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WHEAT STUDIES

OF THE

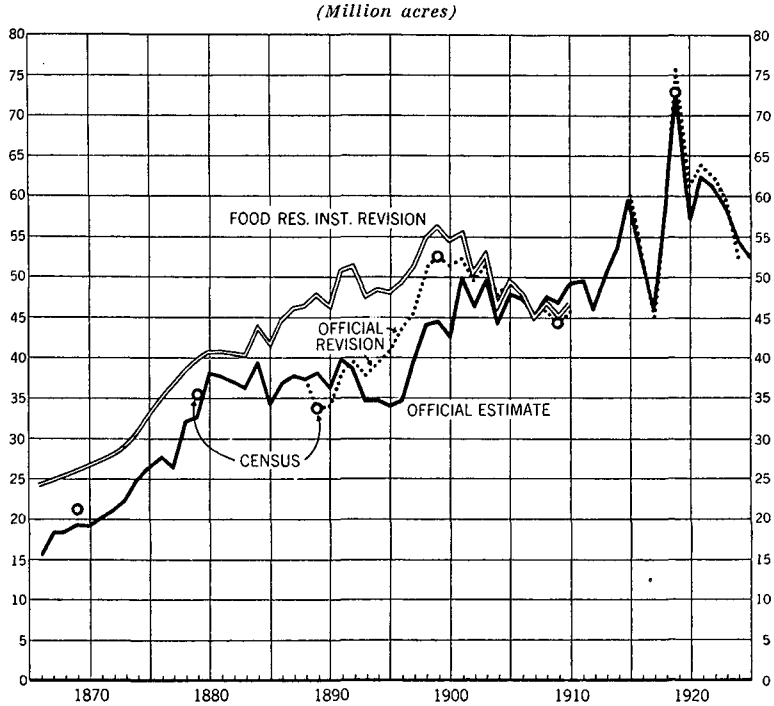
FOOD RESEARCH INSTITUTE

VOLUME II NUMBER 7

WHEAT ACREAGE AND PRODUCTION IN THE UNITED STATES SINCE 1866

WHEAT ACREAGE IN THE UNITED STATES, 1866–1925

(Million acres)



Data on domestic consumption of wheat and flour, seed requirements, and exports demonstrate that the actual production of wheat in the United States prior to 1902 must have been considerably greater than stated in the official estimates. The understatement is found to arise chiefly from errors in the acreage estimates; these have been revised as indicated in the accompanying chart, with corresponding changes in the production estimates.

STANFORD UNIVERSITY, CALIFORNIA

June 1926

THE FOOD RESEARCH INSTITUTE

STANFORD UNIVERSITY, CALIFORNIA

Established in 1921 jointly by the Carnegie Corporation of New York and the Trustees of Leland Stanford Junior University, for research in the production, distribution, and consumption of food

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WHEAT STUDIES

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The central feature of the series is a periodic analysis of the world wheat situation with special reference to the outlook for supplies, requirements, trade, and prices. The volume opens with a review of the previous crop year. Subsequently three surveys of current developments are made at intervals of about four months.

These surveys are supplemented by intensive studies bearing on the appraisal of the wheat situation and outlook and upon related matters of national policy. Typical subjects are indicated in the list of studies shown on the fourth cover page of this issue.

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WHEAT STUDIES

OF THE

FOOD RESEARCH INSTITUTE

VOL. II, NO. 7 STANFORD UNIVERSITY, CALIFORNIA JUNE 1926

WHEAT ACREAGE AND PRODUCTION IN THE UNITED STATES SINCE 1866

A REVISION OF OFFICIAL ESTIMATES

SUMMARY

Evidence has accumulated from various sources indicating that the official estimates of acreage and production of wheat in the United States in certain years have been wide of the truth. Further study of the facts, as assembled in the succeeding pages, indicates that in recent years the estimates have been quite reliable, but proves conclusively that prior to 1902, at least, the official estimates were invariably too low, as were also the census figures. For several years the actual acreage and production are shown to have been as much as 30 to 40 per cent above the official estimates.

Not only are the earlier official estimates demonstrably low, but over considerable periods they show erroneous trends. Whereas the original official estimates show a slight decrease in total wheat acreage in the United States during the fifteen years 1880 to 1895, it can now be shown that the acreage increased some 15 per cent during this period. Again, the original estimates indicate that between 1900 and 1910 total wheat acreage in the United States remained substantially constant, except for year-to-year fluctuations, and was considerably higher than in any previous period. Yet facts now available show that the acreage reached a peak in 1899 which was not equaled again until 1915; between 1899 and 1907 it declined nearly 20 per cent, reaching in 1907 a level lower than in any previous year since 1885. With these errors of the official estimates in both level and trends there were naturally some considerable errors in the estimates of year-to-year changes in acreage and production.

These errors result in giving a seriously distorted picture of the development of wheat growing in the United States. Between 1880 and 1910 in particular, the original acreage estimates and the existing official revisions give a quite erroneous impression of the effects of price changes and of the other forces that were influencing acreage. Studies of the effect of production changes on prices likewise are seriously handicapped by the errors in the production estimates for these years.

The most trustworthy revision of the original acreage and production estimates can be made only with the aid of a thorough analysis, state by state, of all the relevant data in the possession of the Department of

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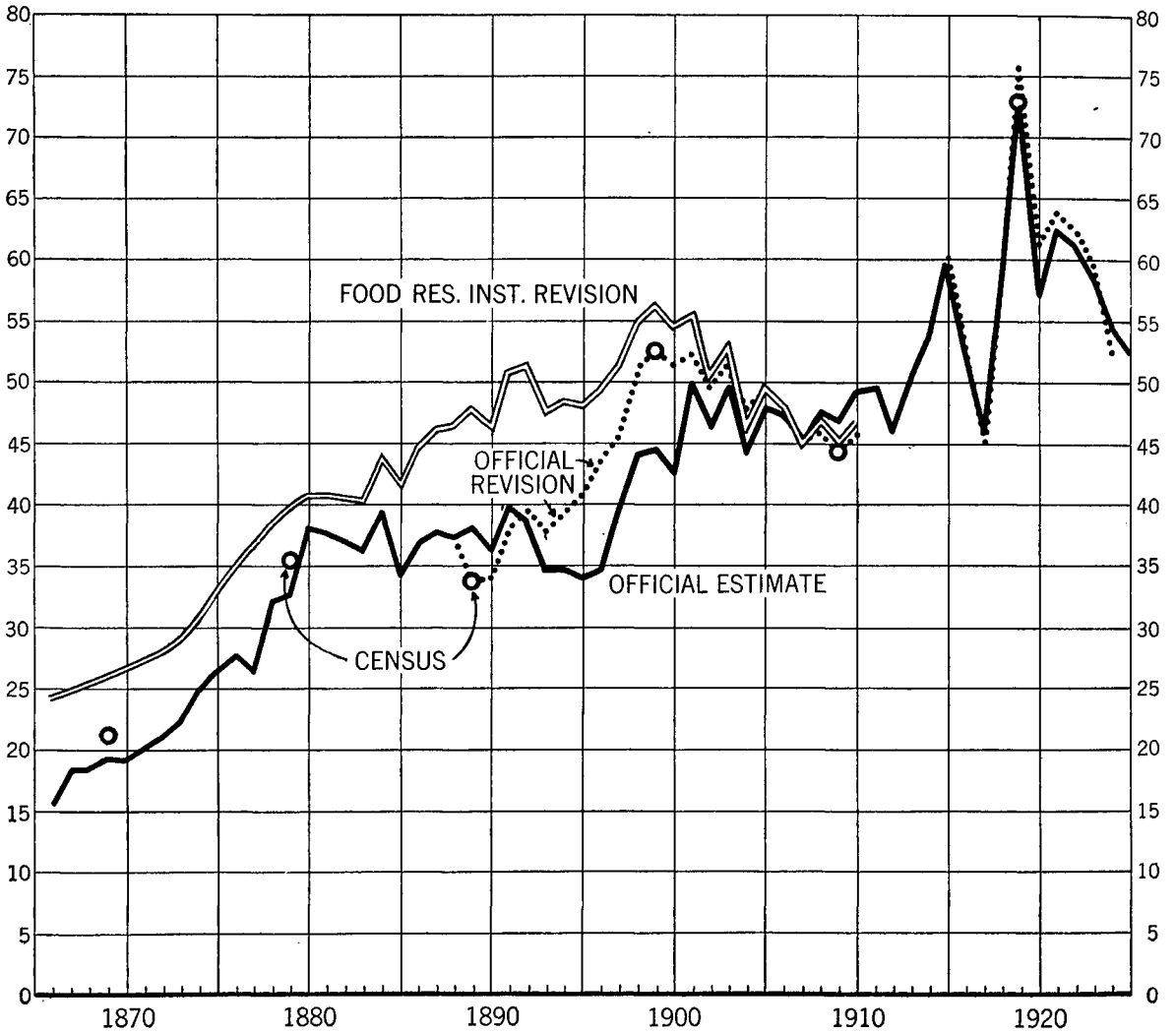
Agriculture or available to it. Such a study was undertaken several years ago by the Division of Crop and Livestock Estimates of the Department of Agriculture, but the magnitude of the task, combined with limitation of funds and the pressure of work on current estimates, has made progress slow.[1]

The principal errors in the original estimates can be removed by treating the United States as a whole, and many of them only by this method. The seriousness of the errors and the need for more reliable figures as a basis for current studies have led us to prepare such a revision for the period 1866–1910, to be used pending the appearance of the more thorough official revision. In brief, the revision is accomplished by determin-

CHART 1.—ESTIMATES OF WHEAT ACREAGE IN THE UNITED STATES, 1866–1925*

(Million acres)



* The official acreage estimates, prior to 1902, are found to have been much too low because they started with census data which were sometimes very incomplete and depended for estimates of subsequent changes on reports of crop correspondents who could not know the facts and who generally understated the actual changes. In recent years the census enumerations and the Department of Agriculture estimates of acreage changes have both been greatly improved. Data given partly in Table 1 and fully in Appendix Table I.

[1] The revised acreage estimates for New York State have recently been published in Department Circular 373, April 1926. The publication is described as "A study of methods to be used in revising crop and livestock estimates of the United States Department of Agriculture."

ing first the general level and trend of production from data on disposition, the principal items in which can be determined quite accurately, and then utilizing the official estimates of acreage and yield per acre to obtain the year-to-year fluctuations.

The acreage estimates thus obtained are shown graphically in Chart 1, compared with the original official estimates, the census enumerations, and the latest official revisions. Table 1 shows our revision of both the acreage and production estimates compared with existing official figures over the period 1880–1900, in which the greatest changes are made. The figures for the entire period since 1866 appear in Appendix Table I. The extent of the revision found necessary is at once apparent. Errors remaining in this revision which can probably be removed by the more thorough and detailed study now in progress in the Department of Agriculture are of such a nature that they cannot materially affect the general level of the revised figures here presented. The more detailed study will undoubtedly alter many of the year-to-year changes here shown, though probably in very few instances to the extent of changing their direction.

The present study, then, considers the evidence on which the principal errors in the original estimates may be demonstrated and applies this evidence in a revision of the estimates of acreage and production of wheat in the United States for the period 1866–1910. In the course of the discussion it describes the methods which have been used in preparing the original official estimates, the improved methods which have been introduced in recent years, and the type and degree of error which may be expected from both the old and the new methods of preparing the estimates.

