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Chapter 7

Agricultural Productivity

THE productivity of an industry may be defined as the ratio of its output to its input. This formula is not as simple as it sounds, for meanings have to be given to both output and input, and specifications for their measurement provided. To a large extent the resulting measure of productivity will depend upon the concepts chosen. Of the two definitions required, that for output offers the least difficulty, and in fact has already been treated at length.[1] So far as possible in measuring output we have excluded the products used by farmers themselves for purposes of seed and feed, but have included agricultural commodities consumed by farm families. We have then combined the physical output of different commodities, using farm prices as weights, to yield indexes for groups as well as for agricultural output as a whole.

No such comprehensive measure will be offered here for agricultural input, which consists of labor, materials (e.g., fertilizer and feed), and the services of land and equipment. Quantities so diverse cannot readily be combined into a single physical measure, and satisfactory statistics for several of them are lacking. If, on the other hand, we relate output in turn to each kind of measurable input, we obtain indexes of productivity which have a definite meaning; but we are debarred at the same time from constructing any single index that could be treated as a *unique* measure of agricultural productivity. Such partial indexes can, however, be put to useful service, and several will be considered in this chapter.

[1] See above, pp. 12-14.

OUTPUT PER WORKER

The most interesting among the productivity concepts are probably those which relate output to the corresponding input of labor. Now labor input can be calculated in terms either of numbers employed, or of hours worked. Since each procedure has its peculiar advantages, we shall confine our attention to the former in the present section, and turn in the one to follow to an examination of data on hours worked in agriculture.

The most comprehensive measure of the agricultural labor force at our disposal is the number of persons gainfully occupied, a quantity which, though not identical with employment, serves as the nearest approximation we can make to the latter in the realm of agriculture. Persons occupied in agriculture are those who so report themselves in the Census of Population; they include farmers and laborers (family and hired), whether or not they were actually employed on the date when the enumerator called. The estimation of numbers occupied in Census years was discussed in Chapter 6 above. For convenience the data shown there (Table 36) may be roughly converted to an annual basis with the help of the Agricultural Marketing Service series for annual employment shown in Table 35. The resulting indexes of labor input and of output per worker are compared on a 1924–29 base in Table 37 with similar data compiled by the National Research Project. It will be recalled that the constituents of the NRP production series are weighted by direct labor requirements instead of by value, and that the NRP employment series pays somewhat less attention than does our own to the variation in Census instructions. In spite of these differences, the results of the two calculations agree closely. According to our own index, output per worker increased somewhat more rapidly than it did according to the NRP figures.

Both productivity indexes—our own and that of the National Research Project—shown in Table 37 are based upon estimates of the number of gainfully occupied persons 10 years of age and over. They are, therefore, open to objection, not only because they measure numbers engaged rather than employment, but for other reasons also. In the first place, as we saw in Chapter 6, these totals are somewhat precarious, since it is a difficult matter to allow for variations in Census instructions. That is to say, the coverage of the original Census totals varies markedly from one Census to

TABLE 37

INDEXES OF PRODUCTION, EMPLOYMENT AND OUTPUT PER WORKER SINCE 1909

1924–29:100

Period	*National Bureau of Economic Research*			*National Research Project*[c]		
	Production[a]	Employment[b]	Output per Worker	Production	Employment	Output per Worker
1909–13	82	106	77	86	106	81
1917–21	88	104	84	90	100	90
1922–26	96	102	94	96	101	97
1927–31	102	97	105	102	99	104
1932–36	94	92	103	93	97	96
1937–38	107	88	122	110	95	116

[a] Derived from Table 6; data are averages for years shown.
[b] Total gainfully occupied; based on data underlying Table 38 below, col. 2.
[c] J. A. Hopkins, *Changing Technology and Employment in Agriculture* (U. S. Bureau of Agricultural Economics, 1941), Table 63.

another, and we have no assurance that the correction we have chosen to apply on this account is appropriate. In the second place, even if the trend in our figures for gainfully occupied can be considered reliable, the figures clearly take no account of the changing composition of the agricultural labor force, and especially of the decline in the proportion of child workers and the increase in the proportion of adult males since the beginning of the century. It will be recalled that to meet this difficulty we have developed a series for the number of farmers plus adult male laborers. This second measure of the labor force suffers from a much smaller degree of uncertainty as to its coverage; but it neglects entirely the work performed by children, and also by women. The main reason for excluding both these categories from the alternative series presented here is to eliminate the uncertainty arising from changing Census instructions. In addition, the purpose of excluding child workers is to avoid the assumption, implicit in the former series, that the substitution of an adult male for a child leaves the labor force unaltered; to a minor degree this is also the reason for the exclusion of women, although their relative importance has not changed greatly since 1900. The second series, for farmers plus adult male laborers, therefore measures more accurately what it sets out to measure, and also represents a much more homogeneous quantity, than does the first employment series considered, i.e., for the total gainfully occupied. Like the first series, the second may be converted roughly to an annual basis with the help of the Agricultural Marketing Service employment series (Table 35).

Since year-to-year variations in our output index are mainly reflections of changes in the weather, it is best, in measuring productivity, to reduce this index to a 5-year average basis; in this manner it is shown for 1900 and annually for 1909 and following years in the first column of Table 38, the initial year being treated as the base. For the sake of comparability our two employment series, for gainfully occupied and for farmers and adult males, have also been reduced to 5-year averages, appearing in columns 2 and 3 of the same table. Because of the decline in the number of child workers (Table 32), the latter is at the same level at the end of the period as at the beginning, whereas the former shows a sizable decline over the four decades considered. These two series for labor input may be employed to indicate a trend in agricultural productivity. Thus, if we divide column 1 by columns 2 and 3, we obtain as A and B respectively in columns 4 and 5

TABLE 38
OUTPUT PER WORKER, FIVE-YEAR AVERAGES, 1900–38
1900:100

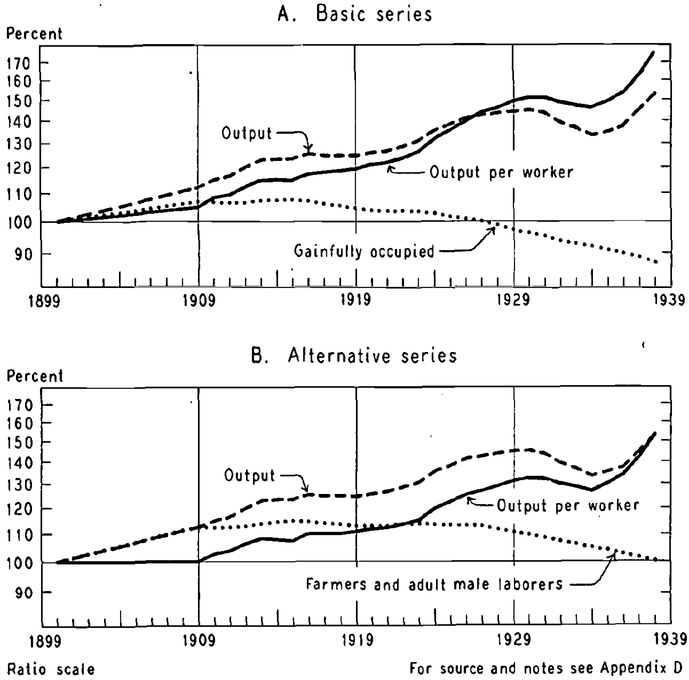
Year	Output	Employment[c]		Output per Worker	
		Gainfully Occupied	Farmers and Adult Male Laborers[d]	A Gainfully Occupied	B Farmers and Adult Male Laborers[d]
	(1)	(2)	(3)	(4)	(5)
1900	100	100[a]	100[a]	100	100
1909	112	107[a]	112[a]	105	100
1910	115	106[b]	112[b]	108	103
1911	116	106	112	109	103
1912	120	107	113	112	106
1913	123	107	113	115	108
1914	123	107	114	115	108
1915	123	108	115	114	107
1916	125	107	114	117	110
1917	125	106	113	118	110
1918	125	105	113	118	110
1919	124	104	113	119	110
1920	126	104	112	121	112
1921	126	104	113	122	112
1922	128	104	113	124	113
1923	130	103	113	126	115
1924	136	103	113	132	120
1925	138	102	113	136	122
1926	141	101	112	140	125
1927	142	100	112	143	127
1928	144	99	111	146	129
1929	144	97	110	149	131
1930	145	96	110	151	132
1931	144	95	109	151	132
1932	139	94	107	148	130
1933	136	93	106	147	129
1934	133	92	105	145	127
1935	135	91	104	149	130
1936	137	90	103	153	134
1937	145	89	102	164	143
1938	154[b]	87	100	176	154

[a] Actual figure for year shown.
[b] Three-year average centered on year shown.
[c] Derived from Table 36, with total employment in Table 35 used for interpolation.
[d] Data for estimating farmers and adult male laborers from the Census of 1940 are not yet available; for years after 1930 this series is computed on the basis of the preceding column.

two alternative measures of output per worker. It will be seen that series A, based on the gainfully occupied population, rises more rapidly than series B, based on farmers plus adult males. This is to be expected, for numbers occupied decline, while farmers and adult males do not change over

Chart 46

OUTPUT PER WORKER IN AGRICULTURE



the period. Between 1900 and 1930 series A rises at a rate of somewhat over 1.5 percent per annum; while series B increases at about 1 percent per annum. After 1930 the decline in output caused by depression, drought and the Agricultural Adjustment program leads to a fall in both indexes of productivity, followed by a recovery in very recent years. In the case of both indexes the most rapid increases occur between 1922 and 1930, and during the last few years of the period.

