*Hours*	*Miles*
1924–26	167	16.8	12.13	27.03	1.43	(2)
1937–39	1,833	30.0	4.10	.88	2.42	1.09
1944–46	2,167	24.2	4.19	(3)	3.00	1.58

[1] Based on data from Ill. Agr. Expt. Sta. (*46, 47*).
[2] Not reported.
[3] Negligible.

In summarizing the historical explanation for trends it appears that the physical and agronomic background furnished a setting which mainly limited soybean expansion in the Corn Belt to the more level areas and to climatic zones for which adapted varieties were available. In addition, the general considerations involved in crop sequences and crop and livestock relationships furnished some limits. But within these limitations there is considerable flexibility for expansion or contraction of soybean acreage.

During the earlier part of the expansion, important elements in the explanation of trends were the development of market outlets, the evolution of grading and marketing machinery, and the introduction of the crop into additional areas and into the hands of farmers who were not fully acquainted with its possibilities.

Probably the chief elements in improving the relative returns from soybeans have been the reduction in costs through mechanization and the increase in acre returns from higher yields. The war expansion was brought about primarily through higher relative prices.

For the future, now that the crop is firmly established, acreage changes are likely to be closely related to changes in relative returns. The main possibilities seem to lie in the direction of improved varieties, but the outlook in regard to rice and demand may be even more important.

ESTIMATES OF FUTURE SUPPLY

The process of making estimates of the future is in one sense a reversal of the appraising of past trends. In studying the past, the actual trends are evident and the task is to explain the causal relationships. In looking forward, on the other hand, it is necessary to begin with an estimate of the causal influences that are expected to operate, to weigh and balance them, and then to attempt to arrive at an estimate of the forward trend. The more that is known about the past behavior of the causal factors, the more confidence can be placed in estimates of their future performance.

In the case of some commodities careful statistical studies of production responses to price and other factors in past periods can furnish a useful basis for estimating future responses. In the case of others, the projection of trends that have been going on steadily for some time may be a fairly simple and safe procedure. In still others, some form of the method of budget estimates has been used with fruitful results. But in the case of soybeans the historical record is so recent and so dynamic as to make any of these methods of doubtful value, if used alone. This means that a larger element of careful judgment is necessary in carrying forward an interpretation of past responses and it means also that special attention must be given to new factors which may be expected to appear.

Alternative Price Relationships

Analysis of the wartime expansion, for example, indicates clearly that soybean production does respond to changes in relationships between prices. Future changes in relative price relationships will affect the acreage and production of soybeans, and competing crops, and different relative prices will have different effects. In order to separate the problem of response to price from that of responses to cost factors, the procedure used in this analysis makes separate estimates for each of three alternative sets of relative prices. The three sets of relative prices were expressed as ratios between the average United States farm prices of soybeans and corn. The ratios were 2.0, 1.6, and 1.2. The middle ratio represents a price situation slightly better than prewar but below the average relationship of the war years. The upper and lower ratios represent a range between which relative prices might stay for some length of time under very favorable or very unfavorable conditions during the next decade.

In using each of the alternative price assumptions, any variations in the future demand situation are held in abeyance for the time being, while attention is centered mainly on the production and cost factors that are likely to affect the comparative advantage of soybeans. With each price assumption, however, some initial attention has to be given to how this situation compares with historical price relationships. The middle ratio of 1.6, as just pointed out, will be intermediate between prewar and wartime. If we could assume that the war and postwar acreages of soybeans and other crops had reached an approximate balance, some decrease in acreage would be expected to result from the lower relative price situation, other factors remaining the same. Similarly, with a ratio of 2.0 one would expect an increase over wartime levels of acreage. But the assumption that wartime and recent acreages were in balance from any long-run point of view is open to serious question. Consequently, some consideration must first be given to this problem.

Balancing Permanent Cropping Systems

Agronomists believe that even on level lands of high productivity a certain balance between intertilled crops, close-growing crops, and sod crops will be necessary over any length of time if a profitable permanent farming system is to be maintained. This balance will be different on different kinds of soils, with different types of farming, with different crop combinations, and with differences in general management. Differences in the structure of prices will probably also affect the balance. But there seems to be almost universal agreement that wartime emergency cropping resulted in extending the proportion of intertilled crops considerably beyond the long-time margin of safety. For a few years there is sufficient flexibility to carry a highly depleting crop program successfully on an emergency basis, but over a longer period the yields will probably decline unless more grass is included in the cropping pattern. The increased use of commercial fertilizer and manure, the better handling of crop residues, the use of cover crops, contouring, and other practices, will greatly help in soil maintenance—but still the problem of balance will remain. The more obvious instances of overcropping have occurred on sloping lands and in many areas of this kind the farmers have quickly recognized the problem. But even in the areas of level land it has become a serious situation on some farms.

Another phase of the whole question of balanced cropping has been brought to the fore by the development of higher yielding strains of nearly all crops. The higher yields of hybrid corn, of improved varieties of oats, of soybeans, and even of legume hays, represent a much greater draft on the fertility of soil than was made only a few years ago. Unless increased use of fertilizers or other practices are sufficient to offset the depleting effect of higher yields still more attention must be given to limiting the intertilled acreage to a safer level.

Various estimates of the desirable level of intertilled acreage that have been made for the Corn Belt involve reductions from wartime levels varying from about 7 million acres to about 13 million acres (*41, 44*). It seems evident that the probable adjustment is likely to be closer to the lower estimate. On a reduced acreage the competition will be very keen between soybeans, corn, and other intertilled crops. It should be pointed out in passing that with soybeans in the picture, the proportion of intertilled crops can be somewhat higher than would have been the case if the crop had not come into the Corn Belt, because it has favorable effects on the soil and on following crops, at least under conditions of level land. On sloping lands it is possible that soybeans have made the situation worse in this respect.

Relative Trends in Production Costs

After the problems of prices and unbalanced emergency cropping systems, the other major question affecting trends in soybean acreage and production in the period ahead is the matter of relative changes in production efficiency. This question has been partially covered in the earlier discussion of past trends. From that consideration it appears that an upward trend in soybean yields greater than for competing crops may be the most influential factor in the relative production costs. Work on variety improvement is expected to benefit a number of crops materially, but for the next decade the effects promise more for soybeans. In the case of some of the competing crops, a large part of the breeding and variety-improvement work is pointed toward resistance to disease. This is true of oats, for example, in which the struggle between the plant breeders and smuts, rusts, and other diseases seems to be unending. If soybeans should develop some serious diseases, this might greatly change the outlook on the variety-improvement front. So far, this does not appear to be likely in the next decade. Brown-stem rot, the most serious soybean disease found in the Corn Belt, seems to be effectively controlled by a 4-year rotation. This and other diseases that represent potential threats are being studied in an intensified program of disease research (*1*).

The development of more balanced cropping systems may contribute to a relatively stronger position for soybean yields, because the crop seems to respond well to a higher level of maintained soil fertility. An offsetting factor may be the increasing use of commercial fertilizers throughout the Corn Belt. Soybeans do not respond as much, immediately, to the application of fertilizer as do other crops. They will benefit, but at a later stage in the cropping sequence. Consequently, the fertilizers will usually be applied to other crops which will therefore gain more from the increase in this practice.

Prospective changes in farm machinery, equipment, and associated labor practices do not seem likely to benefit one crop much more than another with respect to lowering the costs.

These are some of the general considerations on the side of production costs which may affect future trends. To translate them into concrete estimates requires a more specific approach. A detailed procedure was therefore developed to utilize the judgments of a number of people in arriving at estimates for various segments of the problem.

Supply Estimates

The detailed estimating procedure that was adopted, first attempted to make use of the combined judgments of State experiment station committees, and second, to approach the over-all estimates on the basis of an area-by-area approach. The most complete estimates were developed for the two leading soybean States—Illinois and Iowa. The estimates for other States in the Corn Belt and in other regions were developed in a similar way on the basis of earlier analyses in the production-adjustment studies and with the use of supplementary materials.