TABLE 1.—FOOD RESEARCH INSTITUTE REVISION OF ACREAGE AND PRODUCTION ESTIMATES COMPARED WITH ORIGINAL AND REVISED OFFICIAL ESTIMATES, 1880–1900*

Year	Acreage (millions)			Production (million bu.)		
	F.R.I. revision	Original official	Revised official	F.R.I. revision	Original official	Revised official
1880	40.8	38.0	....	535.0	498.6	.....
1881	41.0	37.7	....	417.8	383.3	.....
1882	40.7	37.1	....	553.7	504.2	.....
1883	40.5	36.5	....	469.3	421.1	.....
1884	44.0	39.5	....	571.4	512.8	.....
1885	41.6	34.2	....	432.3	357.1	.....
1886	44.8	36.8	....	555.0	457.2	.....
1887	46.2	37.6	....	558.8	456.3	.....
1888	46.5	37.3	....	516.3	415.9	.....
1889	47.9	38.1	33.6	618.4	490.6	434.4
1890	46.5	36.1	34.0	515.7	399.3	378.1
1891	50.8	39.9	37.8	787.1	611.8	584.5
1892	51.2	38.6	39.6	680.7	515.9	528.0
1893	47.7	34.6	37.9	539.4	396.1	427.6
1894	48.4	34.9	39.4	634.2	460.3	516.5
1895	48.1	34.0	40.8	668.9	467.1	469.5
1896	49.4	34.6	43.9	612.6	427.7	544.2
1897	51.5	39.5	46.0	685.0	530.1	610.3
1898	55.1	44.1	51.0	831.6	675.1	772.2
1899	56.4	44.6	52.6	682.2	547.3	636.1
1900	54.6	42.5	51.4	638.6	522.2	602.7

* This table covers only the period in which the greatest changes have been made in the present revision. Data for the entire period 1866–1925, together with references to sources, will be found in Appendix Table I.

I. EVIDENCE OF ERROR IN OFFICIAL ESTIMATES

The clearest evidence of the errors in the original official estimates of wheat production in the United States is found in the data presented in Chart 2. The irregular solid line represents the quantity of wheat which appears to have been available out of each crop for domestic consumption as food and feed and for waste. The data are expressed in terms of bushels per capita for readier comparison with other evidence on per capita consumption. This per capita domestic retention out of each crop is readily calculated by deducting from the estimated production the seed requirements and the exports of wheat and of flour in terms of its wheat equivalent and reducing the remainder to a per capita basis.[1] Obviously, domestic retention fluctuates widely from year to year as stocks are increased or decreased during the year. The general level, which should correspond with the general level of actual domestic consumption and waste, is

[1] The calculations are shown in Appendix Table II.

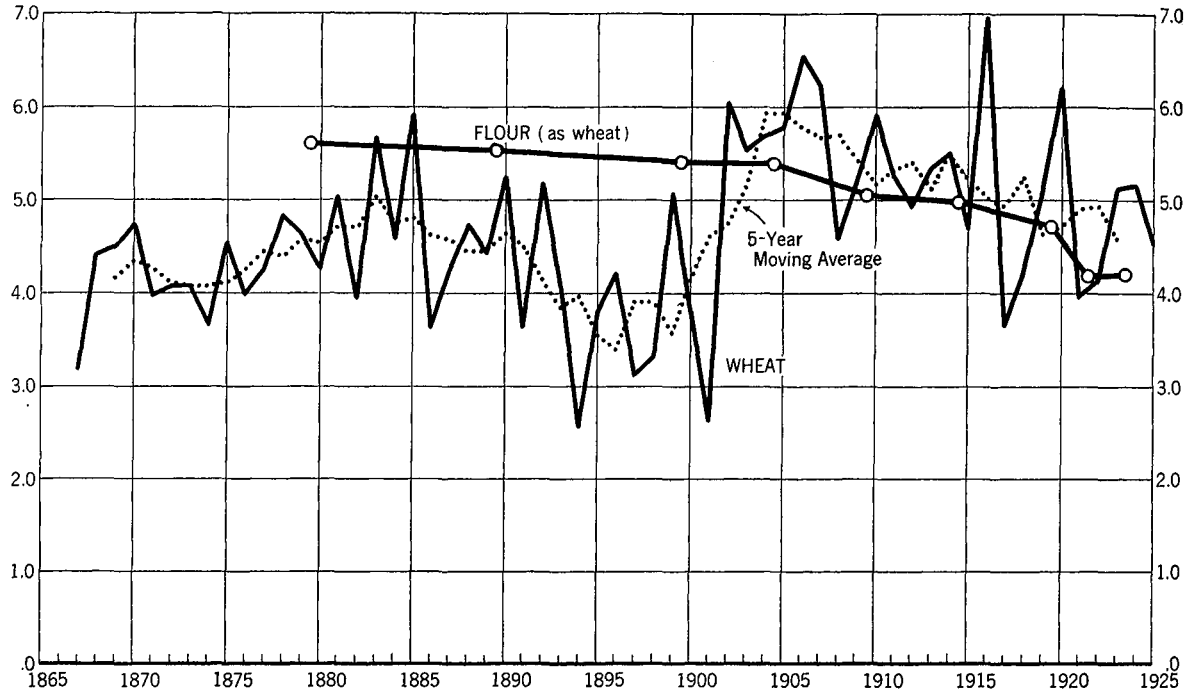
shown more clearly by the five-year moving average, represented by the dotted line.

For comparison with the apparent domestic consumption of wheat per capita, as derived from the production estimates, we have figures on flour milling obtained from the Census of Manufactures. Deducting flour exports from the total quantity milled and correcting for changes in flour stocks during the year gives the apparent consumption of flour in each census year. Converting the flour to terms of wheat on the basis of the average wheat requirement per barrel of flour, as shown by each census, and reducing to a per capita basis, we have the figures shown by the hollow circles in Chart 2, representing the domestic consumption of wheat per capita in the form of flour. Prior to 1901 the apparent domestic consumption of wheat in the form of flour alone is consistently above the quantity of wheat apparently available for domestic consumption for both food and feed and for waste. During the middle 'nineties the annual discrepancy amounts to about 1¾ bushels per capita, or a total of some 120,000,000 bushels for the country.

There seems to be every reason to suppose that the figures on consumption of flour as derived from the census are highly reliable and certainly not excessive. While many mills have not had accurate records and the censuses represent to some extent a collection of millers' estimates, there seems no reason to expect an upward bias in the estimates. Any defects in the census must be largely in the direction of incomplete enumeration with a consequent understatement of the production. The high degree of consistency between the figures on per capita consumption derived from successive censuses (prior to 1909, at least) tends to increase confidence in the figures. The marked drop in consumption indicated in

CHART 2.—WHEAT MILLED FOR DOMESTIC FLOUR CONSUMPTION, 1879–1923, COMPARED WITH WHEAT APPARENTLY AVAILABLE FOR FOOD, FEED, AND WASTE, 1866–67 TO 1924–25*

(Bushels per capita)



* Deducting seed requirements and exports of wheat and flour (as wheat) from the original production estimates, 1866–1900, the quantity left is much less than appears to have been actually milled for domestic flour consumption. Since 1900 a similar calculation based on the latest official estimates shows a reasonable margin, on the average, for feed and waste. Cf. pp. 257–58 and Appendix Table II.

recent years has led to some questioning of the reliability of the later figures, but additional evidence has been found which leaves no question of their substantial accuracy.[1] In view of the uniformity of per capita consumption of flour from year to year, as indicated by the close agreement of the figures for most census years and as supported by common observation, it appears not only that the figures derived from the census give a reliable statement of consumption in those years but also that the lines connecting the figures for census years probably give a reasonably accurate picture of per capita consumption of wheat in the form of flour in the intervening years.[2]

Nor can any conceivable error in calculating from the production estimates the apparent retention of wheat account for more than a small fraction of the discrepancy. If either the figures on wheat exports or the estimates of seed requirements were excessive the apparent retention would thereby be reduced, but any errors in these figures are probably largely in the other direction. Thus while export figures may sometimes tend to run slightly below the facts owing to a failure to record all of the exports, the only factor tending to make them excessive seems to be the possible inclusion of some Canadian grain counted as an export without having previously been included in the imports. There is supposed to have been until recently a small error from this latter source, but it cannot have been a factor during the years in which the discrepancy shown in Chart 1 was greatest, since Canada during those years was exporting only insignificant quantities of wheat. The seed requirements, moreover, are based on the customary figure of 1.38 bushels of seed per acre planted;[3] if there is any significant error here it is in the direction of understatement of the seed requirements for earlier years rather than overstatement, for the adoption of the modern drill has considerably reduced the quantity of seed required per acre.

Finally, any possible errors in the figures on flour exports would have no effect on the discrepancy shown in Chart 2. The exports of flour (in terms of wheat) are subtracted from both the wheat and the flour production figures in arriving at the apparent domestic wheat retention and flour consumption shown in Chart 2, and any errors would affect both equally and have no influence on the discrepancy between them.

Under these circumstances, the fact that during the period 1879–1900 the quantity of wheat ground for domestic flour consumption was much greater than the quantity apparently available for domestic consumption as food, feed, and waste, can be explained only on the ground of a serious understatement of actual production.

II. PLAN AND SCOPE OF REVISION

General Plan

The general method of arriving at the revised estimates is a refinement of one which was in common use in the grain trade in the middle 'nineties, when the trade generally recognized that the current production estimates were considerably under the facts. As noted above, it appears that actual per capita consumption of wheat for human food in the United States changes little from year to year except for a downward trend in recent years, and that estimates derived from the census figures on flour milling furnish a highly reliable basis for judging the general level, year by year,

[1] This evidence is presented in detail in the July number of Wheat Studies, now in press.

[2] This conclusion also is strongly supported by the study of flour consumption to appear in the July number of Wheat Studies.

[3] For earlier years in which the abandonment of winter wheat is not known the seed requirement must be calculated from the acreage harvested. For the purposes of the present calculation it is assumed that the ratio of acreage planted to acreage harvested averaged the same throughout as in the years 1909–1924, namely 1.076 acres planted for each acre harvested. This gives an average seed requirement of 1.48 bushels per acre harvested, which forms the basis for calculating seed requirements prior to 1901. The defects in this assumption are obvious, but there is little basis for reaching a better figure and no modification that could be made would greatly improve the resulting estimates.

of per capita consumption of wheat for human food in the United States. Disappearance of wheat as feed and waste has been variously estimated and is not accurately known,[1] but if we estimate it on the basis of the average difference between domestic disappearance of wheat in the form of flour and total domestic disappearance for food, feed, and waste, as derived from the relatively accurate crop estimates of recent years, we shall probably not be far from the truth. What is perhaps more important, we shall at least obtain a series consistent with the production estimates of recent years. Inspection of Chart 2 (p. 240) shows that this difference, in bushels per capita, has shown no change, except for year-to-year fluctuations, since about 1901. During this period the difference has averaged four-tenths of a bushel per capita.