Before we conclude our discussion of changes in output per worker, we may briefly sketch the outlines of a somewhat broader picture. The Department of Agriculture has published indexes of agricultural production which run back to

TABLE 39

OUTPUT PER WORKER, 1870–1940

1870:100

Year	*Output*[a]	*Employment*[b]	*Output per Worker*	*Percentage Change in Output per Worker in Each Decade*
1870	100	100	100	
				+20
1880	150	125	120	
				+ 9
1890	189	145	130	
				+15
1900	238	159	149	
				+ 8
1910	273	169	162	
				+11
1920	299	167	179	
				+26
1930	345	153	225	
				+26
1940	379	134	284	
			Mean:	+16

[a] For 1870 and 1940, 3-year averages centered on year indicated. For other years, 5-year averages, similarly centered. Data for 1900 through 1930 are derived from NBER index, Table 6. For years before 1900 the extrapolation is based upon the arithmetic index computed by Frederick Strauss and L. H. Bean, *Gross Farm Income and Indices of Farm Production and Prices in the United States, 1869–1937,* Technical Bulletin 703 (U. S. Department of Agriculture, 1940), Table 58. For 1940 the extrapolation is based upon the Bureau of Agricultural Economics index of agricultural production; see *The Farm Income Situation* (U. S. Bureau of Agricultural Economics, Nov. 1941), p. 10.

[b] Numbers occupied in farming as shown in U. S. Bureau of the Census, "Trends in the Proportion of the Nation's Labor Force Engaged in Agriculture: 1820 to 1940" (Press release, March 28, 1942).

1869; and since our own calculations were completed, data for 1940 and (in preliminary form) for 1941 have become available. Moreover estimates of the numbers occupied in agriculture have been made for all Census years since 1870. The indexes in Table 39, which are obtained by extrapolating the series shown in columns 1, 2 and 4 of Table 38, touch a somewhat lower level of accuracy than the material so far considered in this chapter, but they extend over a much longer period. They suggest that the increase in the effectiveness of labor engaged in farming has been continuous, but that it has varied considerably in magnitude from one decade to another. To attempt to relate differences in the rates of growth in different decades to variations in the rate of technical change is tempting. However, the margin of uncertainty surrounding the comparison of employment data drawn from successive Censuses of Population—a topic discussed at length in the preceding chapter—would make such an undertaking hazardous. Similarly, the much more rapid growth in output per worker during the last two decades of the period than in earlier decades invites comment. Here again the explanation may be statistical rather than economic or technological in character. We have already seen that the proportion of women and children in the labor force has declined rather sharply in recent decades, and this fact is responsible, in part at least, for the high rates of growth in productivity reported for the period since 1920. With these summary reflections we leave the subject of output per worker and turn to a different approach to the problem.

DIRECT LABOR REQUIREMENTS

How has the rise in productivity been distributed between different types of agricultural enterprise? This question can be answered only approximately. Despite much regional specialization, very few areas are devoted exclusively to the production of a single crop. For example, although we may speak of the "corn area" or the "cotton area," [2] these regions produce a great deal besides corn and cotton, respectively. Nor do the dairy areas produce only dairy products. The prevalence of "mixed farming" makes it impossible to impute the output of a particular product to a given set of workers. On this account the distribution of changes in agricultural productivity must be studied from an altogether different standpoint. The discussion now to be undertaken differs from that of the preceding section in two important respects. In the present section we shall consider only a few staple products and we shall be concerned with their gross rather than with their net output.

The input of labor, on any farm producing more than one crop or type of livestock, may be divided roughly into two parts, according to whether it can or cannot be imputed to the output of a particular product. Thus the labor involved in plowing, seeding, cultivating and harvesting corn is to be charged to the corn crop alone, since it does nothing to further the production of wheat. Labor that can be allocated in this fashion to the output of a particular product may be compared in a general way to the prime cost of operating a manufacturing enterprise. Such amounts, when measurable, are termed the "direct labor requirements" for the crop or kind of livestock under consideration. Perhaps half the total labor on the average farm can be imputed to some individual product in this manner. The remainder may be termed "indirect labor," and may be compared to "overhead cost" in manufacturing, for while it contributes to the production of the farm as a whole, it cannot be imputed to particular portions of the output. Such labor includes the maintenance of machinery, the care of work animals and of farm structures, fencing, drainage, and so forth.

[2] For the definition of these and other areas, see note a to Table 40 below.

Unlike the number of workers employed, which is the subject of Census inquiry, the amounts of indirect labor, and of direct labor on different crops, can be derived for agriculture as a whole only by an elaborate process of estimation. The basic materials for this purpose are output, or acreage and numbers of livestock, on the one hand, and sample data for hours required for different operations, on the other. We shall first consider the data on direct labor requirements for various products collected by the National Research Project.[3] These can be expressed in hours per unit of product, but since crop yields per acre have not changed markedly,[4] it is more convenient and only slightly less accurate to treat hours per acre. In the case of livestock we use hours per head or per thousand pounds, an arrangement which makes no allowance, however, for the increase in milk production per cow or egg production per chicken. The National Research Project data on hours per acre for five major crops and three kinds of livestock, and for truck crops, are summarized in Table 40. These products account together for about four fifths of the direct labor used by American agriculture.[5] The data in Table 40 are shown in the form of annual averages for the periods 1909–13 and 1932–36 respectively. While events before 1909 are of interest to us, no such systematic analysis of direct labor is available prior to that year: in this section therefore we shall confine attention to the period since 1909.

The figures of principal interest in Table 40 are the averages for the United States, but the areas reporting highest and lowest hours per unit respectively also are shown for

[3] The detailed data and sources will be found in individual reports prepared by the Project; they are conveniently summarized for five major crops, three kinds of livestock, and fifteen truck crops by J. A. Hopkins, *Changing Technology and Employment in Agriculture* (U. S. Bureau of Agricultural Economics, 1941), Ch. VIII, from which source Tables 40 and 41 are mainly taken.

[4] See, however, pp. 278-86 below.

[5] Hopkins, *op. cit.*, Table 54.

each period. It is evident that the regional dispersion of the data on which the averages are based is very considerable: for example, in the eastern dairy area corn requires four times as many hours per acre as it does in the small grain area.[6] This dispersion must in some degree reduce the reliability of the United States averages. Nevertheless, the changes reported over the twenty-five year period are for the most part so large that their direction and significance are scarcely affected by doubts of this nature. For each of the five major crops very marked reductions are reported in manhours per acre, ranging from 15 percent for corn and potatoes to 46 percent for wheat. This last result accords with the rapid mechanization of wheat production noted in Chapter 5. In the case of corn and potatoes the rather moderate declines in labor input per acre are probably a reflection of the greater difficulties encountered in the mechanization of these crops. Curiously enough, the largest absolute reduction in the United States average apparently occurred in the case of cotton, a crop which has perhaps resisted mechanization more than any other; in this instance, however, regional shifts in acreage were an important influence upon labor requirements. Thus the western cotton area, with hours per acre about half the level in other regions, increased the number of acres planted to cotton from 12.4 million in 1907–11 to 13.4 million in 1933–36; while over the same period the combined acreage of the other chief cotton producing areas (eastern, Delta and middle eastern) declined from 19.0 to 14.0 million.[7] This shift was responsible for a large part of the reduction in aver-

[6] In the latter area corn is cut primarily for grain, whereas in the former it is predominantly a silage crop. That this difference is responsible only in part for the regional variation in hours per acre is suggested by the very wide dispersion even among crops harvested exclusively for grain: in the eastern dairy area for the second period oats require six times as many hours per acre as they do in California.

[7] For the regional coverage of these areas, see note a to Table 40. Acreages quoted are from Hopkins, *op. cit.*, Table 43; see also W. C. Holley and L. E. Arnold, *Cotton* (National Research Project, Philadelphia, 1938), Table A-1.