In each State the materials collected in the several years of work on the production-capacity and production-adjustment studies were drawn on heavily (*41*). The usefulness of these materials lay partly in the fact that actual estimates of soybean acreage and production had been made under specified assumptions, particularly in the bench-mark study (*41*) and in the background information and data that had been collected.

The State experiment station committees in Iowa and Illinois consisted of technical specialists and economists who carefully reviewed preliminary estimates prepared by those working intensively on the project, and then made suggestions for revision. The estimates finally reached are the responsibility of the author but the assistance rendered by the State committees was invaluable. Separate estimates were prepared for each type-of-farming area in Iowa and Illinois and were combined to make the State estimates. For each type-of-farming area, historical data were examined and account was taken of the physical characteristics of the area, in estimating profitable future adjustments. The over-all trends in variety improvement and in other factors affecting yields and the interrelationships of competing crops were separately considered for each area in the light of its characteristics.

The forward trends estimated for different type-of-farming areas varied considerably. Some of the most obvious differences were related to the expected changes in areas of sloping land in which the emergency expansion in acreage had gone too far. Differences related to type of farming, particularly as between livestock and cash-grain areas, were particularly noticeable. In the livestock areas a larger proportion of the cropland was required for feed crops. Soil differences affected the results appreciably in areas in which claypan soils predominated, as in southern Illinois and Indiana and in northeastern Missouri. In these areas it has been found that soybeans do especially well as compared with other crops.

In Illinois and Iowa, farm cost-accounting records extending back some years on farms that grew soybeans were helpful. To obtain additional information for this analysis, some special work was undertaken with groups of farmers in four counties in each of these two States. The counties were selected to represent important type-of-farming situations in which postwar adjustment of soybeans might be expected to be different. In each county a group of representative farmers met with the economists working on the project; after examining historical data for the county and typical farm budgets, the group tried to estimate the probable shifts in soybean production for each of the assumed price situations. Their reasons for making each set of estimates were carefully recorded and used in evaluating the results (*15*).

In addition to this special work in eight counties a mailed inquiry was sent to a considerable list of soybean growers in Iowa and Illinois; returns were received from about 180 growers. Some of the questions in this inquiry covered growers' reactions to soybeans and their general intentions with respect to long-run acreages under specified price assumptions. All of this information was used in preparing the estimates by type-of-farming areas, which were reviewed by the State committees and were then revised in accordance with their suggestions.

ILLINOIS AND IOWA ESTIMATES.—Estimates of soybean acreage, yield, and production for Iowa and Illinois resulting from this process are shown in table 11. It should be noted that the estimates were made separately for acreage and yield, and the production data represent simply the product of acreage and yield. The 1955 estimates for the 1.6 ratio indicate somewhat more recession from emergency levels for Iowa than for Illinois, as might be expected considering the differences in average type of farming between the two States. The percentage changes as between the higher and lower price ratios are also different. The elasticity of supply in Iowa both for high and low prices appears to be greater than in Illinois. The low price ratio of 1.2, for example, resulted in 50-percent reduction from the estimated level for the 1.6

ratio in Iowa, compared with only 25-percent reduction in Illinois. The higher ratio of 2.0 was associated with approximately a 25-percent increase in Iowa and about a 12.5-percent increase in Illinois.

TABLE 11.—*Acreage, yield, and production of soybeans harvested for beans, Illinois and Iowa, averages 1935–39, 1942–45, and estimated 1955 at alternative price ratios* [1]

Item	Unit	1935–39	1942–45	1955 price ratios [2]		
				2.0	1.6	1.2
Illinois:						
Acres	1,000	1,493	3,476	2,700	2,400	1,800
Yield	Bushels	20.5	20.8	25.0	25.0	25.0
Production	1,000 bushels	31,099	72,408	67,500	60,000	45,000
Iowa:						
Acres	1,000	338	1,878	1,500	1,200	600
Yield	Bushels	18.1	19.4	24.0	24.0	24.0
Production	1,000 bushels	6,320	36,521	36,000	28,800	14,400

[1] The estimates for 1955 are not forecasts.
[2] Ratio of price of soybeans to price of corn.

ESTIMATES FOR THE CORN BELT AND OTHER REGIONS.—An extension of the estimates for Iowa and Illinois to the rest of the Corn Belt and the development of estimates for the other producing regions were undertaken on the basis of less detailed work but with the same general principles in mind. The resulting estimates of acreage are shown in table 12, and those of yields and production in tables 21 and 22. (They are not forecasts.)

TABLE 12.—*Acreage of soybeans harvested for beans, United States and specified groups of States, averages, 1935–39, 1942–45, and estimated, 1955, at alternative price ratios* [1]

Group [2]	Average, 1935–39	Average, 1942–45	1955 price ratios [3]		
			2.0	1.6	1.2
	1,000 acres	*1,000 acres*	*1,000 acres*	*1,000 acres*	*1,000 acres*
Corn Belt	2,604	8,502	6,750	5,700	3,875
Lake States	44	479	665	480	302
Plains States	7	275	285	215	133
Delta States	97	384	410	320	195
Atlantic States	209	397	365	310	185
All other States	81	259	225	175	110
United States	3,042	10,296	8,700	7,200	4,800

[1] The estimates for 1955 are not forecasts.
[2] For States included in each group, see table 1.
[3] Ratio of price of soybeans to price of corn.

Within the North Central States developments in the past year or so have been especially notable in Minnesota and Missouri and in western fringe areas where the percentage upward trend has been greater than in the central Corn Belt. These developments have occurred partly as a result of the development of varieties adapted for these areas and partly as a result of the more recent recognition of the place of soybeans in the crop economy. Some further progress is expected in the development of varieties for these areas and this will probably place soybeans in a relatively stronger position.

Although the acreage for processing is a very small part of the total production in regions outside of the North Central States, some special factors are of interest in each of the other regions. In the Delta, for example, mechanization of cotton production may cause some increase in soybean acreage in the new cropping systems that will develop. In the old producing region along the Atlantic coast it does not appear that much increase in soybean acreage will take place because of the relatively strong competition from vegetable crops and dairy and poultry production. Throughout the other States in the South and in the Northeast the place of soybean production for beans seems to be very small, although some progress may be made in developing better varieties for these conditions. If the acreage of hay and forage varieties is extended in these areas it will call for an increased production of soybeans for seed rather than for processing.

UNITED STATES SUMMARY.—In summarizing the total picture of soybean acreage and production in the United States it appears that major interest will continue to center on the Corn Belt. The estimated acreages for the United States under the three alternative price assumptions are 8.7, 7.2, and 4.8 million acres, with corresponding production varying from 191 to 107 million bushels (table 13). As compared with wartime and emergency levels the above estimates represent some reduction, but most of the adjustment would occur on farms on which too high a proportion of the cropland has been kept in intertilled crops. At the intermediate and higher price level there would actually be some increase on the most favorably situated farms.

TABLE 13.—*Acreage, yield, and production of soybeans harvested for beans, United States, averages 1935–39, 1942–45, annual 1946–47, and estimated, 1955, at alternative price ratios* [1]

Item	Acres	Yield	Production
	1,000 acres	*Bushels*	*Million bushels*
Average:			
1935–39	3, 042	18. 1	56
1942–45	10, 296	18. 5	190
1946	9, 806	20. 5	201
1947 [2]	11, 125	16. 3	181
1955—price ratio: [3]			
2.0	8, 700	22. 0	191
1.6	7, 200	22. 1	159
1.2	4, 800	22. 2	107

[1] The estimates for 1955 are not forecasts.
[2] Preliminary.
[3] Ratio of price of soybeans to price of corn.

In arriving at these estimates it was assumed that conservation practices will be emphasized to a greater extent in the next few years than they were during the war. It was also estimated that farmers will follow practices that will maintain soil productivity at a level profitable from the long-run standpoint. In the absence of favorable circumstances for wider adoption of such practices, the acreage of intertilled crops may not be reduced as much as has been estimated. This would also mean that these estimates of soybean acreage would be somewhat too low. In some of the newer areas in which the crop has shown good performance in recent years, the acreage may remain at higher levels than estimated if experience continues to be favorable.