Adding to the calculated annual domestic consumption of wheat in the form of flour, feed, and waste, the calculated seed requirements and the net exports of wheat and of flour in terms of wheat, we arrive at what may be called a *total apparent disposition* of wheat. This apparent disposition does not correspond to production in any one year, partly because actual disposition for food, feed, and waste varies slightly, year by year, but chiefly because actual disposition is in some years increased above production by drawing on stocks and in other years decreased below production by building up stocks. Over any period of years, however, production and apparent disposition must be substantially the same; the trend of production must be identical with the trend of total disposition. It has been found possible also to estimate the changes in stocks from year to year and to obtain a still closer estimate of what the actual production must have been.

The apparent disposition of wheat, as thus calculated and corrected for estimated changes in stocks, may be called the *theoretical production.* Dividing the theoretical production for each year by the yield per acre, which seems to have been estimated with a fair degree of accuracy, gives a *theoretical acreage,* shown in Chart 4 (p. 249). This theoretical acreage, like the theoretical production, may vary considerably from the actual in any year, owing chiefly to the effect, not entirely removed, of changes in stocks; but its trend must be substantially the trend of actual acreage.[2]

Although seriously in error as regards the general level and trend, the original acreage estimates since 1880 seem to give a fairly reliable indication of changes from year to year. Prior to 1880 the original acreage estimates seem to be of little value either as an indication of the general level of acreage or of the changes from year to year. Making use of the computed theoretical acreage to determine the general level and trend of the acreage, and of the original acreage estimates since 1880 to determine the changes from year to year, apart from the trend, we obtain a *revised acreage* for each year from 1880 to 1910. For years prior to 1880 it seems impossible to do better than take the smooth curve representing the trend of the theoretical acreage, as the best available basis for the revised acreage. Beginning with 1911 the official estimates, as most recently revised, are employed. The complete series for the revised acreage is shown graphically in Chart 1 (page 238) and statistically in Appendix Table I. Multiplying the revised acreage by the reported yield per acre gives the revised production, shown also in Appendix Table I.

Scope of Our Revision

Approaching the problem of correcting as far as possible the errors in the existing production estimates for past years, it becomes apparent that the official estimates of yield per acre must be accepted substantially as they stand.[3] If revised acreage figures were assembled for each state separately, and used as weights in computing, from the yields by states, a new average yield per acre for the United States, a more trustworthy series would be obtained; but

[1] Certain available evidence on the subject has been discussed in a previous number of Wheat Studies, "The Disposition of American Wheat Supplies," August 1925, I, 308–10.

[2] This statement is not valid if there is any serious error in the general level of the estimates of yield per acre, but all the evidence indicates that the yield estimates may be accepted with considerable confidence.

[3] See below, pp. 243–44.

this would prove a very heavy task, to be undertaken only with the full information available in the records of the Department of Agriculture, and would, in fact, involve duplicating work already under way in the Department. Since the really serious errors are in the acreage estimates,[1] the yield figures may be accepted as they stand and effort concentrated on revision of the acreage estimates. For each year for which the Department of Agriculture has published a revised estimate of yield per acre, the Department revision will be used. Yields indicated by the census are not used, as they have never been accepted by the Department of Agriculture and it may be assumed that the Department has not rejected them without valid reasons.[2] In undertaking the revision of the acreage estimates it seems unwise, as already indicated, to attempt a revision by states. Indeed, the most valuable information on which the revision may be based is applicable only in connection with totals for the United States.

Since 1910, errors in the official estimates which might be corrected by the methods here employed, are so small that no attempt is made to extend the revision to these later years. If a revision for the years 1911–25 is attempted, it should be with the detailed information contained only in the records of the Bureau of Crop and Livestock Estimates. In its final form the present revision stops, therefore, with 1910.

III. CHARACTERISTICS OF OFFICIAL ESTIMATES

Basis of Earlier Estimates

To make clear the basis for the present revision of the earlier estimates of acreage and production of wheat in the United States, it is necessary to consider briefly the methods used in preparing the original production estimates and the problems which were encountered.

Crop estimating appears always to have involved the problem of harmonizing more or less conflicting data derived from different sources. As methods of gathering the data have improved, discrepancies between estimates derived from different sources have become less, but it seems possible to avoid inconsistent estimates only by refusing to consider more than one source and method of deriving the estimates. Sincere effort to arrive at the best possible estimate seems always to result in the necessity of evaluating the relative significance of estimates derived from different sources and harmonizing a mass of more or less conflicting data. In reporting the methods employed, therefore, those preparing the estimate have had either to make the statement very lengthy and detailed, or to confine it to a very general statement of the principles upon which the detailed steps have been based. For one reason or another the latter alternative has usually been adopted; hence our knowledge of the methods which were employed in preparing the early crop estimates is fragmentary and indicates merely the general outline of the principles which governed their preparation.

Production estimates have been obtained in this country almost entirely by combining independent estimates of acreage and of yield per acre, utilizing to some degree various checks on the total. The yield estimates have been obtained by collecting and averaging large numbers of individual estimates of yield per acre in the various localities, mostly obtained from a large group of local crop correspondents. The acreage estimates have been arrived at chiefly by census enumerations for decennial years, supplemented by estimates of percentage changes in acreage from year to year running back to the base year. The estimates of acreage changes were obtained, until some ten years ago, by the same method as the estimates of yield per acre.

The estimates of yield per acre seem, on the whole, to have been quite satisfactory. Farmers and many other well-informed people in any wheat-growing community

[1] This statement also rests on evidence to be presented in the next section.

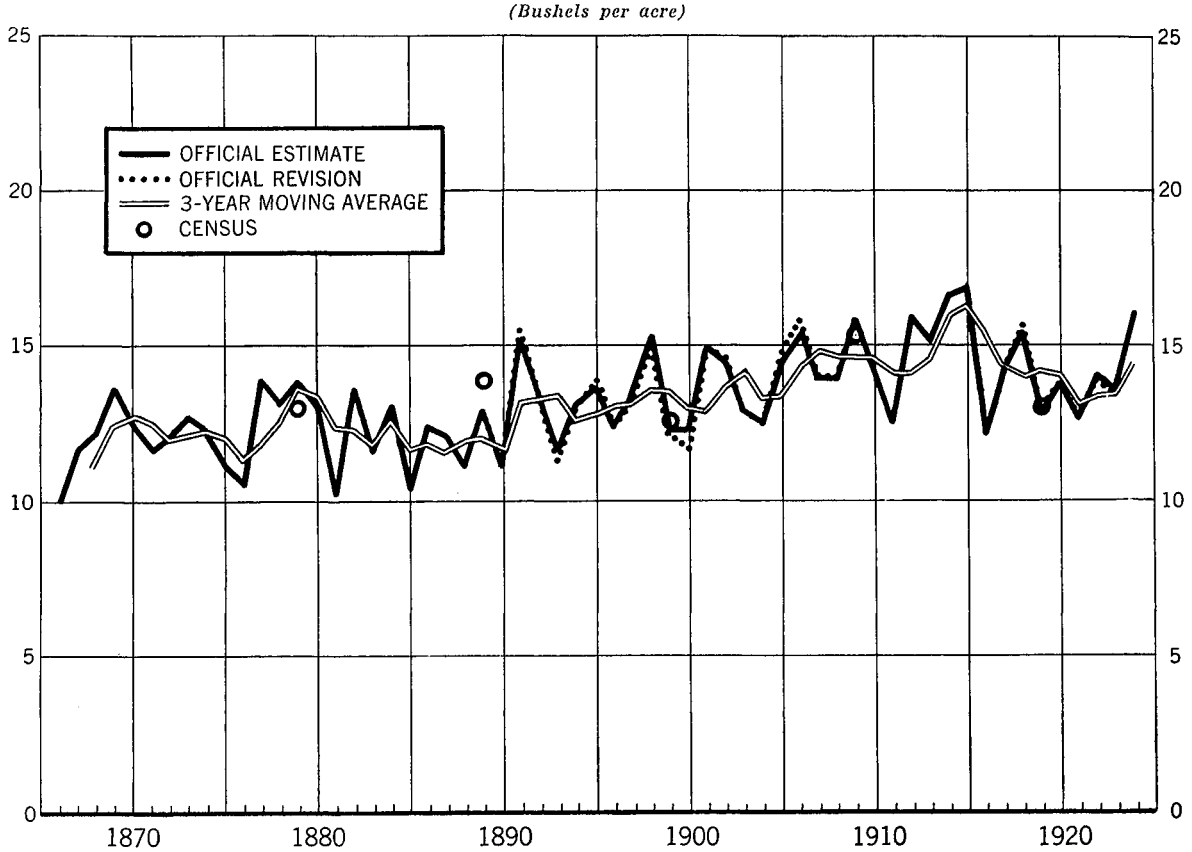
[2] The census data for yield per acre are derived by dividing the reported production by the reported acreage.

usually have a fairly accurate idea of the prevailing yield per acre, and, in the absence of a tendency to bias in the reports or of faulty averaging of the estimates, the errors in individual estimates may be expected to cancel out in the average derived from large numbers of reports. There seems to have been no serious tendency to bias in the reports of yield per acre in the United States, and the errors from faulty weighting in the process of averaging have probably not been great.

In 1918 the United States Department of Agriculture published a revision of earlier estimates of acreage, yield per acre, and production of wheat in the United States, altering the original acreage estimates to bring them into line with subsequent census enumerations, and recalculating the yield estimates by averaging with the weights indicated by the revised acreage estimates. Although in many years the revised acreage estimates differed radically from the original estimates, the revision of the yield estimates resulted in little change except in the year 1900. The original and revised official estimates of yield per acre are shown in Chart 3 and Appendix Table I.

CHART 3.—ESTIMATES OF AVERAGE YIELD PER ACRE OF WHEAT IN THE UNITED STATES, 1866–1924*

(Bushels per acre)



* The original Department of Agriculture estimates of yield per acre have been changed but little in the official revisions. Reliable estimates are much easier to obtain for yield per acre than for changes in acreage and the official estimates, as finally revised, are probably quite trustworthy. Data in Appendix Table I.

The preparation of acreage estimates presents much more difficult problems than appear in arriving at estimates of yield per acre. Some form of census enumeration is necessary as a basis, and for intervening years it has been customary in the United States to depend on estimates of changes in acreage from year to year, collected, prior to 1915, from the same sources as the estimates of yield per acre. It has been

found, however, that estimates of acreage changes from year to year as reported by the regular staff of crop correspondents are subject to large errors, owing chiefly to the fact that it is very difficult for any individual correspondent to know even approximately what acreage changes have occurred within the county or other geographical unit for which he is reporting. Whereas changes in yield per acre are very easily observed and become a matter of common knowledge in any agricultural community, changes in acreage are difficult to determine from casual observation and general impressions are frequently wide of the truth.

Recent Changes in Methods

Beginning with 1915 the previous method of estimating year-to-year changes in acreage was replaced by a method of sampling, reports being obtained on the actual acreage changes on farms representing about two per cent of the total acreage.[1] Changes in acreage on this group of individual farms have proved an excellent index of the general acreage change, giving estimates much superior to those obtained from crop correspondents. Indications of acreage changes thus obtained are supplemented where possible by data from state enumerations and various other sources.

Prior to 1910 the acreage and production estimates issued in December of each year seem never to have been replaced by revised estimates in subsequent years. In 1911, however, the information furnished by the census enumeration of acreage in 1909 was used as a basis for revising the estimate of acreage for 1910. In 1916 the custom was inaugurated of publishing each year a revision of the acreage estimate of the previous year. These revisions have been made with some reference to the evidence respecting disposition of wheat. In 1918 a general revision of acreage estimates was published for the period 1890–1909, in which the original estimates for intercensal years were adjusted with reference to acreage figures reported by the subsequent census. In 1921, apparently for the first time, additional information was used to supplement the general census enumeration for a census year, and the estimate for acreage harvested in 1919 was placed two million acres higher than the census figure.