Table 40

ANALYSIS OF CHANGE IN HOURS PER ACRE OR PER UNIT OF LIVESTOCK[a]

	Hours per Acre or per Unit of Livestock, 1909–13					*Hours per Acre or per Unit of Livestock, 1932–36*					*Change in U. S. Average*		*Change in Hours Associated with:*	
	Regional Averages— Highest		Regional Averages— Lowest		U. S. Average	Regional Averages— Highest		Regional Averages— Lowest		U. S. Average				
	Area	Hours	Area	Hours	Hours	Area	Hours	Area	Hours	Hours	Hours	Percent	Change in Hours per Unit[f]	Regional Shifts[f]
Corn	Eastern dairy	59.4	Small grain	12.9	28.7	Eastern dairy	46.2	Small grain	10.0	24.4	− 4.3	−15	− 5.1	+ .8
Wheat	Eastern dairy	22.7	North-western	9.4	12.7	Eastern dairy	17.2	Cali-fornia	3.2	6.8	− 5.8	−46	− 5.0	− .8
Oats	Eastern dairy	25.1	Small grain	8.8	12.5	Eastern dairy	16.7	Cali-fornia	2.8	8.6	− 3.9	−31	− 4.3	+ .4
Cotton	Middle eastern	139	Western cotton	70	105.3	Middle eastern	130	Western cotton	50	87.6	−17.6	−17	−11.4	−6.2
Potatoes[b]	Pa., N.Y., Me.	102	N.J., Va.	78	89.1	Pa., N.Y., Me.	94	Minn., Wis., Mich., N.J., Va.	65	75.8	−13.2	−15	−11.9	−1.4
Milk cows[c]	Middle eastern	175	Small grain	106	135.1	Middle eastern	174	Small grain	116	139.6	+ 4.5	+ 3	+ 5.0	− .3
Chickens[d]		..		..	..	Middle eastern	2.5	Western cotton, Calif.	1.9	2.15	..	..	..	..
Hogs[e]	Middle eastern	76.6	Corn	26.8	44.8	Middle eastern	77.6	Corn	25.3	42.1	− 2.7	− 6	− .8	−1.9
Truck crops		..		..	..	Range	145	Western dairy	61	113	..	..	..	..

[a] These data, derived by the National Research Project from a wide variety of published and unpublished sources, are taken from J. A. Hopkins, *Changing Technology and Employment in Agriculture* (U. S. Bureau of Agricultural Economics, 1941), Ch. VIII. The two areas reporting the largest and smallest estimated average number of hours per unit, respectively, for each product are shown separately in order to provide some indication of the very considerable dispersion of the averages for different areas about the U. S. averages. In computing U. S. averages for corn, wheat and oats for 1932–36, it is convenient, because of the effects of drought and of the Agricultural Adjustment program, to employ acreages for years more normal than those specified. The U. S. averages for these crops given by Hopkins for 1932–36 are based on annual average acreages for 1927–31; we have preferred to use acreage data for 1937–39, and this accounts for slight differences between the U. S. averages for these crops quoted here for 1932–36 and those given by Hopkins. Data for chickens and for truck crops are not available for the earlier period.

The data for hours per acre or per unit shown in the table for the earlier period relate to 1907–11 in the case of cotton; and for the later period relate to 1934–36 in the case of wheat, oats and potatoes, to 1933–36 in the case of cotton, and to 1933–35 in the case of chickens.

The regional classification underlying the NRP study is as follows:

Corn area: Illinois, Indiana, Iowa, Ohio.
Eastern dairy area: Connecticut, Massachusetts, New Hampshire, New York, Pennsylvania, Vermont.
Western dairy area: Michigan, Minnesota, Wisconsin.
Eastern cotton area: Alabama, Georgia, South Carolina.
Delta cotton area: Arkansas, Louisiana, Mississippi.
Western cotton area: Oklahoma, Texas.
Small grain area: Kansas, Montana, Nebraska, North Dakota, South Dakota.
Middle eastern area: Kentucky, Maryland, North Carolina, Tennessee, Virginia, West Virginia.
Range area: Arizona, Colorado, Nevada, New Mexico, Utah, Wyoming.
Northwestern area: Idaho, Oregon, Washington.
California area: California.

Six states are excluded from this classification, but figures for them are included in U. S. totals: Maine, Rhode Island, New Jersey, Delaware, Florida, Missouri.

[b] Data are available only for three regions (which do not correspond to the areas used elsewhere in the NRP study): Minnesota, Wisconsin and Michigan; Pennsylvania, New York and Maine; and New Jersey and Virginia.

[c] Hours per milk cow; no allowance is made for labor on calves, heifers or bulls. The estimates include the labor used in caring for the cows, milking, cooling, separating and hauling, feeding the cows, cleaning stables, and all work expended directly in producing milk and cream; they do not include labor used in growing feed; see R. B. Elwood, A. A. Lewis and R. A. Struble, *Dairying*, National Research Project Report A-14 (U. S. Department of Agriculture, 1941), p. 69.

[d] Hours per chicken.

[e] Hours per thousand pounds of hogs.

[f] The part of the change associated with a change in hours per unit is

$$\frac{\Sigma (x_2 - x_1) y_1}{\Sigma y_1},$$

where x denotes the hours per unit, y the number of units (acres, head of livestock, etc.), suffixes the first and second period respectively, and Σ summation over all areas. The part associated with regional shifts is

$$\frac{\Sigma x_2 \left(\frac{y_2}{p} - y_1\right)}{\Sigma y_1}, \text{ where } p = \frac{\Sigma y_2}{\Sigma y_1}.$$

These results have been rounded and therefore do not agree exactly with the aggregate changes in the United States averages reported in a preceding column.

age United States hours per cotton acre. As may be seen from Table 40, regional shifts in acreage were not an important influence in reducing hours per acre for the other four crops: indeed in the case of corn and oats there appears actually to have been a slight tendency for production to move in the reverse direction, i.e., from areas with low labor requirements per acre to those with high.

The regional dispersion of unit labor input is also substantial in the case of livestock, but the trend in the United States averages is in marked contrast to that shown for crops. For chickens we have no data for the earlier period, but for milk cows and for hogs the level of direct labor requirements per unit in 1932–36 was practically the same as it had been a quarter of a century earlier.

While the small increase (3 percent) shown in the table for hours per cow may not be statistically significant, it allows us to say with confidence that no substantial decline has occurred.[8] At first sight this result is surprising. Although mechanical improvements in dairying have been slight in comparison with similar improvements in crop production, we might expect the introduction of milking machines and mechanical transportation to have had some influence upon labor requirements. In fact the amount of labor necessary in caring for milk cows depends to a large extent upon the forms in which milk is sold or otherwise distributed. The two outlets for milk which require the largest amounts of farm labor are butter production upon the farm itself and retail sales of milk and cream by the farmer. Milk fed to calves or sold through wholesale channels involves considerably less labor. The percentage of total milk production used for farm butter (including butter consumed in farm house-

[8] Since milk production per cow increased about 11 percent between 1909–13 and 1932–36 hours per pound of milk declined in spite of the apparent rise in hours per cow. See R. B. Elwood, A. A. Lewis and R. A. Struble, *Dairying,* National Research Project Report A-14 (U. S. Department of Agriculture, 1941), Table 15; also Table 50 below.

holds) declined from 31 in 1909–13 to 11 in 1932–36.[9] It is fairly certain that the fraction retailed by farmers themselves has also declined over the period.[10] On both these grounds also we should expect a decline to have occurred in average hours per cow. Nor can the absence of such a decline be explained by a shift from areas with low labor requirements to areas with high: if anything, the trend disclosed in Table 40 has been in the reverse direction.

There can be little doubt that the principal factor tending to maintain the level of hours per cow has been the increasing stringency of sanitary regulation. During the past twenty years states and municipalities have, with the encouragement of the U. S. Public Health Service, made great efforts to raise the quality of dairy products, and especially of liquid milk for human consumption. The resulting improvement has been widespread and extensive, and has obscured any decline that might otherwise have appeared in hours per cow.[11]

For truck crops satisfactory data are not available for the period 1909–13, but we may notice that between 1918–21 and 1932–36 hours per acre declined from 145 to 135 in the case of vegetables for market, and from 80 to 65 in the case of vegetables for processing.[12] The trend in labor requirements per acre for truck crops therefore appears to have been similar to that disclosed for the five major crops mentioned.

In analyzing direct labor input we have so far confined ourselves to a discussion of hours per acre or per unit of livestock. The data on which Table 40 is based allow us also to examine the trend in aggregate consumption of direct labor by each of

[9] E. E. Vial, *Production and Consumption of Manufactured Dairy Products*, Technical Bulletin 722 (U. S. Department of Agriculture, 1940), Table 5; U. S. Agricultural Marketing Service, *Farm Production, Disposition and Income from Milk, 1924–40, by States* (Washington, 1941), Table 2.

[10] See below, Appendix Table A-1, footnote 73.

[11] See especially Elwood, Lewis and Struble, *op. cit.*, pp. 61-67.