The estimates just reviewed are not forecasts, they are "conditional" estimates. It is probable that the actual adoption of conservation practices by 1955 will be less than has been assumed here. With smaller acreages of small-grain and sod crops than are implied, acreage of soybeans may easily be larger than estimated above.

The interpretation placed on the alternative price assumptions by technicians and others working on the estimates may also have resulted in underestimating the acreage of soybeans that would be associated with a given price ratio. During the war, the soybean-corn price ratio averaged about 1.7, as compared with 1.4 in 1935–39. Yet the prevailing opinion was that a ratio of 2.0 would be required to maintain the wartime level of acreage. Experience since the end of the war suggests that a ratio somewhat lower than 2.0 would maintain soybean acreage not far below the wartime level. Consequently, price ratios about 10 percent lower than the 2.0, 1.6, and 1.2 alternatives may be enough to bring forth the estimated acreages with the conservation practices assumed for long-run maintenance of soil fertility.

LONG-TIME DEMAND AND MARKET OUTLOOK

In estimating the long-time demand outlook for soybeans the historical record of utilization is first examined (table 18). In the early years of the record, seed and feed were the principal uses for the soybean crop. The year 1931 was the first time that processing took more bushels than seed. The situation in the early years resulted not only from the lack of processing demand but also because the acreage grown for hay, grazing, and plowing under, constituted a large part of the total soybean acreage. The seed demand for this acreage was therefore relatively important. Feed uses were also important, partly because, with the available processing methods, soybean meal did not have the technical feeding advantage over the whole beans that has since developed. Seed and feed uses have increased over the years, but processing has now become by far the most important outlet for the crop, particularly for the part that is sold and enters commercial channels.

It is clear that an appraisal of the future outlook should be in terms of the market outlets and demand for processed soybean products—soybean oil and soybean meal. These are joint products, in the sense that they are produced together in constant physical proportions. It is true that historically the percentage of oil yield has increased moderately as processing methods have been improved, and some further increase in oil yield will be obtained as a larger proportion of the crop is handled by the more efficient solvent processes. Some variation occurs from year to year with fluctuations in weather and yields. There is also the possibility of some increase in oil content resulting from improvements in breeding for higher oil content. But in the main the joint physical proportions are constant.

A unique technical circumstance about the physical proportions of oil and meal in soybeans as contrasted with other oil crops should be noted. That is, that the ratio of meal to oil is much greater than in the other major oil seeds. Soybeans produce nearly twice as much meal per pound of oil as cottonseed and about three times as much as flaxseed. With the usual relative prices of meal and oil, the values of soybean meal and soybean oil from each bushel of soybeans have been roughly equivalent. In the other oil crops the meal has been a byproduct, making up a minor part of the total value.

About as much attention therefore must be given to the future outlook for soybean-oil meal as for soybean oil when sizing up the total demand situation. Which will be more important in the period ahead will depend, of course, on the relative strength of the various demand factors on either side.

For both oil and meal attention must be directed first to the general factors affecting the total demand for fats and oils on the one hand and the total demand for high-protein feeds on the other. Equally important may be the special factors affecting the demand for soybean oil and soybean meal within the general demand framework. The latter includes a consideration of the supply outlook for competing fats and oils and for competing high-protein feeds. Even though the general demand situation might indicate little change, a decrease or increase in the supplies of competing products might greatly change the demand for soybean products.

Another set of factors influencing demand and market outlets for soybean products may be the progress in technology which will improve the qualities of or lower the costs of processing soybean oil or soybean meal (*36*).

Market Outlets for Fats and Oils

Estimates of the over-all outlet for fats and oils in the United States have been made on the basis of relative prosperity and sustained employment (*12*). The total comes to about 12 billion pounds of fats and oils for 1955.[6] Before the war about two-thirds of the disappearance of fats and oils in the United States was for food uses and one-third for nonfood purposes. The 1955 estimate assumes about the same per capita food consumption of fats and oils as in 1935–39. Long-run dietary factors do not suggest much, if any, increase in per capita use of visible food fats. People will tend to consume more invisible fat in whole-milk products, meats, eggs, and the like, than before the war and will not care to consume a larger quantity in the "visible" form.

The nonfood uses for fats and oils include soaps, paints and varnishes, linoleum, printing ink, and a host of industrial uses. The per capita use for these products is expected to expand in good times. There will be some offsetting circumstances like further development of synthetic detergents and soap substitutes, synthetic resins, and other

[6] Assuming a total United States population of 150 million.

materials, but these are not expected to change greatly the tendency toward increased per capita use of fats and oils for nonfood purposes.

The historical trends since 1924 in the production of soybean oil and other vegetable oils from domestic materials are indicated in figure 10. The rising place of soybean oil in the vegetable-oil total since 1930, and especially since 1937, is striking. The total of the other

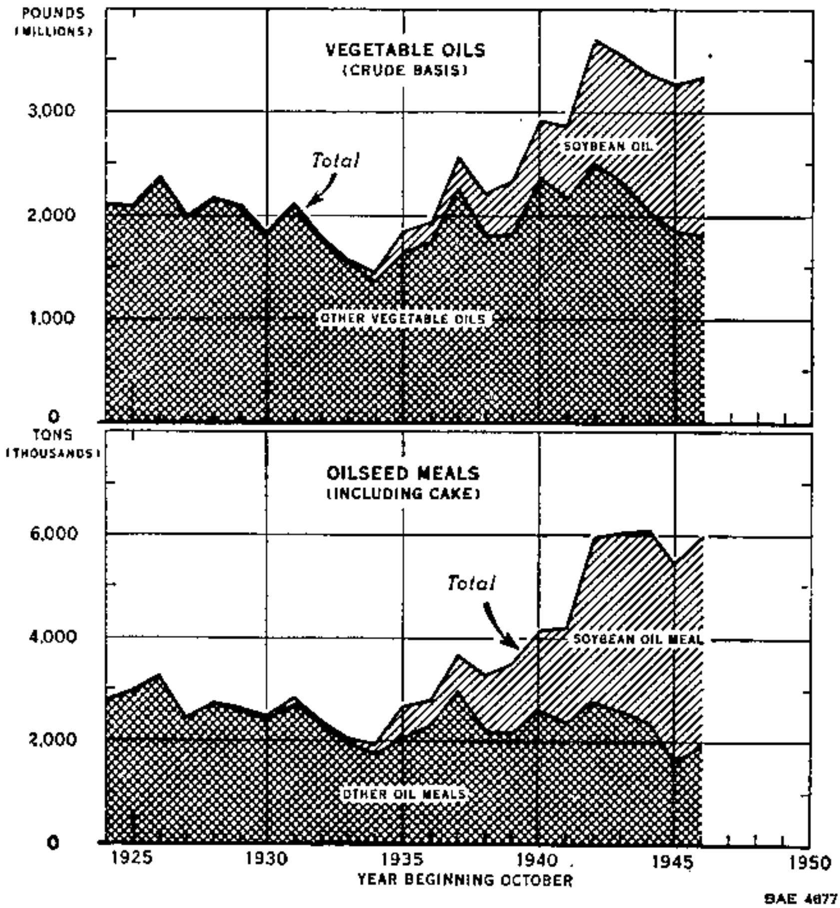

FIGURE 10.—Production of vegetable oils and oilseed meals from soybeans and other oil crops, domestic materials only, United States, 1924–46.

vegetable oils has declined somewhat over the whole period; soybean oil has not only offset this decline but has provided a very substantial increase in the total output of vegetable oil.

Changes in the production of individual fats and oils during recent years, compared with the average for 1935–39, show shifts in the outputs of animal fats as well as in vegetable oils (table 14). Butter production has been reduced because of the increased outlet for whole-milk products of higher value. The other animal fats, with the exception of marine oils, rose considerably with the increased level of livestock production during the war.

Among the vegetable oils, linseed oil showed the greatest increase after soybean oil, and although small absolutely, the percentage increases in corn oil and peanut oil were high.