[1] Cf. explanatory note at the beginning of the statistical section of recent *Yearbooks* of the U.S. Department of Agriculture.

Sources of Error in Official Estimates

During the period 1866–79 the acreage estimates had to be prepared without the assistance of any general enumeration of acreage, the general censuses of 1860 and 1870 having shown total production but neither acreage nor yield per acre. Until the census data for the year 1879 became available the acreage estimates had to be based on an apparent acreage calculated from the reported production in 1859 and 1869 and upon such fragmentary additional data as could be obtained.

Beginning with 1879 the decennial censuses furnished a basis on which acreage estimates for succeeding years could be obtained by applying to the census acreage the estimated percentage changes from year to year. Owing largely to the fact that the crop correspondents knew only very imperfectly what changes had actually occurred in their districts, these estimates of percentage changes from year to year were subject to a considerable error. In particular, they tended to understate the actual change, at least in regions in which there was a persistent expansion or contraction of acreage. Recent studies conducted by the Department of Agriculture indicate that, in addition to the bias toward understatement of the actual rate of change in acreage, the earlier methods had an inherent downward bias, independent of the actual trend of acreage.

It now appears that the census enumeration of 1890 was seriously incomplete as regards the acreage of wheat and that the remaining decennial censuses, while much better, have likewise failed to obtain a complete enumeration.

During the decade following 1879 the current estimates of acreage changes from year to year failed to show the rapid upward trend which continued through most of this period, as will presently appear, so that by 1889 the estimated acreage was

something like 8 or 9 million acres under the actual. The census enumeration for that year, however, showed an acreage nearly four million acres lower yet and resulted in increasing still further the error of subsequent estimates.

Briefly, then, acreage estimates of earlier years have been subject to three kinds of errors: (1) The *general level* of the estimates was subject to error from inadequacies and inaccuracies in the census data on which they were based. (2) The *trend* of the estimates during intercensal periods was likely to deviate considerably from the actual trend of the acreage. (3) The estimated *changes from year to year*, apart from the general trend, were subject to a considerable and quite unknown error, but are probably deserving of consideration. They must be used, however, with the understanding that occasionally a change may indicate the adoption of a new basis for the estimate (as when data from a new general census became available) rather than a belief that the acreage had actually changed as represented.

In connection with this summary of sources of error, it should be said that in many respects it does not apply to the estimates which have been issued during the last ten or fifteen years. While still not perfect, the acreage estimates as now issued are subject to only a small fraction of the error of the earlier estimates.

IV. DETAILED STEPS IN REVISION

Computation of Total Apparent Disposition

The various items in the apparent annual disposition of wheat in the United States are brought together in Appendix Table III. The item of wheat ground for domestic flour consumption is derived from the census figures on flour milling, supplemented where necessary by estimates of grindings in custom mills when these were omitted in the census, and adjusted for exports, imports, and changes in stocks. The apparent consumption of flour in each census year is converted to terms of wheat by applying the ratio of total wheat ground to total flour production, obtained from the census,[1] and reduced to a per capita basis. These are the values shown by the circles in Chart 2 (p. 240). To obtain values for each year 1866–1914, the 1879 value was taken for each year 1866–79, the values derived from the census were used for the years 1889, 1899, and 1914, and values for intermediate years were obtained by interpolation. This interpolation gives a series represented by the lines connecting the circles in Chart 2 except that between 1900 and 1914 the interpolation includes a slight smoothing of the curve.[2] The figures used for each year appear in the second column of Appendix Table III.

Disposition of wheat in the form of feed and waste has been taken at four-tenths of a bushel per capita throughout, for reasons which have been sufficiently discussed above (p. 242). This is perhaps an understatement of the actual amount of this item, especially for earlier years; but if so the error is in the direction of conservatism, as use of a larger figure would result in raising even further the original acreage estimates.

The estimation of changes in stocks may be considered next, as it turns out that they also may best be calculated on a per capita basis. Existing data on stocks are limited to the visible supply figures until 1894, when the compilation of a statement of stocks in "second hands" was begun by the Chicago *Daily Trade Bulletin*. In 1895 the Department of Agriculture began estimating farm stocks July 1. Estimates of stocks in country mills and elevators July 1 were not issued by the Department of Agriculture un-

[1] The ratios used are shown on p. 249, below. They were originally obtained from a manuscript table kindly furnished by the Division of Statistical and Historical Research of the U.S. Department of Agriculture, since published in *Crops and Markets, Monthly Supplement*, April 1926, p. 108. These figures differ slightly from similar data published in *Wheat and Rye Statistics*, U.S.D.A. Statistical Bulletin No. 12, Table 85, which has been superseded by the later computation.

[2] In smoothing, the figure of 5.391 bushels derived from the census for 1904 was lowered to 5.340 bushels, and the figure of 5.054 bushels derived from the census for 1909, raised to 5.160 bushels.

til 1919. Even for the period since 1895, during which fairly complete figures on stocks are available, estimates of the important element of farm stocks are subject to an error which is serious for present purposes: being obtained by applying an estimated percentage each year to the estimated production for the previous year, they are affected by the errors in the crop estimates. Resort is had, therefore, to an indirect estimate which has proved surprisingly effective.

It seems obvious that the size of the carryover at the end of each crop year must depend partly on the level of prices during the year and the consequent promise of profit from carrying supplies into another crop year, and partly on the size of the crop, irrespective of prices, a marked tendency having been observed for the known elements in the carryover to be large following a large crop and vice versa. If the relationship between these two factors and the carryover can be determined, changes in stocks may be estimated from changes in prices from year to year and from corresponding changes in size of the crop.

Since actual per capita domestic utilization of wheat is relatively constant from year to year, a large domestic retention of wheat (estimated production, less net exports) in any year must indicate an increase in stocks, and a small domestic retention, a decrease in stocks. This indication of changes in stocks cannot be used directly because it is impossible in many years, owing to the errors in the production estimates, to determine accurately the normal retention;[1] consequently the difference between the actual retention and its estimated normal, representing the change in stocks, may run too high or too low for several years at a time. To use these estimates of changes in stocks in calculating apparent production from the apparent disposition would introduce into our revised estimate many of the errors which it is desired to eliminate. These defects in the retention figures as an indication of changes in stocks, however, need not seriously affect a calculation of the *average relation* between stocks and the price of wheat and the size of the crop.

If changes in the size of the crop are subsequently to be employed to estimate changes in stocks which will constitute one element in the apparent disposition, the measure of size of the crop must not itself involve errors in trend. Since the principal changes in size of crops arise from changes in yield per acre, the yield figures, which show a consistent trend, may be used as the best available measure of changes in size of the crop.

The problem thus becomes one of determining the average relation between domestic retention on the one hand and the price of wheat and yield per acre on the other. This is conveniently accomplished by correlating first differences[2] of retention with first differences of price per bushel and first differences of yield per acre. The device of correlating first differences is adopted because it offers a convenient means of avoiding the principal errors encountered in correlating the original values of time series involving trend elements, and at the same time minimizes the effect of any breaks in the continuity of any of the series involved. The existence of such breaks in the production series, which necessarily carry over into the retention figures here used, will presently be demonstrated.[3]

One further adjustment of the figures is desirable before proceeding to the correlation. While the device of correlating first differences avoids the principal errors encountered in correlating the original values of time series, one fairly important error ordinarily remains if the trend element in any of the series is very large. The method of correlation involves an implicit assumption that the quantitative relations between the variables remain the same throughout the series. This assumption is not ordinarily justified if the values of the variables show

[1] That is, the retention to be expected if there were no change in stocks. If the production estimates were accurate, the normal retention would be the normal domestic consumption of wheat in all forms and could be represented statistically by a smooth curve. Since the production estimates are in error, the calculated retention is likewise in error and its trend, being thus not a smooth curve, becomes very difficult to determine.

[2] That is, changes from year to year.

[3] Cf. below, pp. 252–53.

divergent trends. It cannot be assumed, for example, that a given change in yield per acre in 1910 will be accompanied by the same change in retention as in 1870, when the average retention was only about half as great as in 1910. To place the three series on a comparable basis the yield figures may be taken as they stand, the retention figures reduced to a per capita basis, and the prices expressed in terms of value (purchasing power) by dividing by the index number of wholesale prices. In this form the changes in level of the three series are negligible.

Correlating the first differences of the figures in this form for the period 1866–1913, it appears that the level of wheat prices during the year has had practically no influence on the year-end carryover during this period,[1] but that yield per acre is very closely related to carryover. The coefficient of multiple correlation is surprisingly high, 0.81, with a path coefficient of +0.80 between first differences of yield and of retention, and a path coefficient of only −0.03 between first differences of value per bushel and of retention.[2] The regression equation indicates that on the average a change of one bushel per acre in the United States yield results in a change of 0.44 bushel in the per capita retention and therefore, by inference, in the per capita carryover at the end of the year.

Carrying the inference a step farther, it appears that for every bushel that the United States yield per acre exceeds its normal, stocks may be expected to increase 0.44 bushel per capita, and for every bushel that the yield falls short of normal, stocks may be expected to decrease 0.44 bushel per capita. In calculating the normal yield from which to measure deviations and thus estimate changes in stocks, it has seemed desirable to use an average of the three years ending with the year in question, since this 3-year moving average will rise in periods of a succession of high yields, and thus make some allowance for the fact that a succession of high yields cannot be accompanied by an indefinite increase in stocks, and vice versa.[3] More accurate allowance for this influence seems unnecessary.

The relationship thus established between yield per acre and changes in stocks forms the basis for calculating the estimated per capita changes in stocks shown in Appendix Table III. The three elements in disposition which have been estimated on a per capita basis may now be combined and multiplied by the population, giving a total apparent disposition as food, feed and waste, and changes in stocks. There remain to be considered only the seed requirements and the exports. Adding these will give the total apparent disposition, from which to calculate the *theoretical acreage* (Chart 4).

In calculating the seed requirements the official estimates[4] may be taken for the years from 1901 on, since the official revised acreage estimates in these years require little correction. For earlier years seed requirements are calculated from the

[1] It cannot be inferred from this that price has no bearing on carryover at the end of the year. Stocks in the hands of elevators are certainly adjusted quite closely in accordance with the relation between current cash prices and the prices of the new crop options. Certain price relations could undoubtedly be found which would help in some measure in estimating year-end carryover, but it seems doubtful whether the gain would be sufficient for present purposes to justify the labor.

[2] A coefficient of correlation may be said to measure the percentage of the variation in one series which can be explained by the variation in other series. The path coefficient is the same as the coefficient of correlation when only two variables are considered; when more than two variables are considered it indicates the percentage of variation in the one series explained by the variation in another single series, the influence of other series considered being separately measured. The difference between the path coefficient and a simple correlation coefficient would be slight in the present case, but under certain conditions a simple correlation results in the appearance of an important influence from one factor when the influence is actually exerted by other factors which happen to be related to the one in question. The use of path coefficients derived from a multiple correlation avoids this error.