[12] Hopkins, *Changing Technology and Employment in Agriculture*, Table 45.

the major types of agricultural activity there listed. The change in this aggregate consumption is of course compounded of changes in hours per unit of the kind just discussed together with changes in the number of units (acres or amounts of livestock). For the earlier period contemporary acreages can conveniently be used, but acreages of corn, wheat and oats harvested in 1932–36 were severely reduced by drought and by the Agricultural Adjustment program. In order to obtain representative figures for aggregate labor requirements in the later period for these crops, we have used average acreages for the crop years 1937–39. The data for acreages and amounts of livestock are summarized in Table 41.

By multiplying acreages and livestock quantities, for each product and region, by corresponding labor requirements of the kind shown in Table 40 total direct labor requirements for each product may be built up. The results of this calculation are shown in Table 42. It will be seen that in the case of each of the five crops for which data appear, a substantial reduction took place in estimated total manhours required for direct labor—a reduction ranging from 35 percent for oats to 22 percent for potatoes. In Table 42 the change shown in column 3 is broken down in columns 5, 6 and 7 into three parts associated with the reduction in manhours per acre, with regional shifts in acreage between farming areas, and with the change in total United States acreage of each crop, respectively. For all crops except cotton more than half of the reduction in direct labor requirements is accounted for by the reduction in hours per acre reported in summary form in Table 40. For cotton, however, more than half the total saving in direct labor can be traced either to the over-all reduction in cotton acreage (Table 41), or to the shift in acreage from the older cotton areas toward Texas and Oklahoma where hours per acre are relatively low. In none of the other four crops did regional shifts apparently affect aggregate labor requirements in an important degree; however, reduction in total acreage led in the case of corn to a sizable decline in the amount of labor used for that crop. There were also reductions of acreage, for the United States as a whole, in oats and potatoes; but the wheat acreage was actually higher in 1937–39 than in 1909–13 (Table 41), although the increase

TABLE 41
SUMMARY OF CHANGES IN ACREAGE AND LIVESTOCK UNITS[a]

Product	*Unit of Measure*	*Period*[b]	*Annual Average*	*Period*[b]	*Annual Average*	*Percentage Change*
		(1)	(2)	(3)	(4)	(5)
Corn	mil. acres	1909–13	101.0	1937–39	91.5	− 9.4
Wheat	mil. acres	1909–13	48.1	1937–39	62.6	+30.2
Oats	mil. acres	1909–13	36.7	1937–39	34.6	− 5.7
Cotton	mil. acres	1907–11	31.8	1933–36	28.4	−10.5
Potatoes	mil. acres	1909–13	1.82	1934–36	1.68	− 7.7
Milk cows	million	1909–13	17.3	1932–36	24.2	+39.7
Chickens	million	1910	336	1932–36	420	+25.0
Hogs	bil. pounds	1909–13	11.9	1932–36	13.7	+14.7
Truck crops	mil. acres	1909–13	[c]	1932–36	3.49	[c]

[a] With the exception of the corn, wheat and oats acreages for 1937–39, all data in this table are taken from J. A. Hopkins, *Changing Technology and Employment in Agriculture* (U. S. Bureau of Agricultural Economics, 1941), Ch. VIII. The former are from *Crops and Markets,* Dec. 1940.
[b] For crops, crop years; for livestock, calendar years.
[c] Not available.

was insufficient to offset a decline in total labor requirements for other reasons (Table 42). For the five crops taken together the 25 percent decline in total labor requirements appears to have resulted from reduction in hours per acre (about two thirds), from over-all reduction in acreage (about one quarter), and from shifts from areas requiring many, to areas requiring few, hours per acre (the small remainder).

There can be little doubt that the substantial reductions observed in hours per acre have been due in the main to mechanization of the types sketched in Chapter 5. To say more is not easy, but we can perhaps suggest the extent to

TABLE 42

ANALYSIS OF CHANGE IN DIRECT LABOR REQUIREMENTS FOR MAJOR PRODUCTS[a]

Product	*Average Annual Requirements* Approximate Period 1907–13	1932–39	Absolute Change	Percentage Change	*Change in Requirements Associated with* Change in Manhours per Acre or per Unit of Livestock[g]	Regional Shifts in Acreage or Livestock[g]	Change in Aggregate Acreage or Livestock[g]
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	(million manhours)				(million manhours)		
Corn	2,898	2,231	−667	−23.0	−512	+78	−233
Wheat	609	429	−180	−29.6	−240	−39	+99
Oats	458	297	−161	−35.2	−157	+14	−20
Cotton	3,343	2,489	−854	−25.5	−364	−196	−294
Potatoes	162	127	−35	−21.6	−21	−3	−11
Total, major crops	7,470	5,573	−1,897	−25.4	−1,294	−146	−459
Milk cows[b]	2,551	3,679	+1,128	+44.2	+93	−7	+1,041
Chickens[c]	722	903	+181	+25.1	0[c]	0	+181
Hogs	535	577	+42	+7.9	−10	−22	+74
Total, livestock	3,808	5,159	+1,351	+35.5	+83	−29	+1,296
Total, major crops and livestock	11,278	10,732	−546	−4.8	−1,211	−175	+837
Truck crops[d]	200	394	+194	+97.0	..	..	..
Total, major products	11,478[e]	11,126[f]	−352	−3.1	..	..	..

[a] The figures in this table are obtained by multiplying estimated hours per acre or per unit of livestock, by areas, by acreage harvested or amount of livestock maintained. With the exception of the corn, wheat and oats acreages for 1932–39, this table is based entirely upon data to be found in J. A. Hopkins, *Changing Technology and Employment in Agriculture* (U. S. Bureau of Agricultural Economics, 1941), Ch. VIII. The hours per acre and per livestock unit for each area are annual averages for the periods shown in Table 40. The acreages and livestock units for each area are annual averages for the periods shown in Table 41. The items (other than truck crops) in-

which the economy of labor has been associated with the adoption of gasoline power on the farm. The National Research Project has indicated that by 1935 the direct saving of labor in field operations through the adoption of the tractor must have been about 165 million hours per year.

> If it is assumed (conservatively) that there were 1.1 million tractors on farms in 1935, that they were operated on the average thirty 10-hour days per year, and that their use resulted in an average increase in effective capacity of 50 percent per operator over the units replaced, the reduction in labor requirements would have amounted to 150 manhours per tractor, or a total of 165 million manhours.[13]

[13] E. G. McKibben and R. A. Griffin, *Tractors, Trucks and Automobiles* (National Research Project, Philadelphia, 1938), p. 36.

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cluded in this table accounted in 1924–29 for about 76 percent of the gross product of the agriculture of the United States (*ibid.*, Table 54).

[b] Includes labor expended on raising calves and heifers and on the care of bulls; *ibid.*, Table 47.

[c] No data are available on the change in hours per chicken between 1910 and 1933–35, and the labor requirements for this product are therefore computed by using the 1933–35 data for both periods.

[d] Data for hours per acre on truck crops are not available by areas for the earlier period.

[e] This total differs slightly from that provided by Hopkins (11,486 million hours; *ibid.*, Table 54) because we have used the data for cows given by him in Table 47; these data do not check exactly with the summary figures in his Table 54.

[f] This total differs slightly from that given by Hopkins (11,128 million hours; *ibid.*, Table 54) owing to our use of acreage data for 1937–39 instead of 1927–31 in the case of corn, wheat and oats.

[g] The part of the change associated with a change in hours per unit (summed over all areas) is

$$\Sigma y_1(x_2 - x_1),$$

where x denotes the hours per unit, y the number of units (acres, head of livestock, etc.), and the suffixes the first and second periods respectively. The part associated with regional shifts is

$$\Sigma x_2 \left(\frac{y_2}{p} - y_1\right),$$

where $p = \frac{\Sigma y_2}{\Sigma y_1}$. The part associated with the change in acreage or units of livestock is $\frac{p-1}{p}(\Sigma x_2 y_2)$.

Undoubtedly the five major crops, for which changes in labor requirements are analyzed in Table 42, are not the only ones to have benefited immediately from the spread of tractor cultivation. We may note, however, that the saving in direct labor associated with a reduction of hours per acre for these five crops amounted to about 1,300 million hours, or close to eight times the estimated direct savings attributable to the advent of the tractor for agriculture as a whole. It is probable, for this reason, that the large reductions in hours per acre have resulted directly from the tractor only to a minor degree, and are to be credited mainly to other influences, notably the improvement in agricultural implements. To the extent that these implements are too heavy or complicated to be used with horses, their very introduction may of course have been conditioned by the tractor. And in this sense a much more substantial fraction of the saving in hours per acre may be traceable to the advent and general adoption of tractor cultivation. Again, the substitution of the tractor for the horse has economized labor, also indirectly, through the decline in the demand for horse feed. To some extent such savings of labor have been offset by an increase in labor devoted to producing and distributing gasoline, but this aspect of the question is not relevant here. The saving of labor in the production of feed for horses has been estimated by the National Research Project at 380 million manhours, broken down as follows: [14]

	(million hours)
Corn	207
Oats	53
Hay	121
TOTAL	381

[14] *Ibid.*, p. 67. It is assumed that 28, 9 and 12 manhours were required per acre in 1936 for producing corn, oats and hay respectively; these rates are applied to the estimated reductions between 1909 and 1936 in acreage required for horse feed shown in *ibid.*, Table D-4. They make no allowance for saving in labor through the abandonment of 4½ million acres of pasture.