TABLE 14.—*Fats and oils produced from domestic materials, and net trade, United States, average 1935–39 and annual 1943–46*

Item	Year beginning October [1]				
	Average, 1935-39 [2]	1943	1944	1945	1946
	Million pounds	*Million pounds*	*Million pounds*	*Million pounds*	*Million pounds*
Butter (actual weight)	2, 178	1, 843	1, 751	1, 453	1, 678
Lard	1, 770	3, 267	2, 118	2, 107	2, 399
Tallow, grease, and other [2]	1, 216	2, 179	1, 990	1, 877	2, 073
Marine oils	262	167	220	175	129
Total animal	5, 426	7, 456	6, 079	5, 612	6, 279
Cottonseed oil	1, 437	1, 179	1, 303	1, 002	1, 011
Soybean oil	324	1, 219	1, 347	1, 415	1, 531
Linseed oil	207	802	416	563	406
Corn oil	138	214	217	183	250
Peanut oil	66	135	89	99	138
Olive oil, edible	4	6	4	2	2
Tung oil	1	2	10	11	13
Total vegetable	2, 177	3, 557	3, 386	3, 275	3, 351
Total production	7, 603	11, 013	9, 465	8, 887	9, 630
Net imports [3]	1, 687				477
Net exports [3]		657	140	57	
Total production and net trade	9, 290	10, 356	9, 325	8, 830	10, 107

[1] Except as noted for imports and exports.
[2] Includes neat's foot oil, wool grease, and very small quantities of unclassified vegetable oils.
[3] Data for calendar years beginning in the marketing year indicated. Imports include oil equivalent of imported materials, principally flaxseed and copra. Exports do not include oil equivalent of oilseeds exported.

The production prospects for about 1955, for each of the fats and oils, have been examined in the report referred to earlier on the basis of general assumptions involving normally full employment and prosperous business conditions in the United States and comparable conditions abroad (*12*). These estimates indicate a total domestic production for fats and oils other than soybeans of about 10 billion pounds. Assuming an import of a little less than a billion pounds of oil equivalent, this leaves an estimated market outlet of about 1.2 billion pounds for soybean oil. The total estimate involved some increase in animal fats and some reduction in vegetable oils from wartime levels. Some increase is expected in livestock fats from a sustained high level of cattle and hog production.

Turning to the vegetable oils, cottonseed oil is tied to the production of cotton fiber. Future production may be higher than some of the recent emergency years but is not likely to rise above the prewar level of output. The output of linseed oil is likely to remain at higher than prewar levels, although lower than wartime peaks. Similar statements can be made for peanut oil and corn oil.

World Trends in Fats and Oils.—World production and trade in fats and oils was affected more by conditions arising in World War II than in any previous conflict. The great destruction of livestock and the slow recovery of livestock numbers have resulted in a great shortage of domestic fats in many European countries. Whaling practically ceased during the war. The coconut- and palm-oil-producing areas of the Philippines and the Dutch East Indies and the soybean areas of Manchuria were cut off from the western nations.

Recovery after the war has taken longer than had been anticipated and the increased livestock and soybean output in the United States has been badly needed. Whaling is being resumed, however, Philippine copra production has increased rapidly since the war, and world livestock numbers will soon increase. Moreover, extensive new plantings of the oil palm and of peanuts in tropical Africa promise to swell supplies within a few years.

Estimates of the world production of fats and oils in 1955, under favorable conditions, run in terms of one-fourth to one-third higher than 1935–39, with world net exports perhaps 20 percent greater (*12*, p. 15). This may easily mean that the United States may have a net import of a billion pounds or more of oil equivalent mainly from coconuts, palm oil, and flaxseed or linseed oil.

Role of Technology

Chemical technology in the processing of fats and oils is more significant than in the case of most agricultural products. There is a long history of advancing knowledge in this field and new developments are constantly occurring over a wide front. These affect the utilization of fats and oils for food, soap, paints, and scores of industrial uses. Some changes in technology tend to widen the market by opening entirely new uses, and others by increasing the range of substitution between different fats and oils.

Soybean oil has benefited from technology both from the general widening of the market and from developments that have increased its range of substitution. These changes do not appear to be reflected in much more favorable prices for soybean oil (table 23). But this does not mean that there has been no relative effect on prices. During the recent period the expansion of the output of soybean oil has been so great as to mask what would otherwise have appeared as a change in relative prices. Changes in technology that are still in the initial steps are likely to have even greater influence in the years to come.

Hydrogenation was the outstanding development among several associated advances during the last generation. This is a process for hardening liquid oils into solid fats by the addition of hydrogen to the unsaturated fatty acids.

Along with hydrogenation there were other substantial advances in the technology of processing fats and oils and in preparing them for use in the food industries. Similarly in the nonfood and industrial fields a continued stream of new technology has greatly modified the production of soaps, paints, and other industrial products. In Germany, synthetic fats have been developed from coal and considerable quantities were manufactured during the war because of a shortage of natural fats.

Recent research in this country has resulted in several processes for producing high-quality drying oils and for improving food fats and oils by preventing the development of undesirable flavors. A dehydrating process applied to castor oil made it possible to use this oil in the drying industries during the war. The development of suitable antioxidants for lard now makes possible the production of bland shortenings from animal fats. Initial commercial success with this process indicates that it may be a notable further step affecting the interchangeability of fats.

Enormous expansion in the production of soybeans in the United States has directed much attention to the processing methods for soybean oil. In its characteristics soybean oil may be said to be rather intermediate between food oils and drying oils. Hence research efforts have been devoted to improving its qualities in both fields. Lack of stability in flavor has been one of the chief difficulties in using this oil in food preparations but definite progress has been made in overcoming this problem. The wartime findings of German chemists recently made available have been helpful. Several current research projects at the Northern Regional Research Laboratory of the United States Department of Agriculture, as well as similar projects in industrial concerns, are vigorously pursuing the search for a more effective and efficient method of eliminating or preventing the development of objectionable flavors (*36*, *33*).

One of the most promising new processes is "fractionation." By this is meant the physical separation of an oil into two or more fractions or segments, each differing in chemical structure. In the case of soybean oil one fraction would be a superior food oil and the other a better drying oil. Pioneering research in this direction has been carried out by the Northern Regional Research Laboratory and by several industrial laboratories. A few commercial concerns have been building fractionation plants and at least one has had such a plant in operation for several years.

Other processes for separating soybean and other oils have been studied and have been used with some success. They include fractional distillation, crystallization, selective adsorption, and molecular distillation. Distillation procedures are at present the most important of the fractionation processes and are used commercially by several companies. With improvements likely to follow, fractionation may become as striking a landmark in the history of the technology in fats and oils as hydrogenation. Like hydrogenation, it operates to increase the range of substitution possible between different fats and oils.

Development of fatty derivatives for industrial use is another field of current chemical research that holds promise. The fatty acids that are found in the vegetable oils are a noteworthy source of raw materials for manufacturing detergents, emulsifiers, resins, plasticizers, synthetic drying oils, and many other products.

Several new products derived from soybean oil were produced commercially during the war. One of these, a rubber substitute, Norepol, was produced on a large scale for a short time and was satisfactory under commercial conditions. Another material, Norelac, a type of resin, was developed for use in protective coatings and for coating papers to make them waterproof; it is now marketed commercially.

MARKET OUTLETS FOR HIGH-PROTEIN FEEDS

The over-all market outlet for soybean oil meal and the products with which it competes is mainly that for high-protein feeds. Small quantities of soybean meal are used for human food, and some go for industrial purposes, but probably more than 90 percent of the total disappearance is for use as animal feed. The food and other uses may increase but the basic situation is not likely to change enough during the next decade to greatly influence average prices of soybean meal.

The high-protein feeds have experienced a remarkable expansion in recent years (table 15). The picture for the oil meals, which now make up nearly two-thirds of the total tonnage of high-protein feeds, is shown in figure 10 which brings out the striking fact that soybean meal has contributed most to the upward trend.