The term "path coefficient" was suggested and its uses were carefully developed by Sewall Wright in a paper on "Correlation and Causation" in the *Journal of Agricultural Research*, January 3, 1921. The same coefficient had been used earlier by Truman L. Kelley in *Educational Guidance*, Teachers' College Contributions to Education, No. 71, 1914, and perhaps others, but without the same emphasis on its significance. The methods of computation are conveniently described by Wallace and Snedecor in *Correlation and Machine Computation*, Iowa State College of Agriculture and Mechanic Arts, 1925.

[3] The 3-year moving average is shown in Chart 3, p. 244, plotted to the last year of the group.

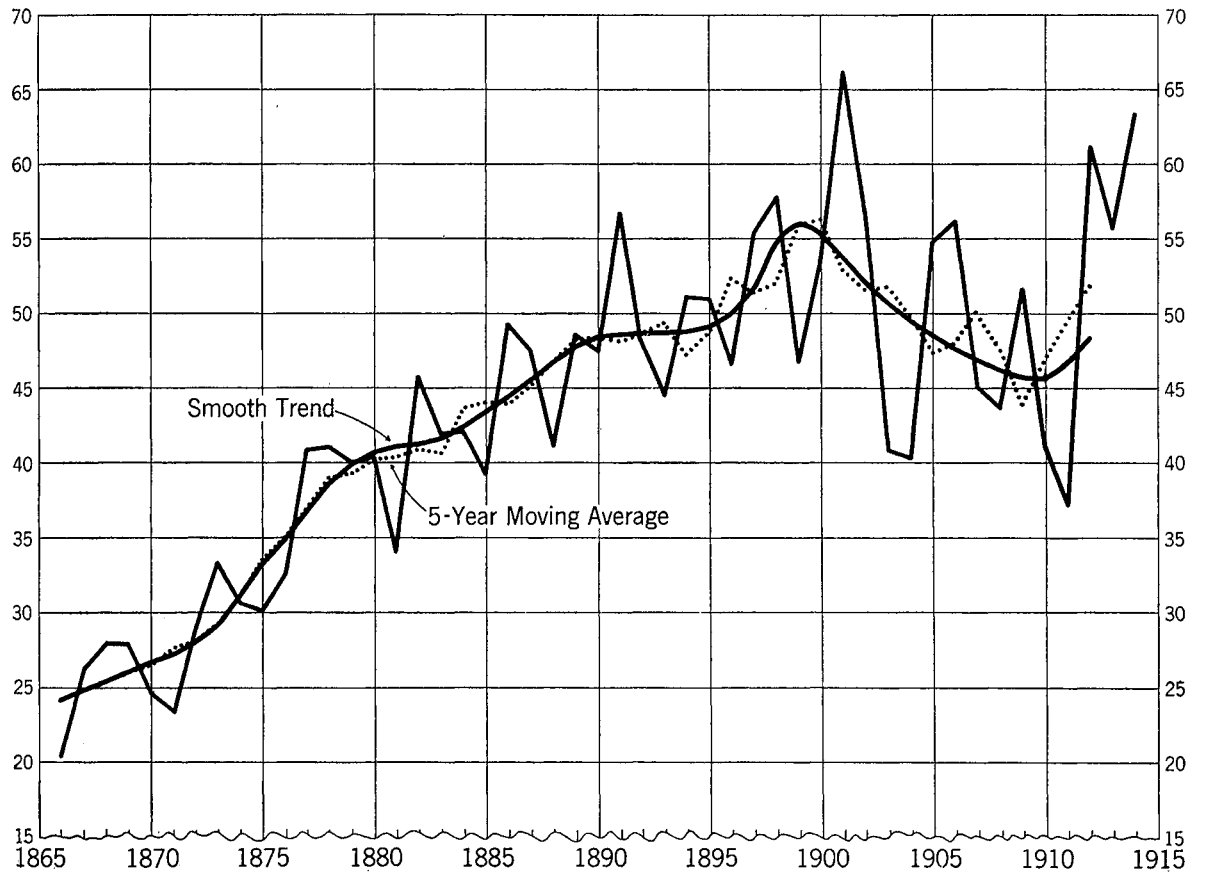
[4] Available, for example, in U.S. Department of Agriculture Statistical Bulletin No. 12, Table 43.

theoretical acreage. Since the theoretical acreage is a harvested acreage, allowance must be made for seeding of winter wheat acreage subsequently abandoned. The winter wheat acreage abandoned averaged 7.6 per cent of the total winter and spring wheat acreage harvested for the years 1909–24. The customary figure of 1.38 bushels of seed per acre sown is accordingly increased to 1.48 bushels as an average requirement per acre harvested. While the seed requirement is involved in calculating the theoretical acreage, the computation is readily made by working back from the latest years, since the seed for one year comes out of the crop of the previous year.

Net exports (less imports) of wheat and of flour in terms of wheat are readily calculated from the statistics of foreign trade. It is desirable, however, to convert the flour to its wheat equivalent on the basis of 4.7 bushels per barrel throughout, instead of at 5 bushels per barrel as in the official figures prior to 1880 and 4.5 bushels in the official figures since that date. Figures recently compiled by the Division of Statistical and Historical Research of the United States Department of Agriculture from the census milling statistics show that the actual ratio of wheat ground to flour milled in the United States averaged either 4.70 or 4.71 bushels per barrel in 1909, 1914, 1921,

CHART 4.—THEORETICAL ACREAGE AND "TRUE" TREND OF ACREAGE, 1866–1914*

(Million acres)



* Total production and total disposition of wheat are necessarily equal each year, but because there are unavoidable errors in the estimates of disposition (chiefly in the estimates of changes in carryover) the estimated disposition is considered as a *theoretical* production. Dividing the theoretical production for each year by the reported yield per acre gives the theoretical acreage. While the errors in the estimates of disposition seriously affect year-to-year values of the theoretical acreage, they influence its trend only slightly and the latter may be considered as the true trend of acreage. The calculations are shown in Appendix Table III.

and 1923. Between 1889 and 1923 the extreme variation was from 4.63 to 4.77 bushels per barrel, with no evidence of any substantial downward trend. Prior to 1889 the ratio probably averaged higher, but the figure for the one earlier census for which the ratio has been calculated (1879) gives so little indication of the true normal for those earlier years that it seems as well to use the ratio of 4.7 bushels per barrel throughout. The figures for each census are as follows:[1]

Year	Bu. per bbl.	Year	Bu. per bbl.	Year	Bu. per bbl.
1879	4.85	1904	4.76	1919	4.63
1889	4.77	1909	4.70	1921	4.71
1899	4.73	1914	4.70	1923	4.71

For the years 1901–14 Appendix Table III may be completed by filling in the official estimates of seed requirements, adding the various elements in the apparent disposition (including the estimated changes in stocks) to obtain the theoretical production, and calculating the theoretical acreage by dividing the theoretical production by the yield per acre as given in the official estimates. The seed requirement to come out of the 1900 crop is then calculated from the theoretical acreage for 1901 and the remaining values for 1900 are computed as before. The theoretical acreage for 1900 gives the basis for calculating seed requirements to come out of the 1899 crop, and the computation may be continued thus back to 1866.

Calculation of "True" Trend of Acreage

The theoretical production just calculated and the theoretical acreage derived from it may differ considerably from the actual production and acreage in individual years, owing chiefly to inaccuracies in the estimates of changes in stocks. Their trends, however, must be practically identical with the trends of actual production and acreage.[2] For present purposes only the trend of the theoretical acreage need be considered. Chart 4 (p. 249) shows the theoretical acreage for the years 1866–1914, together with its trend, which is the 5-year moving average, smoothed. In smoothing the moving average, attention has been given to the tendency of a moving average to give a slightly distorted picture of the trend in the neighborhood of turning points, and this tendency has been corrected as far as possible. While the theoretical acreage cannot be considered to give a true picture of the changes in acreage from year to year, it seems probable that this trend is a reliable representation of the true trend of acreage during the period. For convenience in subsequent discussion it will be referred to as the "true" trend of acreage, retaining the quotation marks, however, to avoid the danger of reposing more confidence in it than it may deserve.

Deviations of Actual Acreage from "True" Trend

If any evidence is to be obtained on the year-to-year deviations of actual acreage from the "true" trend just calculated, it must be deduced from the official acreage estimates. It is desirable first to verify the earlier assumption that the year-to-year changes in the original acreage estimates are really deserving of consideration.[3] This may be done by utilizing the fact that if the changes from year to year in the original acreage estimates were absolutely accurate, a correlation of the changes in the original acreage estimates with the changes in the theoretical acreage, as calculated above, would show that on the average each change in the acreage estimated was accompanied by an equal change in the theoretical acreage except as influenced by the fluctuations of sampling.[4] In technical

[1] Cf. *Crops and Markets, Monthly Supplement*, April, 1926, p. 108.

[2] The factors which may cause the trend of the theoretical acreage to differ slightly from the trend of the actual acreage are summarized on pp. 256–57.

[3] The original acreage estimates are used, despite the fact that they show somewhat greater errors than the official revised estimates available over part of the period, because the nature of the errors can be more accurately determined and eliminated.

[4] This statement follows from the fact that the theoretical acreage may be assumed to show the full effect of all actual changes in acreage, though obscured by the presence of other influences (notably the errors in estimating stocks for the purpose of calculating the theoretical acreage), and the further fact that these other influences are probably not closely related to changes in actual acreage and may be viewed as substantially random errors. The state-

terms, the coefficient of regression would be unity. The presence of random errors in the original estimates will reduce the coefficient of regression below its theoretical value of unity. When errors are present there is always a certain presumption that any change in the estimated acreage arises partly from an error and the regression coefficient automatically (and necessarily) discounts the estimated change by the amount of the "probable" error in the estimate. If the changes in the estimated acreage are generally accurate as to direction, but tend to understatement in amount, the regression coefficient may be greater than unity, and vice versa.

Correlating the first differences of the acreage estimates with the first differences of the theoretical acreage for the years 1866–80, a small *negative* correlation is found, bearing out the judgment previously reached from other evidence that the year-to-year changes in the estimates for this period are valueless except as an indication of the trend of the acreage. For the period from 1880 to 1914, however, the correlation is positive and indicates that a change of 1 million acres in the original estimate is accompanied, on the average, by a change of 0.6 million acres in the theoretical acreage.[1] Although the probable error is large, the relationship shown by the statistics is in complete agreement with the hypothesis reached from a study of the facts surrounding the preparation of the original estimates and indicates that they may be used with considerable confidence as an indication of the actual changes from year to year except in those years in which adoption of a new base causes a break in the continuity of the original estimates.

Since the original acreage estimates for the period 1866–79 appear to throw no light on the acreage changes from year to year, there appears no choice but to rest content with the assumption of a regular and continuous change during this period as represented by the "true" trend of acreage. The final figures in the present revision, accordingly, show merely the trend of acreage during this period with no attempt to estimate the fluctuations about the trend.

Beginning with 1880, it appears that the original estimates are capable of throwing light on the year-to-year deviation of acreage from its trend. To make use of the valuable evidence contained in the original estimates it is necessary to separate these estimates into their two statistical elements, their trend and their deviations from trend. The trend element can then be discarded and the "true" trend of acreage substituted in its place, while the deviation element can be retained and utilized in reaching the final revised estimates.