It will be seen that this estimate accounts for practically the whole reduction in labor requirements in corn cultivation, and in the case of oats for the entire reduction, associated with decreases in acreage, reported in Table 42.

In contrast to experience with the five major crops listed, the three principal kinds of livestock each absorbed more labor in the later than in the earlier period. For cows the increase was 44 percent, for chickens 25 percent,[15] and for hogs 8 percent. To a slight extent the increase in labor on cows is accounted for by an actual rise in hours per cow (Table 40). By far the most important source of the increase in total labor on cows, however, was the expansion in their number; the same is true of hogs, and probably also of chickens.

In the case of truck crops a sizable increase in total labor requirements is reported. The increment cannot, however, be imputed to various types of change as it can with the other products shown.

The combined result of these differing trends, for all the products indicated, is a net decline of about 3 percent in total hours worked. To summarize broadly: for major crops, a small decline in acreage and a large decline in hours per acre together cut total labor requirements by 25 percent; for livestock a large increase in numbers and a small increase in hours per head together raised labor requirements by 35 percent. Truck crops, which now consume more labor than either oats or potatoes and almost as much as wheat, doubled their combined labor input. Close to 2 billion manhours used annually for crop raising in 1907–13 were no longer needed for this purpose in 1932–39. More than two thirds of the labor so displaced was absorbed by the increasing de-

[15] The estimates are of course confined to chickens on farms. No data are available for hours per chicken in the earlier period, and this percentage is computed on the assumption that such hours underwent no change. Even if hours per chicken have in fact declined, it is highly unlikely that any reduction has been of sufficient magnitude to upset the conclusion that total hours on chickens increased over the quarter of a century considered.

mands of livestock production, and one tenth was transferred to the cultivation of truck crops; the remaining fifth of the labor displaced by major crops represented a net reduction in combined labor requirements for all the various products shown, a reduction equal to about 3 percent of the total.

TOTAL LABOR INPUT

In the preceding sections of this chapter we have approached the problem of measuring the labor input of agriculture from two altogether different angles: on the one hand, the use of numbers gainfully occupied as a reflection of total employment, and on the other, the examination of hours of direct labor required for the gross output of different products. At this point we are prompted to inquire whether there is any way in which we can integrate these two approaches.

The problem may be sketched in the following terms. Given total hours of direct labor for all products, and given also some measure of the hours spent for indirect or "overhead" labor, we could arrive at a figure for total annual labor input measured in hours. Dividing this by the number of workers, we should obtain as a result an estimate of the average number of hours worked per year per worker. This would be one possible procedure. As an alternative, given average hours worked per year and multiplying by employment, we could again estimate total annual labor input in hours. Deducting total hours of direct labor (which we can approximate), we should then obtain an estimate for the input of indirect labor. Unfortunately we have reliable information neither about the ratio of direct to indirect labor in agriculture, nor about the average number of hours worked on farms. It might seem the part of wisdom, therefore, to abandon the attempt to relate our data for numbers occupied to our data for direct labor required by specific products. Nevertheless, the question has seemed of sufficient interest to warrant a hypothetical calculation, wherein plausible assumptions must do duty where necessary for information that is not available.

In this highly tentative reconstruction, it seems best to begin with hours worked per year, for which scattered data have been summarized in Table 43. We know, for example, that average annual hours per worker are highest where livestock has to be cared for, i.e., in the corn and dairy areas; and lowest where there is little livestock but marked seasonal variation in the demand for labor on crops, i.e., in the cotton areas.[16] The evidence in Table 43 has been assembled from a large number of different studies, and the data are doubtless not fully comparable. It suggests that in spite of the probable increase in 1917–18, hours worked per year have been subject to a declining trend over the past thirty years and may perhaps have been significantly lower in 1932–36 than in 1909–13. This decline might well have been more pronounced were it not for the increased attention given to livestock in conformity with more stringent sanitary regulations.[17] Nevertheless, the decline in hours worked per year, when averaged over the entire occupied population (Chapter 6), must have been very slight, for two factors have operated to eliminate workers with very low hours per year. First, among those reported as gainfully occupied a marked decline has occurred in the proportion of children, who presumably work fewer hours per year than adults. Second, mechanization has caused a reduction in peak labor requirements at harvest time, thus probably eliminating some casual laborers, reported as occupied but working few hours per year. It is quite unlikely that the effects of these two factors are properly represented in the data of Table 43, which should be regarded rather as average hours worked by "full-time adults."

The considerations advanced in the preceding paragraph

[16] Hopkins, *Changing Technology and Employment in Agriculture,* p. 148.
[17] *Ibid.,* p. 26. See also p. 261 above.

TABLE 43

HOURS WORKED PER YEAR[a]

Region	Years	Type of Farm	Number of Cases	Annual Hours per Worker
Corn Area				
Northern Ohio	1923	General	17	3,283
Southern Ohio	1923	"	20	3,027
Marshall County, Iowa	1922–24	"	34	2,880
Shelby County, Iowa	1922–24	"	36	2,950
Iowa County, Iowa	1925–27	"	62	3,237
Hancock County, Ill.	1914–16	"	23	2,985
"	1920–22	"	26	3,162
Champaign-Piatt Counties, Ill.	1920–22	"	26	2,884
"	1923–27	"	58	2,847
"	1928–30	"	52	2,834
"	1931–35	"	112	2,754
Western Dairy Area				
Northfield, Minn.[b]	1905–12	"	64	3,453
Marshall, Minn.[b]	1905–11	"	41	3,311
Halstad, Minn.[b]	1905–12	"	58	3,410
Wisconsin	1922	Dairy	23	3,405
Northern Minnesota	1925	"	29	3,242
Southern Minnesota	1923	General	23	3,224
Eastern Dairy Area				
Seneca County, N. Y.	1919	Dairy	218	3,370
New York	1914–20	"	229	3,055
"	1921–25	"	156	3,138
"	1926–30	"	326	2,989
"	1931–35	"	396	2,981
Small Grain Area				
South Dakota	1925	Small grain	19	3,098
North Dakota	1925	"	22	3,076
Kansas	1925	"	21	3,273
Montana	1920	Irrigated crops	16	2,831
Range Area				
Colorado	1924	"	21	2,590
Middle Eastern Area				
North Carolina	1925	Tobacco and livestock	20	2,781
Western Cotton Area				
Texas	1925	Cotton	19	2,024
Other States				
Missouri	1912–14	General	28	3,020

[a] Except where otherwise stated, all data in this table are from J. A. Hopkins, *Changing Technology and Employment in Agriculture* (U. S. Bureau of Agricultural Economics, 1941), Table 14. The composition of the areas will be found in note a to Table 40.

[b] T. P. Cooper, F. W. Peck and Andrew Boss, *Labor Requirements of Crop Production,* Bulletin 157 (Minnesota Agricultural Experiment Station, 1916), Tables III and IX.

have suggested as a working basis the hours per year shown in Table 44. For the reasons given we may doubt whether there has been any actual decline in the averages if these could be computed for all occupied persons. We have therefore preferred to make alternative assumptions: (1) that hours per year were 5 percent higher in 1909–13 than in 1932–36; (2) that hours per year were the same in the earlier as in the later period. Next, we may estimate the average number of workers, by areas (Table 45). These figures lead, on the basis of

TABLE 44

ASSUMED AVERAGE ANNUAL HOURS PER WORKER GAINFULLY OCCUPIED, BY AREAS[a]

Area	*1909–13*		*1932–36*
	(1)	(2)	
Corn and dairy	3,150	3,000	3,000
Small grain	3,045	2,900	2,900
Cotton	2,205	2,100	2,100
Other	2,730	2,600	2,600

[a] These annual averages are roughly based on material in Table 43 and upon considerations advanced in the text. They are necessarily highly speculative and are intended only as rough approximations for use in the tentative reconstruction of total labor input undertaken on the following pages. For 1909–13 two alternative assumptions are made: estimate (1) implies that hours per year were 5 percent higher in 1909–13 than in 1932–36; estimate (2) assumes hours per year were the same in 1909–13 as in 1932–36.