TABLE 15.—*High-protein feeds produced from domestic materials, and net trade, United States, average 1935–39, annual 1943–46*

Item	Year beginning October				
	Average, 1935–39	1943	1944	1945	1946 [1]
	1,000 tons	*1,000 tons*	*1,000 tons*	*1,000 tons*	*1,000 tons*
Oilseed cake and meal:					
Soybean	849	3,446	3,698	3,837	4,085
Cottonseed	2,088	1,749	1,916	1,410	1,428
Linseed	187	744	375	484	369
Peanut	49	109	92	80	113
Total	3,173	6,048	6,081	5,811	5,995
Gluten feed and meal	565	842	864	776	997
Animal proteins [2]	2,800	2,740	2,582	2,447	2,456
Total production	6,538	9,630	9,527	9,034	9,448
Net imports [3]	339	432	206	215	200
Total production and net trade	6,877	10,062	9,733	9,249	9,648

[1] Preliminary.

[2] Includes tankage and meat scraps, fish cake and meal, dried-milk products, and dry equivalent of skim milk, buttermilk, whey, and whole milk estimated fed on farms. Data for 1935–39 are estimates.

[3] Includes oil-meal equivalent of imported flaxseed and copra as well as direct imports of high-protein feeds. Export data used do not include oil-meal equivalent of oil-seeds exported.

Several factors have been responsible for an increased demand for high-protein feeds. Studies of the nutritional requirements of farm animals and comparisons with actual rations have shown that in the aggregate not enough protein is being fed in the United States (*16*). More livestock producers have come to appreciate this situation and, with the favorable price conditions of recent years, have fed better balanced rations. The higher level of livestock production has also increased the total use of protein feeds.

For high-protein feeds, as for fats and oils, a prosperous economy and a sustained high level of employment are necessary conditions for a strong demand and price situation. In some respects, an economic recession might have worse effects on the demand for livestock products and high-protein feeds than on the demand for fats and oils. If livestock prices drop, farmers will use less protein feed and will rely more on home-produced rations.

The rapid growth of the mixed-feed industry before the war and during the last few years has been another stimulant in the demand for oil meals. The manufacturers of mixed feeds find it profitable to utilize high-protein feeds in their prepared rations. The long-run trends in livestock production seem to involve relatively greater increases in dairy and poultry, which tend to use more commercially prepared rations than do other classes of livestock.

Feeding experience has shown that greater proportions of soybean meal than of the other common vegetable-oil meals can be used successfully in extending animal-protein supplements for poultry and hogs.

Other competing sources of protein include high-protein hay and pasture, and synthetic proteins. Conservation programs may stimulate grassland agriculture, and this could result in some substitution for purchased concentrates. The evidence so far, however, seems to indicate that improved roughage feeding is accompanied by improved concentrate feeding and higher production per head, so in general there is more rather than less demand for commercial protein feeds.

Urea is a new source of protein that has some usefulness for cattle. This nitrogenous substance is not a nutrient, but it can be used in making protein by bacteria that live in the digestive tract of cud-chewing animals, if fed in limited quantities with low-protein feeds.

Soybean meal must also compete with the other oilseed meals. The average production for 1935-39 and for recent years shows the major place of soybean meal in the present total (fig. 10 and table 15). Linseed-meal output from domestic flaxseed does not seem likely to expand greatly and production from imported flaxseed will probably be less because Argentine plants may process more flaxseed at home in order to retain the linseed meal for the Argentine cattle feeders. The volume of peanut meal does not seem likely to become very large. Cottonseed meal, which is next after soybean meal in volume, is not likely to exceed prewar levels. Consequently, soybean meal is in a favorable competitive position so far as the other high-protein oil meals are concerned.

Food Uses of Oil Meals.—Several of the oil meals have future possibilities for expansion in the field of direct food use. Small quantities of peanut flour and cottonseed flour have been successfully prepared and utilized. But the main commercial possibility seems to lie in the expanded use of soya flour and grits. The important nutritional values present in soybean meal make these products especially useful in improving diets at relatively low cost. Soya flour is not a substitute for wheat flour, but is used as a supplement in the enrichment of baking products and other foods. It has also become widely used as an ingredient in the manufacture of candy.

As processing methods improve the palatability of soya flour, some increase in consumption will result. Recent research with the alcohol-extraction process, for example, shows that a highly palatable flour can be produced. Should this method prove economical in large-scale operation, soya flour will probably become increasingly popular.

Just before the war less than 1 percent of the production of soybeans was used in making soya flour but in 1943 the quantity produced had risen to 3 percent of the total crop. A large proportion of this output was bought by the Government for lend-lease and foreign relief. Soya grits were promoted during the war chiefly as a meat extender and soya flour as a fortifier of cereal products (*38*).

Industrial Uses of Oil Meals.—Industrial uses of the oil meals are varied and have promise for the future. At present, they account for only a small proportion, probably less than 5 percent, of the total use of all oil meals. The use of oil meals in commercial fertilizer provided one prewar outlet that will probably be available again. Oil meals are also used to make protective coatings, cold-water paints, synthetic fibers, plastics, adhesives, and other products. In some of these products soybean meal, especially, has pioneered.

The future of plastics made from oil meal has attracted much attention. The vision of a "plastic civilization" is intriguing, but unreal. Some of the early success with soybean plastics has not been followed up, and it must be recognized that competition with other materials is especially keen in the plastic industries.

The basic raw materials for most plastics are derived from coal tar, petroleum, and alcohol. The oil meals have served mainly as extenders when they have been used. The most recent chemical developments in plastics seem to involve the manufacture of new synthetic raw materials with special properties ranging all the way from the older types of synthetic resins to the new synthetic rubbers. With research and development taking this direction it is not clear how far the oil meals will share in the probable expansion in plastic production.

Possibly more important than plastics, at least in supplying an outlet for soybean-oil meal, is the use of this meal in plywood adhesives. Plywood bonded with soybean adhesives is considered water resistant but not waterproof. Recent research indicates that water resistance is increased by removing the protein from the oil meal. During the war, the plywood industry was required to produce large quantities of waterproof plywood for the aircraft industry. Phenolic resins were used. Research at the Northern Regional Research Laboratory developed a method of using soybean meal as an extender in the phenolic resins. This development helped to extend supplies of phenolic resins for adhesives during the closing phases of the war when they were critically short.

Summary of Market Outlets.—From the preceding discussion, it appears probable that the long-time market outlet may be somewhat stronger for soybean-oil meal than for soybean oil. The demand for both depends on prosperity and maintaining a high level of living in the United States. Foreign competition may bear more heavily on fats and oils than on oil meals, and soybean oil is more vulnerable for this reason. Oil meals are bulkier and more expensive to ship, and they enter international trade to a lesser extent. On the other hand, improvements in processing technology may strengthen the place of soybean oil among the domestic oils, more than will be the case for soybean meal.

COMPARISON OF PROSPECTIVE SUPPLY AND DEMAND

The ultimate place of soybeans in the American farm economy will be the equilibrium position resulting from a balancing of the supply and demand forces that have here been examined. As we have seen, this equilibrium position in the past has been a changing dynamic affair which would have been very difficult to forecast with any degree of accuracy. Some of the supply changes, notably progress in variety improvement and in mechanization of harvesting operations, were key factors. The wartime demand and price situation was also a very important factor.

From the long-run view it must be recognized that soybeans have a more flexible supply position than do other oil crops. This is true whether oils or oil meals are considered. The competing fats and oils come from products or sources that are inherently more inflexible in supply. Many of them are products in which fats or oils are by-products. Somewhat the same statement can be made for the oil meals and for the competing high-protein feeds. In consequence, changes in the demand for fats and oils or for high-protein feeds, whether favorable or unfavorable, will bear more heavily on soybeans. The position of soybeans in the cropping systems of the Corn Belt also happens to favor flexibility in response to shifts in relative price conditions.

After both the supply and the demand outlook for soybeans are appraised, the conclusion seems evident that changes in demand and market outlets may be more significant than changes in the basic cost and supply forces affecting soybeans over the next decade. Under the over-all assumptions, a soybean-corn price ratio in the neighborhood of 1.6 seems not unlikely. This would be a lower-price ratio than the one that has prevailed in recent years and would be associated with a harvested acreage of about 7.2 million acres and a production of 160 million bushels, by about 1955. This equilibrium position would assume that enough time had elapsed to bring about a stable adjustment between costs and prices and that the cropping system as a whole had become adjusted to a profitable long-run basis, with a proper balance between intertilled, close-growing, and sod crops.