Assembling the available evidence on the nature of the trend element in the original estimates — a necessary preliminary to choosing the method of measurement and elimination—it appears that it is a compound trend, the resultant of two distinct components. The first component represents the influence of sources of error which affected the original estimates. These errors have been shown above (pp. 245–46) to arise from errors in the base to which the successive estimates of change were applied and from a bias in the estimates of change. The second component represents the influence of the trend of the actual acreage. There seems no reason to doubt that, after 1879 at least, the estimates were actually influenced by the real trend of acreage, though modified in their trend by the errors mentioned above.

ment deserves some qualification, however, owing to the possibility that changes in acreage may be accompanied by like changes in stocks, which would not have been accounted for by the method used for estimating stocks. If this is the case, an actual increase in acreage would result in an unnoted increase in stocks, an apparent disposition less than the actual, and a theoretical acreage less than the actual. If such is the case, then, actual changes in acreage would be understated, on the average, in the theoretical acreage; that is, in so far as the changes in theoretical acreage reflect actual acreage changes, they would be understated. Owing to the influence of other factors the total variation in the theoretical acreage is much greater, of course, than the variation of actual acreage.

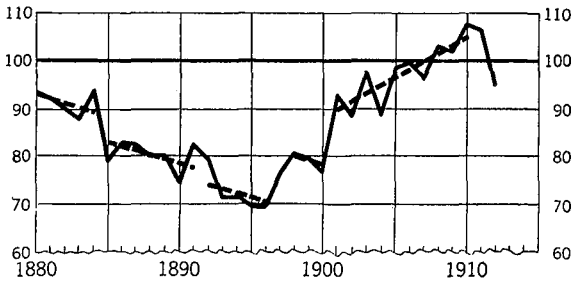
The characteristic of regression equations involved in the statement in the text, namely, that when the values used for the independent variable are accurate measures of a causal factor, the presence of random errors in the measures of the dependent variable will not obscure the true relationship beyond the limits of the fluctuations of sampling, is demonstrated in a paper by the present writer on "The Statistical Determination of Demand Curves" in the *Quarterly Journal of Economics*, August 1925, pp. 526–39.

[1] The regression coefficient is 0.63 with a probable error of ±0.31. The coefficient of correlation is +0.22 ±0.11.

The second component in the trend of the original acreage estimates may be eliminated by dividing the original acreage estimates by the ordinates of the "true" trend. The resulting ratios, expressed as percentages, appear in Chart 5 and Appendix Table IV.

CHART 5.—RATIOS OF ORIGINAL OFFICIAL ESTIMATES TO "TRUE" TREND OF ACREAGE, 1880–1912*

(Percentage of "true" trend of acreage)



* The original acreage estimates after 1880 appear to contain significant information regarding the deviations of actual acreage from its true trend. Study of the influences affecting the original estimates indicates that this "deviation element" may be isolated by reducing the estimates to percentages of the "true" trend of acreage and removing the remaining trends, shown by the dotted lines. The percentages thus obtained are applied to the true trend (Chart 4) to obtain our final revised acreage estimates (Chart 1). Cf. Appendix Table IV.

Having thus removed the "true" trend of acreage from the original estimates, the resulting figures express merely the deviations of acreage from the "true" trend—in so far as they are reflected in the original estimates—and the errors of the original acreage estimates. In terms of the statistical classification, we have remaining in these ratios (1) the "error component" of the trend element of the original acreage estimates, representing the principal errors in the original estimates; and (2) the deviation element in the original acreage estimates, representing the deviations of acreage from its trend together with an indeterminate residuum of error in the deviations. It remains, therefore, only to eliminate the error component of the trend element in the original acreage estimates.

The "error component" in the trend of the original acreage estimates arises from a certain initial error in the acreage taken as the base (derived from a census or otherwise), and from an accumulation of successive errors in the estimates of acreage changes from year to year. Since the errors in the estimates of changes from year to year result from a bias inherent in the method used and from a failure to show the full measure of the upward or downward trend in the actual acreage, they will tend to add to the initial error a uniform or very slowly changing annual increment. The "error component," therefore, can be represented by a smooth curve, or trend, of the percentages shown in Chart 5. The trend cannot be continuous throughout the period, however, since each adoption of a new basic acreage figure, as when the results of a decennial census became available, implies a new "initial" error with the trend of error continuing upward or downward from that point. The errors, therefore, must be represented by a curve with several breaks.

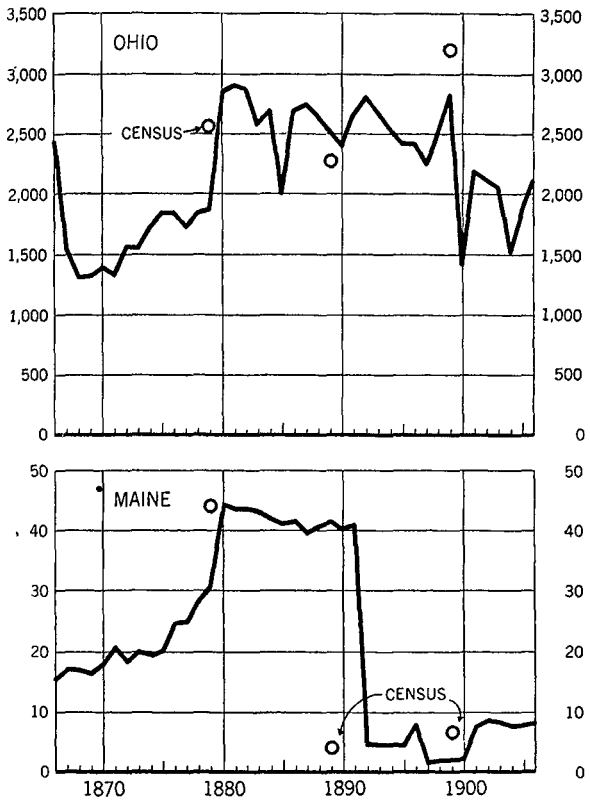
The points at which these breaks occur are not clearly apparent either in the original acreage estimates for the United States or in the curve (Chart 5) of the percentages of the original estimates to the "true" trend of acreage. The changes which accompanied them, however, seem always to have resulted in obvious breaks in the trend of the acreage estimates for certain individual states. The type of breaks observed in the trends for individual states is illustrated by the original acreage estimates for Maine and for Ohio, shown in Chart 6. Maine exhibits the most extreme breaks found, while Ohio represents a fairly typical example. In certain states, such as Kansas, the natural irregularity of the series prevents the detection of the breaks.

To determine the position of the significant breaks in trend of the acreage estimates, the figures for 35 individual states in which breaks in the trend of estimates could be detected were examined and the years in which apparent breaks occurred were listed for each state. In the figures for Maine, for example, as shown in Chart 6, a study of the trend of the estimates prior to 1879 and after 1880 indicates quite clearly that the sharp increase in the estimates between 1879 and 1880 must represent a change in the basis of the estimates rather than a real shift to a new high level of

acreage. The sharp drop in 1892 is even more clearly the result of a break in the continuity of the estimates. Further breaks seem to have occurred in 1897 and in 1901.

CHART 6.—ACREAGE OF WHEAT IN OHIO AND IN MAINE AS SHOWN BY ORIGINAL OFFICIAL ESTIMATES AND DECENNIAL CENSUSES, 1866–1906*

(Thousand acres)



* In general, changes in the original acreage estimates really represent estimated changes in acreage, but in certain years they reflect principally a change in the basis of the estimates, such as occurred when data from a decennial census indicated that earlier estimates had been in error. Such changes in the basis of the estimates, causing breaks in their continuity, are clearly apparent in the estimates for Ohio between 1866 and 1867, and between 1879 and 1880. In the statistics for Maine they appear even more clearly at 1880, 1892, 1897, and 1901. A tabulation of these breaks and of similar ones in the statistics for thirty-three other states appears in Table 2. Data from United States Department of Agriculture Bulletin No. 57, *Wheat Crops of the United States, 1866–1906.*

In the acreage estimates for Ohio breaks seem quite clearly to have occurred in 1867 and 1880. In the light of subsequent evidence it seems probable that certain other changes represent breaks in the continuity of the estimates rather than real changes in acreage, but they are not clearly enough marked to justify listing them as such in the present tabulation.

The results are assembled in Table 2, which shows for each year the number of states that appeared to show a break in the continuity of the acreage estimates in that year. The acreage estimates for many of the states do not cover the earlier years, and in later years estimates for a few states are dropped, making it desirable to compare the number of breaks observed in any year with the number of states included in the group in that year.

TABLE 2.—NUMBER OF APPARENT BREAKS IN CONTINUITY OF WHEAT ACREAGE ESTIMATES FOR INDIVIDUAL STATES, BY YEARS, 1866–1903

Year	Number of states showing apparent breaks			Total number of states in group
	Down	Up	Total	
1867	4	4	8	23
1868	0	1	1	24
1869	1	2	3	25
1870	3	1	4	26
1871	2	2	4	27
1872	0	1	1	27
1873	1	2	3	27
1874	0	0	0	27
1875	1	2	3	27
1876	1	4	5	27
1877	2	3	5	26
1878	0	3	3	26
1879	0	1	1	26
1880	1	8	9	26
1881	0	1	1	28
1882	1	0	1	28
1883	0	0	0	35
1884	0	2	2	35
1885	4	1	5	35
1886	1	0	1	35
1887	1	1	2	34
1888	0	2	2	33
1889	1	1	2	33
1890	0	0	0	33
1891	1	0	1	33
1892	14	0	14	33
1893	0	0	0	33
1894	0	0	0	33
1895	1	1	2	33
1896	0	2	2	33
1897	4	13	17	33
1898	1	8	9	34
1899	0	1	1	34
1900	1	4	5	34
1901	4	6	10	33
1902	4	0	4	33
1903	0	2	2	33

Making allowance for the probability that certain of the breaks listed represent actual changes in the level of acreage for the state rather than mere changes in the basis of the estimates, the concentration of the breaks on certain years is still impressive. The frequency of the breaks during the period prior to 1879 substantiates again the conclusion previously reached[1] that during this period the estimates of changes from year to year are of no present value. In view of the difficulties which must have been encountered at the time in obtaining a satisfactory basis for the estimates, it is surprising, indeed, that they should have kept up so well with the general trend of the acreage. In this respect the estimates during the next fifteen years were much less successful.

Following 1879, breaks in the trends of acreage estimates for the individual states concentrated quite clearly on the years 1880, 1885, 1892, 1897, 1898, and 1901. Three of these points of concentration, 1880, 1892, and 1901, are explained by the appearance of data from a new decennial census and corresponding changes in the basis for the estimates. The reason for the numerous breaks in 1885 is not clear. In 1897 and in 1898 there was undoubtedly a remarkable expansion of wheat acreage, resulting from the high prices of the preceding years, which may have led to listing as breaks certain cases of actual acreage increase, but the existence of a change in the basis of the estimates in 1897 at least cannot be doubted and probably a lesser change actually occurred in 1898. The fact that the current official production estimates were far too low was generally recognized in the trade, at least as early as 1892, as is apparent from discussions in the trade papers of the period, and it is probably significant that in the summer of 1897 a new statistician took charge of the preparation of the estimates.