TABLE 45

AVERAGE NUMBER OF WORKERS GAINFULLY OCCUPIED, BY AREAS[a]

Thousands

Area	*1909–13*	*1932–36*
Corn and dairy	3,339	2,635
Small grain	763	686
Cotton	4,129	3,540
Other	3,387	3,156
United States	11,619	10,017

[a] The data in this table are obtained by adjusting the series for total employment in Table 35 to conform to the level of the Census year estimates in the last line of Table 31. The required breakdown of the former series will be found in J. A. Hopkins, *Changing Technology and Employment in Agriculture* (U. S. Bureau of Agricultural Economics, 1941), Table 11.

the hypothetical annual hours per worker of Table 44, to tentative estimates for total labor input in manhours (Table 46). How much of these totals can we account for in terms of measurable direct labor requirements? The data on direct labor summarized in Table 42 cover only the products shown

TABLE 46

AVERAGE ANNUAL LABOR INPUT, BY AREAS[a]

Billion manhours

Area	*1909–13*		*1932–36*
	(1)	(2)	
Corn and dairy	10.5	10.0	7.9
Small grain	2.3	2.2	2.0
Cotton	9.1	8.7	7.4
Other	9.2	8.8	8.2
United States	31.2	29.7	25.5

Source: Tables 44 and 45.
[a] On basis of hours assumed in Table 44.

there—five major crops, three kinds of livestock, and truck crops. However, we have rough values for the percentages of major crops and livestock, in terms of direct labor requirements, to total agricultural production. Thus the coverage of the data in Table 42 (not including truck crops) ranges by areas from 32 percent in California to 86 percent in the Delta cotton area.[18] Taking the data in Table 42 by areas, and adjusting for coverage with the help of these percentages, we may obtain rough totals for direct labor on all products (Table 47).

The precarious nature of the results shown in Tables 46 and 47 has already been emphasized. Even the estimates for direct labor, which have been taken from studies by the National Research Project, are surrounded by a substantial margin of uncertainty. The figures for total labor input measured

[18] Hopkins, *op. cit.*, Table 54.

TABLE 47

DIRECT LABOR, AND ITS RATIO TO ANNUAL LABOR INPUT, BY AREAS[a]

Area	1909-13			1932-36	
	Average Annual Direct Labor	Percent of Average Annual Input[b]		Average Annual Direct Labor	Percent of Average Annual Input
	(billion manhours)	(1)	(2)	(billion manhours)	
Corn and dairy	4.7	45	47	4.9	62
Small grain	1.2	50	53	1.3	64
Cotton	5.3	58	61	4.3	57
Other	3.6	39	41	3.7	45
United States	14.8	48	50	14.1	55

[a] The estimates for direct labor are obtained by applying coverage adjustments, by areas, to the data in Table 42. The percentages are obtained by expressing these estimates for direct labor in terms of the figures for total labor input shown in Table 46.

[b] Estimate (1) assumes hours per year 5 percent greater in 1909–13 than in 1932–36; (2) assumes hours per year the same in 1909–13 as in 1932–36. See Table 46 above and discussion in text.

in manhours, although plausible enough, are in reality little more than guesswork. If, however, these results are even roughly correct, it would appear that while the input of direct labor (measured in hours) declined about 5 percent, total labor input (also measured in hours) fell by some 15 or 20 percent (Table 46). As a consequence, the share of direct labor in total labor input appears to have increased from about 50 to about 55 percent (Table 47). We have assumed that hours worked per year remained constant or declined; only if average annual hours per gainfully occupied worker actually rose between 1909–13 and 1932–36 could the conclusion reached be readily upset.

How is such a result to be interpreted? So far as crops are concerned, it is probable on a priori grounds that the considerable economy in direct labor suggested by Table 42 has been accompanied also by some savings of indirect labor, for it may be supposed that gasoline power units require less time for maintenance than do work animals. One estimate puts the reduction in overhead labor due to this cause at half a billion manhours.[19] On our assumptions the aggregate decline in overhead labor appears to have been much greater than this, and if estimate (1) is adopted, nine or ten times as great. Consequently there seem to have been other economies in overhead labor besides those attributable to the reduction in the burden of caring for work animals. Some of these no doubt arise indirectly from the introduction of gasoline power: trucking, for example, takes less time than animal transportation.

Although there has been a substantial reduction in direct labor on crops, the economy in direct labor as a whole has of course been very slight—apparently less than a billion manhours annually, or perhaps 5 percent. The explanation for this small saving is to be found in the fact that the substantial reduction in hours per acre in the case of staple crops has been largely offset by the growth in the importance of livestock and to a lesser extent of truck crops (Table 42). Consequently for agriculture as a whole the reduction we report for overhead labor is, over the quarter of a century considered, very much larger than the reduction in direct labor requirements. To summarize: for the United States as a whole, it seems fairly certain that direct labor has increased in importance relatively to total labor input, despite the sharp reductions which have occurred in hours per acre for practically all crops.

While the ratio of direct to total labor appears to have risen only moderately for the United States as a whole, it seems to have gone up rather sharply in the corn, dairy and

[19] E. G. McKibben and R. A. Griffin, *Tractors, Trucks and Automobiles* (National Research Project, Philadelphia, 1938), Sec. VI. The estimate quoted is built up as follows: economy in caring for work horses displaced, 280 million hours; in caring for horses retained, 160 million hours; and in growing young stock, 50 million hours.

small grain areas, and to have fallen slightly in the cotton areas. Because of the uncertainty concerning the assumptions underlying Table 47, these conclusions cannot be regarded as positively established, but they are at least suggestive, and it is worth while to inquire whether they are plausible. Changes in the ratio of direct to total labor appear to be associated with corresponding changes in the distribution of activity between crops and livestock. We presented in Table 42 evi-

TABLE 48

SHIFTS IN DIRECT LABOR, BY AREAS[a]

Million manhours

	Five Major Crops			*Livestock (Cattle, Hogs, Chickens)*		
Area	1909–13	1932–36	Change	1909–13	1932–36	Change
Corn and dairy	1,662	1,191	−471	1,848	2,420	+572
Small grain	524	299	−225	330	529	+199
Cotton	3,964	2,943	−1,021	541	759	+218
Other	1,320	1,139	−181	1,097	1,451	+354
United States	7,470	5,573	−1,897	3,816	5,159	+1,343

[a] The data shown in this table provide a partial breakdown of, and are derived in the same manner as, the material in Table 42 above; except for crops in 1932–36 they will be found in Hopkins, *op. cit.*, Table 54. The U. S. total for livestock in 1909–13 differs slightly from that shown in Table 42 above (3,808 million hours) because the latter is derived from Hopkins' Table 47: see footnote e to Table 42 above.

dence of a substantial shift in direct labor from crops toward livestock. In Table 48 this shift is broken down by areas. The decline in direct labor for crop production and the increased requirements for livestock apparently occurred in all four major regions shown in that table, but the incidence of the shift varied considerably. This variation is apparent from the percentages in Table 49, which gives the ratio of direct labor on crops to direct labor on crops and livestock in each region at the two dates. In both the corn and dairy areas and the small grain area, where the ratio of direct to total labor has risen appreciably, the shift appears to have been largest: the percentage of direct labor engaged in crop production declined by 14 and 25 percentage points respectively. In "other areas," where the ratio of direct to total labor seems to have increased only slightly, the shift from crops to livestock was apparently more moderate: labor on crops declined by 11

TABLE 49

PERCENTAGES OF DIRECT LABOR ENGAGED IN CROP PRODUCTION, BY AREAS[a]

Area	*1909–13*	*1932–36*
Corn and dairy	47	33
Small grain	61	36
Cotton	88	79
Other	55	44
United States	66	52

[a] Percentages shown in this table are computed from the data in Table 48, and cover five major crops and three livestock enterprises only.

percentage points. Finally in the cotton area, where the ratio of direct to total labor appears to have remained unchanged or to have fallen slightly, the shift from crops to livestock was comparatively slight: 9 points.

These results suggest that a shift toward livestock production tends to increase the ratio of direct to total labor. And if this is so, it might be thought that those areas (notably corn and dairy) where livestock is most important should show a higher value for this ratio than the areas (such as cotton) where comparatively little livestock is raised. In Table 47, however, either our measures are too rough, or the areas in question are too dissimilar in character for such a relationship to emerge at all clearly. True, the relative importance of direct labor in the corn and dairy areas had become, in 1932–36, greater than that in the cotton areas, but it was still no greater than in the small grain area.