None of the forward estimates made in this study are to be considered as forecasts. The reader is cautioned again to remember that the estimates are made on the basis of certain assumptions including considerable attention to the adoption of conservation practices that had been estimated to be necessary for profitable farming over the long run. There is some difference of opinion even among technicians as to the safe proportion of intertilled crops in the total crop acreage and of the place of soybeans among the intertilled crops on different soils. Moreover, farmers may not adopt conservation practices so rapidly as has been estimated. In other instances they may adopt practices that will involve a higher acreage of soybeans.

Those who are inclined to forecast can therefore find grounds for estimating a higher acreage and production of soybeans than indicated by these estimates. On an emergency basis, and for short periods, a considerably higher acreage of soybeans and other intertilled crops could be grown.

SUMMARY

Soybeans have become an important crop in the United States only within the last 20 years, although they were grown in China in ancient times and were introduced here many years ago. They were first grown in this country as a forage and green-manure crop, but the recent rapid increase has been almost entirely for beans for processing. The wartime expansion tripled the acreage of soybeans harvested for beans.

The three main soybean regions in the United States are the Corn Belt, the Mississippi Delta, and the Atlantic Coast States. The Corn Belt has by far the heaviest concentration, but the other two regions are noteworthy .

The explanation for the rapid rise of soybean production lies partly in the dynamic changes in the technology of production, processing, and marketing, and partly in the development of more favorable demand and price relationships during the war.

Regional and national trends in the production of soybeans appear to have been limited by climate, topography, and soils.

However, soybeans can be grown under a wider range of climatic conditions than many crops, provided adapted varieties are available. The first great contribution of the plant scientists was to select and breed the adapted varieties.

Topography and the danger of soil erosion appear to constitute the factors that limit most the location of soybean acreage. For this reason soybeans for beans are concentrated on areas of level land.

On level lands, soybeans have a beneficial effect on the soil and on succeeding crops. This is partly due to the physical effect on the soil and partly to nitrogen fixation.

Intercrop competition is complex but soybeans compete with all the crops in the cropping system rather than with one or two. For the whole period 1924–47, the expansion in soybeans in the Corn Belt seems to have been offset by a contraction in small grains and, to a lesser extent, in corn. For the war period alone most of the increase came from idle land and rotation pasture; some came from small grains and hay.

Yields of soybeans have almost doubled since 1924 mainly because of improved varieties and reduced harvesting losses and in spite of the tremendous expansion in acreage.

The introduction of small combines for harvesting soybeans removed the chief bottleneck to soybean production under American conditions and simultaneously reduced the labor involved and increased the harvested yields.

During the period of rapid mechanization net returns per acre probably rose more rapidly from soybeans than from other crops.

Most of this occurred before the wartime expansion, however. During the war returns per acre increased relatively more from soybeans than from corn, but the chief reason was the relatively higher price.

Estimates of future trends in soybean acreage, yield, and production were made with the assistance of State experiment station committees in Illinois and Iowa and with help of other background information in other States.

The 1955 data are not forecasts, but are estimates based on alternative prices and demand conditions, and upon the conservation practices estimated necessary for profitable farming in the long run. Under the three alternative soybean-corn price ratios, 2.0, 1.6, and 1.2, the production of soybeans in the United States about 1955 is estimated at 191 million, 159 million, and 107 million bushels, respectively.

The long-time outlook in regard to the demand for soybeans suggests that about equal weight be given to outlets for oil and meal.

The long-time outlook indicates a strong domestic demand for fats and oils, especially soybean oil, because of the inelastic supply of most of the competing fats and oils. In the world situation regarding fats and oils, however, current shortages will disappear in time and more plentiful supplies may then increase our imports.

The long-time outlook for high-protein feeds including soybean oil meal appears even stronger than that for fats and oils, assuming a high level of livestock production and a growing recognition of protein-feed deficits.

On balance, the combined supply and demand outlook, under the assumed conditions, suggests a price for soybeans relatively lower than in recent years but above the prewar price. With this situation it is estimated that the production of soybeans would be less than in recent years although about three times as high as in 1935–39.

TABLE 16.—*Acreage, yield, and production of soybeans in the United States, 1924–47*

Year	Acres planted			Acres harvested		Grazed or plowed under	Yield per acre harvested		Production	
	Grown alone	Interplanted [1]	Equivalent solid [2]	For beans [2]	For hay		For beans	For hay	Beans	Hay
	1,000 acres	*1,000 acres*	*1,000 acres*	*1,000 acres*	*1,000 acres*	*1,000 acres*	*Bushels*	*Tons*	*1,000 bushels*	*1,000 tons*
1924	1, 567	417	1, 782	448	1, 147	187	11. 0	1. 13	4, 947	1, 299
1925	1, 539	476	1, 785	415	1, 175	195	11. 7	1. 01	4, 875	1, 185
1926	1, 871	502	2, 127	466	1, 431	230	11. 2	1. 18	5, 239	1, 687
1927	2, 057	571	2, 350	568	1, 556	226	12. 2	1. 18	6, 938	1, 837
1928	2, 154	556	2, 439	579	1, 609	251	13. 6	1. 23	7, 880	1, 974
1929	2, 429	743	2, 807	708	1, 774	325	13. 3	1. 16	9, 438	2, 051
1930	3, 072	786	3, 473	1, 074	2, 062	337	13. 0	. 94	13, 929	1, 938
1931	3, 835	909	4, 304	1, 141	2, 772	391	15. 1	1. 26	17, 260	3, 479
1932	3, 704	893	4, 165	1, 001	2, 738	426	15. 1	1. 25	15, 158	3, 433
1933	3, 537	813	3, 957	1, 044	2, 506	407	12. 9	1. 16	13, 509	2, 917
1934	5, 764	858	6, 207	1, 556	4, 227	424	14. 9	1. 08	23, 157	4, 545
1935	6, 966	1, 028	7, 503	2, 915	4, 044	544	16. 8	1. 34	48, 901	5, 422
1936	6, 127	2, 115	7, 183	2, 359	3, 116	1, 708	14. 3	. 96	33, 721	3, 002
1937	6, 332	2, 261	7, 464	2, 586	3, 469	1, 409	17. 9	1. 36	46, 164	4, 731
1938	7, 318	2, 541	8, 587	3, 035	3, 724	1, 828	20. 4	1. 43	61, 906	5, 335
1939	9, 565	2, 710	10, 920	4, 315	4, 590	2, 015	20. 9	1. 48	90, 141	6, 772
1940	10, 487	2, 589	11, 782	4, 807	4, 819	2, 156	16. 2	1. 34	78, 045	6, 450
1941	10, 068	2, 555	11, 345	5, 889	3, 546	1, 910	18. 2	1. 30	107, 197	4, 616
1942	13, 696	2, 426	14, 912	9, 894	2, 621	2, 397	19. 0	1. 36	187, 524	3, 555
1943	14, 191	2, 475	15, 428	10, 397	3, 177	1, 854	18. 3	1. 21	190, 133	3, 837
1944	13, 118	1, 861	14, 050	10, 232	2, 583	1, 235	18. 8	1. 18	191, 958	3, 041
1945	13, 007	1, 537	13, 777	10, 661	1, 939	1, 177	18. 0	1. 28	192, 076	2, 476
1946	11, 662	1, 530	12, 427	9, 806	1, 533	1, 088	20. 5	1. 29	201, 275	1, 984
1947 [3]	12, 894	1, 518	13, 654	11, 125	1, 372	1, 157	16. 3	1. 21	181, 362	1, 666

[1] Grown with other crops. [2] Acreage grown alone, with an allowance for acreage grown with other crops. [3] Preliminary.