The numerous breaks occurring in 1900 and in 1902 as well as in 1901 are perhaps to be accounted for by delay in making available the census data for certain states, a few becoming available in 1900, most of the rest in 1901, but some delayed until 1902. It may be, however, that all the breaks actually occurred in 1901, but that the extreme fluctuations in acreage occurring at this time led to mistaken judgments as to the precise date of the break in some cases. The evidence in the original estimates for Ohio, for example, did not seem quite sufficient to justify listing a break in any of these years, being subject to the interpretation that there was a sharp but irregular downward trend in acreage from 1892 to 1904, but if a break had been listed it would have been placed at 1900. Study of the original estimates in conjunction with the census figures, however, as shown in Chart 6, suggests that the drop in 1900 was actually estimated to have occurred and that it was the subsequent increase in 1901 which reflected a change in the basis for the estimates.

The important breaks in the continuity of the acreage estimates in more recent years appear quite clearly in the official revisions of the original estimates as shown in Chart 1 (p. 238). In 1911 the original estimates for 1909 and 1910 were revised, the census figure being taken for 1909 and a new estimate issued for 1910, based on the census figure for the previous year. The census total for 1919 agreed almost exactly with the estimate published before the census was taken, but indicated that the 1919 estimates for certain states had been in error. At the same time evidence was obtained that the census figures for certain states were incomplete. The result was that in 1921 a revised acreage estimate for 1919 was published, higher than either the census or the original estimate. This revised figure was used as the basis for subsequent estimates.

Returning, then, to the problem of determining the trends in the percentages of the original acreage estimates to the "true" trend of acreage, as shown in Chart 5, it appears that the trends of these percentages must be broken in each of the years in which there were breaks in the continuity of the estimates, namely (between 1880 and 1914) in 1885, 1892, 1897, 1898, 1901, and 1911. The presence of these breaks makes it necessary to fit trends to a series of five very short periods and an additional "per-

[1] Cf. discussion on pp. 245 and 251, above.

iod" of one year only. Only the last period, 1901 to 1910, is long enough to permit even a moderately trustworthy determination of the slope of the trend line. There is reason to believe, however, that the slopes of the trend lines for the four earlier periods should be very similar, if not identical. The slope of the trend lines measures the inherent "bias" or tendency to cumulative under- or overstatement in the estimates of changes from year to year. This bias, it will be remembered, is partly a result of the method of obtaining the estimates and probably partly a function of the trend of the actual acreage. During the period from 1880 to 1900, neither the method of obtaining the estimates nor the trend of the actual acreage appears to have changed greatly, and it seems probable, therefore, that little error is involved in assuming that the bias in the estimates of year-to-year changes (and consequently the slope of the trends of the percentages under consideration) remained constant during these years. The period covered is much too short to justify any attempt to measure changes in the bias.

On this assumption, the *slope* of the trend lines for the four periods, 1880–1884, 1885–1891, 1892–1896, and 1898–1900, may be determined simultaneously from the data for the entire period, 1880–1900, omitting only 1897, leaving the *level* of each trend line to be determined by the data for its own period.[1] Calculated thus, considerable confidence may be placed in each of the first four trend lines.

[1] The equation for the trend is written:

$$y = a + bt + c_1k_1 + c_2k_2 + c_3k_3$$

in which

y = the value of the series to which the trend is fitted;

t = time, measured in years from 1880 as origin;

k_1 = 0, 1880–84; 1, 1885–91; 0, 1892–1900

k_2 = 0, 1880–91; 1, 1892–96; 0, 1897–1900

k_3 = 0, 1880–97; 1, 1898–1900

a, b, c_1, c_2, c_3, are constants the values of which are to be determined.

Solution by the method of least squares yields the equation,

$$y = 93 - 0.900t - 5.514k_1 - 8.200k_2 + 3.100k_3,$$

the graph of which from 1880 to 1900 gives the trend lines shown for these years in Chart 5.

The trend of the percentages between 1901 and 1910 seems to be a straight line, which may be determined directly from the data.[2] Determination of a "trend" value for 1897 can be only by a rough approximation, but we shall not be far from the truth if we assume that the correction between 1896 and 1898 of the errors in the current acreage estimates was two-thirds accomplished in 1897 and one-third in 1898.

Difficulties incident to the wide fluctuations in the theoretical acreage after 1910, resulting from the wide fluctuations in stocks, discourage extension of the present revision beyond 1910. The decreased accuracy in the revised figures after this period, together with the fact that the original estimates are relatively much better after 1910, would render very questionable the superiority of such revised figures over the official estimates.

The ordinates of trend thus obtained represent the "error component" in the trend of the original acreage estimates. Subtracting them completes the elimination of the two components of the trend element, leaving only the element of deviations from trend. These deviations, being already in terms of percentages of the "true" trend, may be applied by adding to the ordinates of the "true" trend the corresponding percentage deviations.[3] The detailed computations are shown in Appendix Table IV and the resulting series appears as the double line in Chart 1 (p. 238).

[2] The equation, obtained by the method of least squares, is $y = 88.31 + 1.687t$, the origin for t being 1900.

[3] It may appear to the careful student that a slightly different statistical procedure should have been adopted. If it could be assumed that the original acreage estimates gave a strictly accurate picture of the percentage change in acreage from year to year except for the error in their trend, a slightly different method would be indicated. Under such conditions the percentage deviations of the original estimates from their trend would give an accurate measure of the percentage deviations of the actual acreage from its trend (assuming consistent methods of determining the various trends). To give full recognition to this relationship, the ordinates of trend representing the error component should be applied to the "true" trend to obtain the trend of the original estimates themselves, and the deviations expressed as percentages of this trend. Application of these percentages to the ordinates of the "true" trend would complete the computation.

Probably the original acreage estimates do in fact give a reasonably accurate picture of the percentage

V. RELIABILITY OF OUR REVISION

Its Limitations

At various stages in the process of revision described above, certain errors and limitations have been noted in the fundamental data employed and in the methods used. Broadly speaking, the revised figures may be said to represent the original acreage and production estimates with two types of correction: an adjustment of year-to-year changes where the change in the original figures was affected by an alteration in the basis of the acreage estimates, and an adjustment of the general level and trend of the original figures to bring them into agreement with data on total disposition of wheat. Accordingly only one type of possible error may be supposed to have been removed from the year-to-year fluctuations, and the general level and trend remain subject to such errors as are present in the general level and trend of the disposition data. The nature of the errors which may thus remain in our final revised estimates of acreage and production may be briefly summarized.

1. The official estimates of yield per acre (as most recently revised) have been accepted as they stand. Errors in the year-to-year changes in the yield figures will cause proportionate errors in the year-to-year changes in our revised production figures. Errors in the level and trend of the yield figures will not affect the level and trend of our revised production figures, but will cause inversely proportional errors in the level and trend of our revised acreage figures. It appears probable, however, that none of these errors is large.

2. The general level and trend of our revised acreage and production estimates may both be affected by possible errors in the values taken for items in the apparent disposition. These include per capita domestic utilization for food and for feed and waste, the average per acre seed requirement, and the ratio of wheat ground to flour milled (used in converting flour exports into terms of wheat). In each doubtful case the preference was given to a value more likely to be too low than too high. Any error which may have come from these sources must tend to make the revised estimates too low.

3. The general level and trend of our revised acreage and production estimates would likewise be affected by errors in the export data, our revised production estimates being lowered by the amount of any deficiency in the figures on exports and raised by the amount of any excess. There is no evidence of significant errors in export statistics during the period covered.

4. The details of the trend of the acreage and production estimates are affected if the "true" trend of acreage (Chart 4, p. 249) does not accurately represent the trend of the theoretical acreage. Defects in the method of estimating changes in stocks have their sole effect, if any, in contributing to errors in the determination of this "true" trend. To some degree errors in this "true" trend must result in corresponding deviations of the curve in Chart 5 from its

changes in acreage from year to year, and their deviations from trend should be measured as a percentage of the ordinates of their own trend rather than as a percentage of the ordinates of the "true" trend. Expressed thus, the percentages would show a wider fluctuation than when expressed in terms of the larger ordinates of the "true" trend. The deviations from trend indicated by these percentages must be influenced, however, by a certain element of error. Under such conditions the most probable estimates of the actual deviations are obtained by multiplying the partly erroneous measures by a regression coefficient (if such is obtainable), which will generally be smaller than the theoretical coefficient of unity which would be used if the measures were accurate. The principle involved is mentioned above (p. 250, n. 4).

The best available indication of the magnitude of the coefficient required in this case is furnished by the coefficient of regression of first differences of theoretical acreage on first differences of the original acreage estimates, which was found to be + 0.63 (p. 251, above). The coefficient would have been slightly smaller if percentage changes had been used instead of first differences.

It appears, therefore, that the theoretically more rigorous method here outlined would have yielded measures of the deviations from trend of the original estimates larger than those obtained by the method used, but would have reduced them again in estimating the most probable actual deviations of acreage from the "true" trend. Consequently the simpler method of adjustment actually employed not only is in keeping with the imperfect character of the fundamental data, but also yields essentially the same results as would have been obtained by the more refined method.

trends and the subsequent application of these deviations in obtaining our final revised acreage will correct the error in the "true" trend. The principal opportunity for error in determining the "true" trend occurs between the years 1895 and 1902.

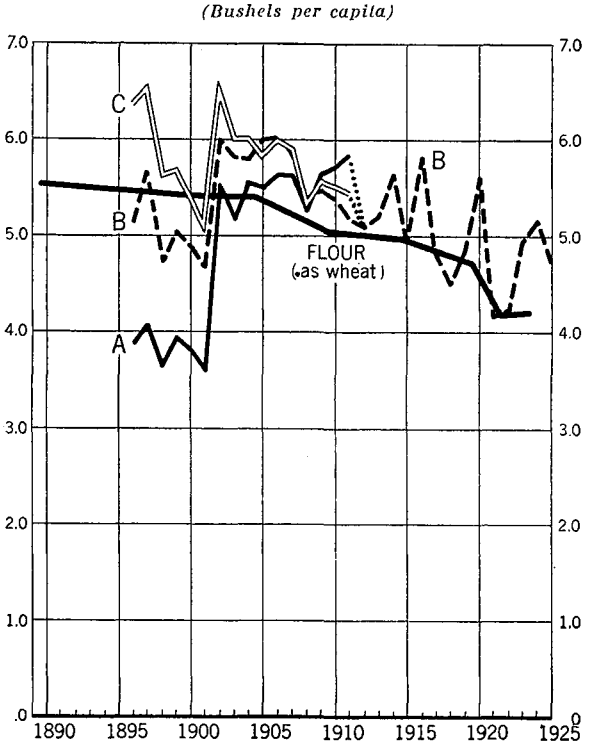
5. The year-to-year fluctuations in our revised acreage and production estimates for the period 1866–79 make no attempt to reflect any acreage changes except those implied by the trend of the acreage. After 1880 the year-to-year changes shown in the acreage are those of the original estimates and are subject to all the errors of those estimates except that the latter have been corrected to show the trend of acreage as it actually occurred (subject to the limitations noted above) and further corrected to eliminate most, at least, of the errors arising from breaks in the continuity of the original estimates. The uncertainty in the corrections for the breaks in the continuity of the original estimates is greatest in the period 1896–1901.

Evidence of Accuracy

The reliability of our revised acreage and production estimates may be checked by testing whether the results agree with evidence from other sources. One obvious test is the comparison of the domestic disappearance of wheat for food, feed, and waste, as calculated from our revised production estimates, with the domestic disappearance of wheat in the form of flour as calculated from the census data on flour milling. This is the test by which the errors in the original estimates were demonstrated. Its significance depends, of course, upon the accuracy of the figures derived from the census, but it appears that the latter are quite reliable and certainly give the most trustworthy evidence available on domestic disappearance of wheat for food.