It is nonetheless a plausible assumption that an increase in the relative importance of livestock production should raise the ratio of direct to total labor. For livestock must be tended, and must therefore absorb direct labor, all the year round; at the same time the demands of livestock upon machinery and work animals, whose maintenance requires overhead labor, are limited. Crops, on the other hand, require direct labor only at certain seasons of the year, but impose substantial demands for overhead labor for the maintenance of work animals and machinery. It seems probable that technological changes have reduced the direct labor requirements of crop production in larger measure than they have lessened the need for overhead labor: reductions in hours per acre for the five major crops have resulted in an economy of about a billion and a quarter hours of direct labor (Table 42), while the saving in overhead labor through the supersession of work animals by tractors has been put at only half a billion hours.[20] Presumably then, in the absence of a shift toward livestock production, there would have appeared a general fall in the ratio of direct to total labor for agriculture as a whole. The effect of the increased share of labor devoted to livestock may therefore be viewed as a factor which has more than outweighed the decline in the ratio of direct to total labor attributable to technological changes in crop production. In the corn and dairy areas the shift toward livestock appears to have been more than sufficient to offset this decline, and to have led to an actual increase in the relative importance of direct labor. In the cotton areas, on the other hand, factors making for a decline in the ratio of direct to total labor appear to have been in the ascendant; among these may be mentioned the migration of cotton production to Texas and Oklahoma where direct labor requirements per acre are much below those still prevailing in the older cotton areas.[21]

[20] See above, footnote 19.
[21] See above, p. 262.

YIELDS PER ACRE AND PER LIVESTOCK UNIT

It will be recalled that the discussion of labor requirements in the second section of this chapter was confined on grounds of convenience to a treatment of hours per acre and per livestock unit, and was limited to the period following 1909 because data on direct labor for earlier periods are lacking. We are more interested, however, in output of product than in acres cultivated, and the discussion in that section must now be supplemented by some consideration of the trend in yield per acre and per unit of livestock. Moreover, since much of the data is available for long periods of years we need not restrict ourselves here to the period since 1909.

Crop yields fluctuate with great violence from one year to another, and on this account the data in Table 50 and Chart 47 are shown in the form of 5-year averages. It will be seen from Table 50, which shows the trend in crop yields since the turn of the century, that few substantial changes have occurred. Most of what was said above concerning the trend in hours per acre holds also, therefore, for hours per physical unit of gross product. Yet there are some notable exceptions to this generalization, for marked increases have appeared, particularly in very recent years, in the yields of cotton and potatoes, and also of rice and tobacco—crops whose labor requirements were not treated separately above. In these cases, of course, hours of direct labor per bushel have fallen even more than hours per acre.

Crop yields are influenced by a wide variety of factors besides weather: particularly by the extent to which the application of fertilizer or of improved methods of cultivation offsets erosion and the natural exhaustion of the soil; by the development of new and more productive seed varieties; and by the appearance of fresh pests or improvements in the control of existing ones. Moreover, the United States averages quoted here may quite possibly conceal the effects of shifts

TABLE 50

CHANGES IN YIELD PER ACRE AND PER LIVESTOCK UNIT[a]

Averages for years indicated

Product	*Unit of Measure*	*1897–1901*	*1907–11*	*1917–21*	*1927–31*	*1937–40*
Major crops						
Corn	bushels	25.3	26.5	27.2	24.7	28.4
Wheat	bushels	13.8	14.0	13.4	14.7	14.0
Oats	bushels	29.2	26.1	30.5	29.8	31.7
Cotton	pounds	196	186	164	171	250
Potatoes	bushels	81	95	99	114	125
Other crops						
Barley	bushels	24.1	21.1	21.7	22.6	22.7
Rye	bushels	13.0	13.3	12.1	12.2	12.4
Buckwheat	bushels	16.1	17.2	16.0	15.1	15.5
Rice	bushels	27.0	36.5	38.4	45.4	49.9
Flaxseed	bushels	8.4	7.8	6.1	6.4	9.1
Tame hay	tons	1.27	1.27	1.30	1.31	1.37
Sweetpotatoes	bushels	84	95	96	90	85
Tobacco	pounds	784	827	785	771	927
Sugarcane[b]	tons	[d]	17.0[e]	15.4	14.9	20.5
Sugar beets	tons	[d]	[d]	9.5	11.1	12.3
Vegetables[c]	tons	[d]	[d]	4.0[f]	3.4	3.4
Livestock						
Milk	pounds per milk cow	[d]	3,779[e]	3,781	4,510	4,497
Eggs	per laying chicken	[d]	85[e]	88	93	102

[a] Acres refer to acreage harvested. Data are taken from *Agricultural Statistics, 1941*. For milk, additional data are from R. G. Bressler, Jr. and J. A. Hopkins, *Trends in Size and Production of the Aggregate Farm Enterprise, 1909–36* (National Research Project, Philadelphia, 1938), Tables A-95 and A-96. Data for vegetables from *Crops and Markets,* December 1940.

[b] Sugarcane for sugar and for seed.

[c] Asparagus, snap beans, cabbage, cantaloups, carrots, cauliflower, celery, sweet corn, cucumbers, lettuce, onions, peas, spinach, tomatoes, watermelons. The coverage, even of these items, is not complete.

[d] Not available.

[e] Average 1909–11.

[f] Average 1919–21.

between regions with differing yield levels. While we have not investigated this question in detail, we have thought it worth while to test the trend in the yield of a number of important crops for which data are readily available since 1866. The average annual change computed by least squares is shown for six such crops in Table 51. The figures in the column called "fiducial level" measure the expectation that the value shown for the annual change in yield would be obtained by chance if the true trend were perfectly horizontal. It is evident that the trends reported, small even in the case of potatoes, must be considered significant in all cases except corn.

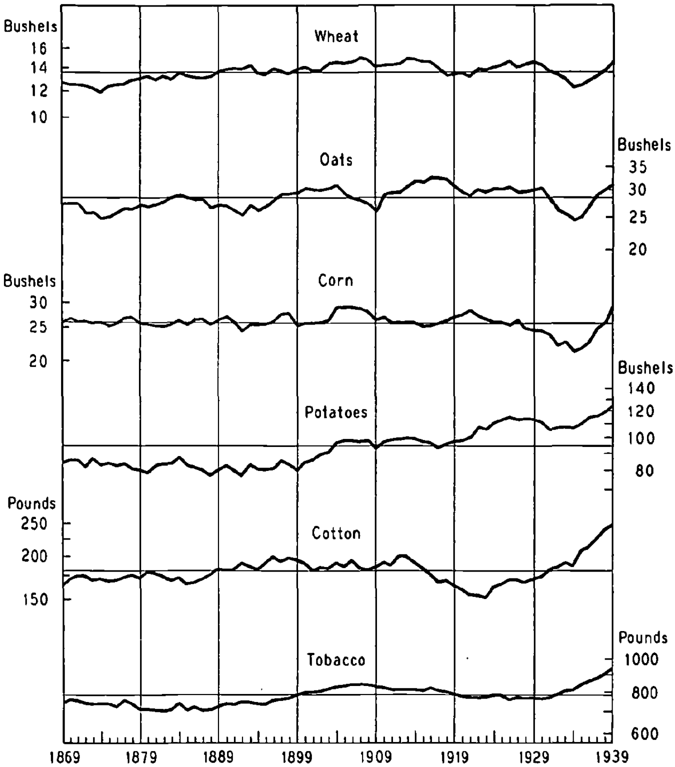
The absence of any upward trend in the yield of corn suggests that, at least until very recently, it has been fighting a losing battle against pests and soil depletion. Moreover there has been a slight shift in acreage away from the high-yielding regions of the corn area toward lower-yielding dairy states. The commercial development of hybrid corn in the middle 1930's is likely in time to reverse this situation, perhaps very shortly. Yields per acre of hybrid corn apparently run up to 35 percent above corresponding yields of open-pollinated varieties formerly in use.[22] Hybrid corn was first introduced commercially in the early 1930's, and employed in 1939 to plant about one quarter of the entire corn acreage; it gained most rapid acceptance in the Corn Belt itself. The increase in yield obtained by its use—from 10 to 20 percent—is apparently much the same in regions with a low yield as in regions with a high yield per acre.[23]

The slow increase in the yield of wheat—0.15 percent per annum over the last three quarters of a century—is the outcome of a conflict between improved techniques, on the one

[22] L. K. Macy, L. E. Arnold and E. G. McKibben, *Corn* (National Research Project, Philadelphia, 1938), p. 16.

[23] U. S. Department of Agriculture, *Technology on the Farm* (Washington, 1940), pp. 21-22; A. A. Dowell and O. B. Jesness, "Economic Aspects of Hybrid Corn," *Journal of Farm Economics*, Vol. XXI (May 1939), pp. 479-88.