TABLE 17.—*Percentage that the acreage of soybeans harvested for beans is of the acreage planted for all purposes, United States and selected groups of States, averages 1925–29, 1930–34, and 1935–39, and annual 1940–47* [1]

Period or year	United States	Corn Belt	Lake States	Plains States	Delta States	Atlantic States	All other States
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1925–29	24	33	15	31	13	30	8
1930–34	26	34	6	21	10	31	9
1935–39	37	51	14	16	9	29	8
1940	41	54	24	30	9	32	10
1941	52	72	37	57	14	35	10
1942	66	82	57	73	31	44	20
1943	67	85	70	79	26	36	19
1944	73	88	69	89	30	37	19
1945	77	91	83	90	29	43	18
1946	79	93	85	88	37	44	23
1947 [2]	81	93	90	91	37	53	29

[1] For States included in each group see table 1.
[2] Preliminary.

TABLE 18.—*Supply and utilization of soybeans in the United States, 1924–47*

Year beginning Oct. 1	Supply				Utilization					Carry-over Sept. 30
	Total stocks Oct. 1 [1]	Production [2]	Imports	Total supply [3]	Seed	Feed [4]	Processed for oil and meal	Exports [5]	Other uses [6]	
	1,000 bushels	*1,000 bushels*	*1,000 bushels*	*1,000 bushels*	*1,000 bushels*	*1,000 bushels*	*1,000 bushels*	*1,000 bushels*	*1,000 bushels*	*1,000 bushels*
1924	5	4, 947	60	5, 012	1, 900	1, 207	307	----------	1, 596	2
1925	2	4, 875	71	4, 948	2, 289	1, 174	351	----------	1, 134	(7)
1926	(7)	5, 239	67	5, 306	2, 525	1, 311	335	----------	1, 133	2
1927	2	6, 938	70	7, 010	2, 687	1, 631	559	----------	2, 133	(7)
1928	(7)	7, 880	77	7, 957	2, 984	1, 473	882	----------	2, 548	70
1929	70	9, 438	64	9, 572	3, 762	1, 730	1, 666	----------	2, 298	116
1930	116	13, 929	54	14, 099	4, 724	2, 763	4, 069	----------	2, 049	494
1931	494	17, 260	49	17, 803	4, 633	2, 867	4, 725	2, 161	3, 295	122
1932	122	15, 158	13	15, 293	4, 490	2, 264	3, 470	2, 450	2, 561	58
1933	58	13, 509	6	13, 573	7, 615	2, 111	3, 054	----------	767	26
1934	26	23, 157	5	23, 188	10, 066	2, 036	9, 105	19	1, 643	319
1935	319	48, 901	4	49, 224	8, 875	3, 898	25, 181	3, 490	7, 419	361
1936	361	33, 721	17	34, 099	9, 539	2, 741	20, 618	19	889	293
1937	293	46, 164	3	46, 460	10, 947	3, 273	30, 310	1, 392	198	340
1938	340	61, 906	3	62, 249	14, 667	4, 554	44, 648	4, 424	−7, 009	965
1939	965	90, 141	2	91, 108	15, 974	5, 365	56, 684	10, 979	1, 713	393
1940	393	78, 045	1	78, 439	15, 141	4, 999	64, 056	284	−6, 731	690
1941	690	107, 197	(7)	107, 887	20, 385	3, 925	77, 151	489	−63	6, 000
1942	6, 000	187, 524	(7)	193, 524	20, 980	6, 016	133, 454	917	19, 620	12, 537
1943	12, 537	190, 133	(7)	202, 670	19, 758	5, 496	142, 306	962	19, 995	14, 153
1944	14, 153	191, 958	4	206, 115	18, 885	3, 598	153, 402	5, 090	17, 402	7, 738

See footnotes at end of table, p. 58.

TABLE 18.—*Supply and utilization of soybeans in the United States, 1924–47*—Continued

Year beginning Oct. 1	Supply				Utilization					Carry-over Sept. 30
	Total stocks Oct. 1[1]	Production[2]	Imports	Total supply[3]	Seed	Feed[4]	Processed for oil and meal	Exports[5]	Other uses[6]	
	1,000 bushels	*1,000 bushels*	*1,000 bushels*	*1,000 bushels*	*1,000 bushels*	*1,000 bushels*	*1,000 bushels*	*1,000 bushels*	*1,000 bushels*	*1,000 bushels*
1945	7, 738	192, 076	(7)	199, 814	16, 473	3, 724	159, 460	2, 858	12, 973	4, 326
1946	4, 326	201, 275	(7)	205, 601	17, 392	3, 101	170, 146	3, 142	6, 496	5, 324
1947[8]	5, 324	181, 362								

[1] Factory and warehouse stocks only, through Oct. 1, 1941; total stocks, Oct. 1, 1942–47.

[2] Crop of calendar year, for example the 1924 crop was 4,947 thousand bushels.

[3] Sum of stocks, production, and imports. The "total supply" data for years before 1942 do not include stocks on farms, in country elevators, and at terminal markets.

[4] Fed to livestock on farms where produced.

[5] Data not available for years before 1931. Includes shipments to United States territories beginning Oct. 1, 1937.

[6] Residual item. Includes soybeans fed to livestock other than on farms where the soybeans were produced. It may also include small quantities used for human food. Before 1931 it includes exports. Before 1937 it includes shipments to United States territories. The minus quantities shown for 3 years are explainable by the fact that there were unreported supplies (stocks, Oct. 1) on farms, in country elevators, and in terminal markets.

[7] Less than 500 bushels.

[8] Preliminary.

TABLE 19.—*Utilization of soybean oil by classes of products, United States, 1931–47*

Year	Food products				Nonfood products						Total domestic disappearance
	Margarine	Shortening	Other [1]	Total	Soap	Paint and varnish	Other drying oil products [2]	Miscellaneous nonfood products	Loss, including oil in foots [3]	Total	
	1,000 pounds	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*	*1,000 pounds*
1931	622	10, 869	7, 261	18, 752	3, 816	6, 256	3, 773	923	1, 625	16, 393	35, 145
1932	3	4, 889	14, 166	19, 058	5, 571	7, 485	5, 139	844	1, 158	20, 197	39, 255
1933	7	489	9, 153	9, 649	4, 235	8, 568	7, 150	1, 182	867	22, 002	31, 651
1934	24	2, 735	10, 284	13, 043	1, 354	10, 451	4, 062	949	823	17, 639	30, 682
1935	1, 740	52, 452	21, 366	75, 558	2, 549	13, 003	5, 784	749	5, 468	27, 553	103, 111
1936	14, 261	113, 897	59, 270	187, 428	5, 023	14, 471	4, 821	1, 532	8, 959	34, 806	222, 234
1937	31, 791	90, 798	20, 037	142, 626	10, 274	16, 143	2, 685	1, 367	9, 926	40, 395	183, 021
1938	39, 885	137, 133	79, 247	256, 265	10, 897	15, 183	6, 601	2, 403	14, 046	49, 130	305, 395
1939	70, 822	201, 599	117, 297	389, 718	11, 177	21, 720	11, 633	4, 199	16, 265	64, 994	454, 712
1940	87, 103	212, 317	107, 468	406, 888	17, 612	29, 828	16, 432	7, 442	20, 924	92, 238	499, 126
1941	75, 634	215, 967	140, 147	431, 748	24, 737	41, 594	20, 816	10, 550	26, 412	124, 109	555, 857
1942	133, 346	335, 555	129, 530	598, 431	31, 510	25, 307	8, 115	6, 132	41, 540	112, 604	711, 035
1943	198, 020	568, 405	205, 263	971, 688	15, 428	20, 462	18, 512	14, 884	92, 999	162, 285	1, 133, 973
1944	211, 105	620, 257	274, 856	1, 106, 218	3, 258	19, 105	17, 543	14, 295	69, 184	123, 385	1, 229, 603
1945	206, 642	683, 011	242, 708	1, 132, 361	4, 219	25, 624	20, 133	16, 443	66, 322	132, 741	1, 265, 102
1946	200, 681	743, 527	292, 744	1, 236, 952	3, 545	30, 435	36, 490	24, 443	77, 440	172, 353	1, 409, 305
1947 [4]	227, 595	705, 180	245, 539	1, 178, 314	5, 375	89, 496	69, 316	36, 737	69, 204	270, 128	1, 448, 442

[1] Mainly utilized in salad and cooking oils, mayonnaise, and salad dressings, and direct use in homes, bakeries, restaurants, and institutions. Includes unreported disappearance of soybean oil; that is, difference between total domestic disappearance and total factory consumption, including loss and oil in foots.