Chart 47
CROP YIELDS
Five-Year Averages, 1869 - 1939



Ratio scale
Horizontal lines show average 1866-1941
For source and notes see Appendix D

hand, and the exhaustion of the soil and shifts toward climatically less favored areas, on the other. The introduction of new varieties has been slowly gaining over rust and insect pests, while irrigation and crop rotation have helped to compensate for the irregularity of precipitation in some of the newer wheat areas.[24] In particular it has been found useful

[24] R. B. Elwood, L. E. Arnold, D. C. Schmutz and E. G. McKibben, *Wheat and Oats* (National Research Project, Philadelphia, 1939), Ch. V.

in the dry areas to leave the land fallow. Nevertheless, yields have actually declined in the range area of the western plains, whereas in California diminishing acreage has been accompanied by higher yields on the acres remaining.[25] The average annual percentage increase in the yield of oats has been about the same as for wheat, and the crop has been subject to much the same influences, although losses due to infection have been somewhat less serious. Except in areas of extremely low or uncertain rainfall, rust in one form or another is the main

TABLE 51

ANALYSIS OF CHANGE IN YIELD PER ACRE

Selected Crops, 1866–1940

Crop	*Unit of Measure*	*Mean Annual Change in Yield per Acre*	*Ratio of Mean to Its Standard Error*	*Fiducial Level*	*Mean Annual Percentage Change in Yield per Acre*
Corn	bushels	−.0084	.50	.6	0
Wheat	bushels	+.0199	2.64	.01	+.15
Oats	bushels	+.0427	2.20	.03	+.15
Cotton	pounds	+.4344	3.21	<.01	+.24
Potatoes	bushels	+.5277	9.07	<.01	+.56
Tobacco	pounds	+1.5994	5.42	<.01	+.21

obstacle faced by both these crops. Sprays have been developed; and since 1936 a campaign has been undertaken for the destruction of the buckthorn and barberry bushes of the Great Plains which act as intermediate hosts to the fungus. It seems most likely, however, that the problem will eventually be solved through the medium of improved varieties, both of wheat and of oats.[26]

The average annual increase in the yield of cotton is about one-quarter percent—greater than that shown by either wheat or oats. Here again new varieties have played their part, par-

[25] *Ibid.*, pp. 6-7.
[26] *Ibid.*, Ch. V.

ticularly in resisting the attacks of the boll weevil. The problem has been to produce varieties that mature early enough to escape the ravages of the weevil, and yet offer a reasonably long staple. This problem has not yet reached its solution. It seems certain that cotton yields would have increased very much more rapidly but for this form of infestation, and the primary influence in rising yields must probably be credited to improvements of fertilizers and their increasing use. No doubt the average yield for the United States as a whole also would have risen more rapidly but for the shift of production toward the western cotton area, Texas and Oklahoma, in which appreciable amounts of fertilizer are not used, the farmers being content with comparatively low yields per acre.[27]

The greatly augmented yield of potatoes—more than 0.5 percent per annum on the average—is attributable largely to the importance of three states—Maine, Idaho and Colorado. The yield per acre is well above the national average in these states, and is still increasing; moreover there have been decided acreage shifts in their favor. Concentration upon the potato in each of them has apparently made profitable extensive use of commercial fertilizer and pest control.[28] New varieties also have played their part. Potatoes show a wider regional disparity in yield than do most other crops: for example, Maine, Idaho and California each had an average yield of more than 250 bushels an acre in 1937–40, compared with less than 100 bushels in Minnesota, North Dakota and several other important potato-producing states. These differences do not seem to be traceable to climatic or soil conditions; and it is clear that an improvement in cultural practices in the less efficient regions would have a marked effect upon average yields from year to year in the nation as a whole.

[27] Holley and Arnold, *Cotton,* Sec. IV.

[28] H. E. Knowlton, R. B. Elwood and E. G. McKibben, *Potatoes* (National Research Project, Philadelphia, 1938), Sec. III.

Tobacco yields have probably been increased as a result of more intensive cultivation in response to acreage restrictions under the AAA, and especially to the Kerr-Smith Act of 1934. But the rise in yields antedates these restrictions, and is to be traced also to the growing importance, ever since the early 1920's, of flue-cured cigarette tobacco in North Carolina: both yields and acreage have swelled in this state.

Among other crops, the figures in Table 50 suggest a rising trend in the yield of sugar beets. This results largely from sharply increased yields in California during the past fifteen years; in that state the crop was introduced into especially suitable areas and disease-resistant varieties were selected for cultivation.[29]

Yields of vegetables, although data are available only since 1919, appear to show a downward trend. Reasons for this have been summarized as follows:

> The effect of new varieties on yields . . . has been obscured by many other factors which have tended, on the whole, to decrease yields. It is quite generally believed among horticulturalists that diseases and insect pests take a heavier toll than they did in former years. A relative shift of vegetable acreage to poorer lands and the decline in fertility of much of the irrigated land through the accumulation of deposited salts have tended further to reduce yields. With the great increase in vegetable production, and particularly during the depression, many farmers entered into vegetable production without previous experience and sufficient knowledge to obtain high yields. The ever-increasing emphasis on quality has also probably affected yields through closer culling and by causing vegetables to be harvested at smaller sizes when the quality is choicer.[30]

[29] L. K. Macy, L. E. Arnold, E. G. McKibben and E. J. Stone, *Sugar Beets* (National Research Project, Philadelphia, 1937), p. 11.

[30] J. C. Schilletter, R. B. Elwood and H. E. Knowlton, *Vegetables* (National Research Project, Philadelphia, 1939), p. 17.

The data summarized in Chart 36 (Chapter 3) suggest, however, that the downward trend in the yields of these crops may have been arrested.

In Table 52 the material in Table 50 has been used for the construction of indexes of yield per acre and per livestock unit, as a further aid to the examination of the trend in these data. It will be seen that in 1927–31 crop yields were not on the average significantly different from the level prevailing three decades previously; but that during the most recent decade a rise of 15 to 20 percent apparently took place. We cannot be certain, of course, how far this increase has been attributable to the particular circumstances of individual crops, and how far to more intensive cultivation or

TABLE 52

INDEXES OF YIELD PER ACRE AND PER LIVESTOCK UNIT[a]

1907–11:100

Product	*1897–1901*	*1907–11*	*1917–31*	*1927–31*	*1937–40*
Five major crops[b]	100.0	100.0	95.4	99.9	120.0 103.3[f]
Fifteen crops[c]	100.3	100.0	95.8	99.8	118.5 103.9[g]
Milk and eggs[d]	..	100.0	101.2	116.7	119.0
Combined index[e]	..	100.0	97.5	105.7	116.5 108.6[g]

[a] These indexes are based upon the data given in Table 50; the yields shown in that table have been weighted by the product of price and acreage required for net output (or number of animals) for 1899, 1909, 1919, 1929 and 1937 with the use of the Edgeworth formula. Figures are averages for years indicated.

[b] Corn, wheat, oats, cotton and potatoes.

[c] These comprise the various crops in Table 50 with the exception of truck crops.

[d] Eggs per laying chicken; milk per milk cow.

[e] Data for fifteen crops; and for milk and eggs.

[f] Excluding cotton for the comparison of 1937–40 with 1927–31.

[g] Excluding cotton and tobacco for the comparison of 1937–40 with 1927–31.

the selection of the better soils as a result of acreage restrictions associated with Agricultural Adjustment. To what extent the increase will prove permanent it is still more difficult to say. Acreage restrictions have probably played a part in the case of cotton and tobacco, and perhaps also in that of wheat. Although we have no data for milk cows and chickens before 1909, it seems clear that the increase in their productivity is more marked and of longer standing than that of crop acres.

CONCLUSION

From the results cited here it is evident that during the forty years under review the trend in the yield of crops per acre has had very little effect upon agricultural productivity as a whole, except for very recent years. The series for output per worker in Table 38 were probably depressed somewhat during the middle of the period by low yields, especially for cotton. But if yields per acre of all crops had remained constant throughout, it is unlikely that these indexes of productivity would have been changed, except for the last two or three years of the period, by more than a point or two. In these most recent years, by contrast, yields exercise an important influence. The rise in output per worker reported for 1937 and 1938 (Table 38)—a rise which is all the more striking if one considers that the indexes are 5-year averages—must be ascribed largely to the sharp upswing in yields per acre, particularly of cotton and tobacco.

If the increase in productivity between 1900 and 1930—a rise of about 30 percent in output per adult male—is due not at all to changes in yield per acre, to what can it be attributed? So far as crops are concerned, it must be credited entirely to reductions in hours per acre, and in associated indirect labor. These reductions were, as we have seen, substantial. In the case of livestock, on the other hand, there was no economy in hours of direct labor per animal, but milk per cow and eggs per chicken were already increasing steadily before 1930. There may also have been a shift toward more economical feeds or methods of feeding, but we can say little on that point. Meanwhile livestock benefited indirectly through economies in the labor needed to raise feed crops. Since we cannot divide the labor supply between crop production on the one hand and livestock raising on the other, we are unable to distribute the increase of productivity accurately between these two sectors of the industry. Nevertheless, the foregoing discussion lends support to the view that the largest part of the measurable gain in output per worker since 1900 is associated with crop rather than with livestock production. This is not to imply that the greatest scope for further increase of efficiency is to be found in the latter rather than in the former kind of activity. Yet it is true that mechanization has been the largest single influence in reducing labor input per unit of product; and it is true also that mechanization has lagged notably in livestock production. Whether this lag is to prove permanent or will be overcome in the years to follow, only the future can disclose.