[2] Difference between total estimated use in drying-oil products and factory consumption in paint and varnish.

[3] Foots are used in nonfood products, largely in manufacture of soap and fatty acids. Estimated since June 1942 as difference between crude oil used in refining and production of refined oil.

[4] Preliminary.

Data published by Bur. Agr. Econ. in Fats and Oils Situation, November–December 1947. *(37)*

TABLE 20.—*Supply and utilization of soybean-oil meal and cake, United States, 1924–46*

Year beginning October—	Supply			Utilization		
	Domestic production	Imports	Total supply	Feed	Food, industrial and other	Exports
	1,000 tons	*1,000 tons*	*1,000 tons*	*1,000 tons*	*1,000 tons*	*1,000 tons*
1924	7.6	18.3	25.9	25.9		
1925	8.6	19.8	28.4	28.4		
1926	8.3	23.9	32.2	32.2		
1927	13.7	47.7	61.4	61.4		
1928	21.5	69.5	91.0	91.0		
1929	40.7	73.5	114.2	114.2		
1930	98.6	24.0	122.6	122.6		
1931	114.7	18.6	133.3	133.3		
1932	84.3	28.3	112.6	112.6		
1933	73.9	25.0	98.9	98.9		
1934	220.4	64.2	284.6	266.6	18.0	
1935	613.1	20.0	633.1	614.1	19.0	
1936	495.8	55.7	551.5	531.5	20.0	
1937	724.1	15.5	739.6	718.6	21.0	
1938	1,064.4	12.3	1,076.7	1,019.7	22.0	35.0
1939	1,348.8	12.1	1,360.9	1,275.6	23.0	62.3
1940	1,543.4	8.1	1,551.5	1,491.1	35.0	25.4
1941	1,844.9	0	1,844.9	1,785.1	40.1	19.7
1942	3,200.3	0	3,200.3	3,073.9	105.5	20.9
1943	3,446.0	0	3,446.0	3,322.8	107.1	16.1
1944	3,698.5	0	3,698.5	3,627.1	61.4	10.0
1945	3,837.3		3,837.3	3,655.0	181.4	.9
1946 [1]	4,085.4	0	4,085.4	3,744.0	199.4	142.0

[1] Preliminary.

TABLE 21.—*Average yield per acre of soybeans harvested for beans, United States and specified groups of States, averages 1935–39, 1942–45, and estimated 1955 at alternative price ratios* [1, 2]

Group [3]	1935–39	1942–45	1955 price ratios [4]		
			2.0	1.6	1.2
	Bushels	*Bushels*	*Bushels*	*Bushels*	*Bushels*
Corn Belt	19.2	19.6	23.6	23.7	23.7
Lake States	14.6	13.9	18.0	17.9	17.9
Plains States	7.5	11.8	14.2	14.2	14.1
Delta States	10.6	13.6	16.8	16.8	16.9
Atlantic States	12.3	12.2	14.8	14.8	14.7
All other States	8.5	12.8	14.4	14.5	14.6
United States	18.1	18.5	22.0	22.1	22.2

[1] The estimates for 1955 are not forecasts.
[2] Average yields for 1955 are weighted averages derived by dividing total production by total acreage. Totals for regional and national acreage and production were built up from estimates of acreage, yield, and production made separately for each State.
[3] For States included in each group see table 1.
[4] Ratio of price of soybeans to price of corn.

TABLE 22.—*Production of soybeans in the United States and specified groups of States, averages 1935–39, 1942–45, and estimated 1955 at alternative price ratios* [1, 2]

Group [3]	1935–39	1942–45	1955-price ratios [4]		
			2.0	1.6	1.2
	1,000 bushels	*1,000 bushels*	*1,000 bushels*	*1,000 bushels*	*1,000 bushels*
Corn Belt	51,142	166,983	159,600	135,100	91,900
Lake States	668	7,002	11,940	8,600	5,400
Plains States	57	3,193	4,060	3,050	1,880
Delta States	1,031	5,139	6,900	5,390	3,290
Atlantic States	2,565	4,835	5,400	4,600	2,720
All other States	704	3,271	3,250	2,530	1,610
United States	56,167	190,423	191,150	159,270	106,800

[1] Estimates for 1955 are not forecasts.
[2] Totals for regional and national production were built up from estimates made separately for each State.
[3] For States included in each group see table 1.
[4] Ratio of price of soybeans to price of corn.

TABLE 23.—*Seasons average prices of soybeans, soybean oil, soybean-oil meal, and of other specified vegetable oils and oil meals in the United States, 1924–46*

Year [1]	Soybeans per bushel		Vegetable oils, per pound				Oil meals, per ton			
	United States average farm price [2]	For crushing at Chicago [3]	Soybean oil at midwestern mills [4]	Cottonseed oil at southeastern mills [5]	Linseed oil at Minneapolis [6]	Peanut oil at southeastern mills [5]	Soybean oil meal at Chicago [7]	Cottonseed oil meal at Memphis [7]	Linseed oil meal at Minneapolis [8]	Peanut oil meal at southeastern mills [9]
	Dollars	*Dollars*	*Cents*	*Cents*	*Cents*	*Cents*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
1924	2.46			9.5				39.05	43.31	39.20
1925	2.34			10.0				33.60	45.24	39.90
1926	2.01			7.8	10.3			30.75	45.67	45.25
1927	1.81			8.8	9.2			45.65	48.35	46.85
1928	1.88			8.4	9.3			41.40	52.99	45.65
1929	1.88		9.1	7.3	13.6	7.5	50.40	36.70	52.72	36.75
1930	1.37		6.3	6.4	9.2	6.6	32.52	26.60	35.85	28.65
1931	.50		3.4	3.2	6.6	3.6	20.83	13.70	27.22	18.20
1932	.54		4.6	3.5	6.3	3.9	27.17	15.80	21.50	18.60
1933	.94	.84	5.9	4.1	9.4	4.8	33.34	21.70	32.24	27.15
1934	.99	1.06	7.8	8.5	9.0	9.0	34.12	32.30	39.50	29.30
1935	.73	.96	7.4	8.6	9.0	8.8	28.66	22.40	26.20	22.75
1936	1.27	1.43	9.1	9.2	10.0	9.2	40.61	34.35	43.95	36.20
1937	.85	.93	5.7	6.6	9.8	6.9	27.71	22.40	38.14	25.45
1938	.67	.85	4.8	6.0	8.4	6.0	25.98	22.15	38.56	21.65
1939	.81	.96	4.9	5.6	9.6	6.3	28.90	27.60	31.78	30.05
1940	.90	1.06	7.0	6.5	8.6	7.2	30.49	26.65	27.04	24.05
1941	1.55	1.68	11.2	12.3	11.1	12.7	41.87	36.60	37.42	40.70
1942	1.61	1.72	11.8	12.8	13.3	13.0	42.80	37.80	42.43	39.25
1943	1.81	1.90	11.8	12.8	14.4	13.0	51.91	48.55	45.33	53.00
1944	2.05	2.20	11.8	12.8	14.3	13.0	52.00	48.50	45.50	53.00

1945	2. 08	2. 13	11. 9	12. 8	14. 3	13. 0	62. 39	55. 05	47. 50	60. 15
1946	2. 57	3. 04	22. 9	24. 8	29. 9	25. 3	81. 10	74. 55	80. 65	72. 20

[1] Year beginning October for soybeans, and soybean oil and meal; September for peanut oil and meal; August for cottonseed oil and meal; July for linseed oil and meal.

[2] Crop-year average prices, by States, weighted by production to obtain United States average.

[3] No. 2 yellow soybeans, bulk, in carlots. Simple average through 1938; weighted average in later years.

[4] Domestic crude in tank cars.

[5] Crude, f. o. b., in tanks.

[6] Raw in tank cars.

[7] In carlots, bagged, 41 percent protein.

[8] In carlots, bagged, 34 to 37 percent protein.

[9] F. o. b., 45 percent protein.

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