Chart 7 shows the domestic disappearance of wheat per capita for food, feed, and waste, as it appears when derived from (*A*) the original official estimates, 1895–1910, (*B*) the revised official estimates, 1895–1924, and (*C*) our revised estimates, 1895–1910, together with the domestic disappearance of wheat per capita, in the form of flour, as derived from the census data on flour milling. The curves of domestic disappearance of wheat represent production, as indicated by the various estimates, less exports, seed requirements, and changes in farm and country mill and elevator stocks and visible supply. Estimates of changes in farm stocks and of seed requirements are themselves partly dependent on the acreage and production estimates. The estimates of these items used in computing disappearance as indicated by the various production estimates are in each case based

Chart 7.—Wheat Milled for Domestic Flour Consumption, 1889 to 1923, Compared with Domestic Disappearance of Wheat 1895–96 to 1924–25, as Calculated from (*A*) Original Official Estimates, (*B*) Revised Official Estimates, and (*C*) Food Research Institute Revision*



* The Food Research Institute revision is the only series of production estimates which leaves a reasonable margin for feed and waste between 1895–96 and 1900–1901. Between 1901–1902 and 1908–1909 the official estimates in their revised form give just as reasonable results as our revised estimates, but in 1909–10 and 1910–11 show again a questionably low margin for feed and waste. The wide variations in apparent disappearance between 1895–96 and 1901–1902 suggest that important errors may remain even in our revised estimates for these years.

on the particular series of estimates with which they are to be used. The figures on stocks are of course incomplete, and the fluctuations in the various curves of wheat disappearance are at least partly the result of changes in stocks incompletely or inaccurately estimated.[1] The wheat disappearance figures based on our final revised production estimates are the only ones which leave any margin for feed and loss during the period from 1895–96 to 1900–1901. From 1902–03 to 1908–09 the disappearance figures derived from our revision run very close to those from the official revision, but in 1909–10 and 1910–11 our revised figures again leave a larger and apparently a more reasonable margin for feed and waste than the official revision. As noted above (pp. 255 and 257) our revised estimates are subject to the greatest possibility of error between the years 1895 and 1902; yet even here they seem distinctly better than other available estimates.[2]

A rough indication of the reasonableness of the final revised acreage figures for earlier years is obtained by comparing them with the profitableness of wheat growing, as indicated by the average value of the crop per acre.[3] Changes in wheat acreage are determined by a variety of factors, including weather and the profitableness of alternative crops, but may be expected to bear some relation to the profitableness of wheat growing. From 1879 to 1884 the average value per acre of the wheat crop declined successively, year after year, and the previous rapid increase in acreage was sharply checked, the normal upward trend starting again only in 1886. An extraordinarily high value per acre of the crop in 1891 was followed by large acreages in 1892 and 1893, succeeded again by low values and low acreages in the middle 'nineties. Then came high values in 1896 and 1897, followed by a sharp increase in acreage in 1897, 1898, and 1899. Altogether, the changes shown in our revised acreage estimates agree very well with the natural expectation.

In conclusion, then, it may be said that the present revision brings the estimates of production of wheat in the United States into agreement with the data on disposition and gives a much more reasonable picture of the development of wheat growing in the United States than appears in the original acreage estimates. While subject still to certain imperfections, it provides a greatly improved basis for determining the effect of price changes on the acreage of wheat in subsequent years and for studying the influence of changing production on prices, exports, and year-end carryovers.

[1] Disappearance of wheat in the form of flour is computed from census milling statistics, exports, and changes in flour stocks as described on pp. 246 and 249 above. Apparent disappearance of wheat for food, feed, and waste is calculated from the various production estimates shown in Appendix Table I by deducting net exports, changes in stocks, and seed requirements. The export figures used are shown in Appendix Table II. Changes in stocks are computed direct from data in U.S. Department of Agriculture Statistical Bulletin No. 12, Table 43, except for farm stocks used in connection with the original official estimates and our revised estimates. The estimates of farm stocks being themselves dependent on the estimates of production, separate series of estimates of farm stocks are derived for use with these two production series by multiplying the appropriate production estimate by the Department's estimate of percentage of the crop remaining on farms the following July 1. Seed requirements are calculated for the years 1895–1900 at 1.48 bushels per acre harvested the following year (cf. p. 241, n. 3 above) as indicated by the appropriate series of acreage estimates. For the years 1901–1925 seed requirements deducted from the revised official production estimates and from our revised estimates are those shown in U.S. Department of Agriculture Statistical Bulletin No. 12, Table 43. The seed requirement deduction from the original official estimates is 1.38 bushels per acre planted the following year as shown by the original estimates.

[2] Study of Chart 7 suggests that even our final revised estimates are too low in the years 1897–1900, which would imply that they are too high in a few earlier and later years. It is possible, however, that the irregularities in the curve of wheat disappearance between 1895 and 1902 result from changes in stocks not completely or accurately estimated. Changes in stocks are known to have been unusually large during these years, and the effect of errors and deficiencies in estimates of stocks would be correspondingly great. Further alteration of our estimates to make the disappearance figures appear more reasonable during this period would bring them into conflict with other evidence. Altogether it seems wiser to leave them as they stand, pending the more thorough revision by the Department of Agriculture. In our judgment the divergent evidence can be harmonized only if it is found that the estimates of yield per acre during this period require revision, or that the year-to-year changes in acreage were greater than those shown by the official estimates. There is independent evidence for both of these hypotheses, but the final answer must await completion of the more comprehensive revision by the Department of Agriculture.

[3] A chart of farm value per acre is conveniently available in the 1921 *Yearbook* of the U.S. Department of Agriculture, p. 148.

This study has been prepared by Holbrook Working. The numerous difficult statistical computations involved are chiefly the work of Adelaide M. Hobe. The writer is indebted to several members of the Bureau of Agricultural Economics of the U.S. Department of Agriculture for valuable information used in the course of the study and to the directors and other members of the staff of the Food Research Institute for numerous suggestions and criticisms

APPENDIX

TABLE I.—ACREAGE, PRODUCTION, AND YIELD PER ACRE OF WHEAT IN THE UNITED STATES, 1866–1925: ORIGINAL AND REVISED OFFICIAL ESTIMATES, CENSUS ENUMERATIONS, AND FOOD RESEARCH INSTITUTE REVISION

Year	Acreage *(thousands)*				Yield per acre *(bushels)*			Production *(thousand bushels)*			
	Dept. of Agriculture		Census[c]	F.R.I. revision[d]	Dept. of Agriculture		Census[c]	Dept. of Agriculture		Census[c]	F.R.I. revision[d]
	Original[a]	Revised[b]			Original[a]	Revised[b]		Original[a]	Revised[b]		
1866	15,424	.....	.....	24,200	9.9	....	....	152,000	.....	.....	239,600
1867	18,322	.....	.....	24,800	11.6	....	....	212,441	.....	.....	287,700
1868	18,460	.....	.....	25,400	12.1	....	....	224,037	.....	.....	307,300
1869	19,181	.....	.....	26,000	13.6	....	....	260,147	.....	287,746	353,600
1870	18,993	.....	.....	26,600	12.4	....	....	235,885	.....	.....	329,800
1871	19,944	.....	.....	27,200	11.6	....	....	230,722	.....	.....	315,500
1872	20,858	.....	.....	28,000	12.0[e]	....	....	249,997	.....	.....	336,000
1873	22,172	.....	.....	29,000	12.7	....	....	281,255	.....	.....	368,300
1874	24,967	.....	.....	31,100	12.3	....	....	308,103	.....	.....	382,500
1875	26,382	.....	.....	33,200	11.1	....	....	292,136	.....	.....	368,500
1876	27,627	.....	.....	34,800	10.5	....	....	289,356	.....	.....	365,400
1877	26,278	.....	.....	36,600	13.9	....	....	364,194	.....	.....	508,700
1878	32,109	.....	.....	38,500	13.1	....	....	420,122	.....	.....	504,400
1879	32,546	.....	35,430	39,800	13.8	....	13.0	448,757	.....	459,483	549,200
1880	37,987	.....	.....	40,840	13.1	....	....	498,550	.....	.....	535,000
1881	37,709	.....	.....	40,960	10.2	....	....	383,280	.....	.....	417,800
1882	37,067	.....	.....	40,710	13.6	....	....	504,185	.....	.....	553,700
1883	36,456	.....	.....	40,460	11.6	....	....	421,086	.....	.....	469,300
1884	39,476	.....	.....	43,950	13.0	....	....	512,765	.....	.....	571,400
1885	34,189	.....	.....	41,570	10.4	....	....	357,112	.....	.....	432,300
1886	36,806	.....	.....	44,760	12.4	....	....	457,218	.....	.....	555,000
1887	37,642	.....	.....	46,180	12.1	....	....	456,329	.....	.....	558,800
1888	37,336	.....	.....	46,510	11.1	....	....	415,868	.....	.....	516,300
1889	38,124	33,580	33,580	47,940	12.9	12.9	13.9	490,560	434,383	468,374	618,400
1890	36,087	34,048	.....	46,460	11.1	11.1	....	399,262	378,097	.....	515,700
1891	39,917	37,826	.....	50,780	15.3	15.5	....	611,780	584,504	.....	787,100
1892	38,554	39,552	.....	51,180	13.4	13.3	....	575,949	527,987	.....	680,700
1893	34,629	37,934	.....	47,730	11.4	11.3	....	396,132	427,553	.....	539,400
1894	34,882	39,425	.....	48,410	13.2	13.1	....	460,267	516,485	.....	634,200
1895	34,047	40,848	.....	48,120	13.7	13.9	....	467,103	569,456	.....	668,900
1896	34,619	43,916	.....	49,400	12.4	12.4	....	427,684	544,193	.....	612,600
1897	39,465	46,046	.....	51,500	13.4	13.3	....	530,149	610,254	.....	685,000
1898	44,055	51,007	.....	55,070	15.3	15.1	....	675,149	772,163	.....	831,600
1899	44,593	52,589	52,589	56,380	12.3	12.1	12.5	547,304	636,051	658,534	682,200

[a] There is some ambiguity in the use of the terms "original" and "revised". Official acreage estimates have usually been changed several times during the course of each crop year as additional information became available. The "original" estimates shown above represent what appears to be the last of these successive estimates during each crop year. For the purpose of this table a "revised" estimate is an altered estimate issued in a subsequent crop year. Data from U.S. Department of Agriculture *Yearbooks* and *Crops and Markets*.

[b] For the years 1910 and 1915–24 these are revised figures published one or two years after the original estimates. For earlier years they are figures of the comprehensive revision first published in 1918. Data from U.S. Department of Agriculture *Yearbooks* and *Crops and Markets*.

[c] Data from *Twelfth Census*, 1900, Vol. VI, and *Fourteenth Census*, 1920, Vol. V. The census does not collect figures on yield directly, but derives the yield from the reported acreage and production.

[d] Beginning with 1911 the figures in this column are the latest official estimates, included here to form a continuous series of the most trustworthy data now available for the period 1866–1925. The Department of Agriculture estimates for 1924 and 1925 are subject to further change in December 1926, in the light of the Census of Agriculture for 1924 and other data.

[e] Prior to 1911 this figure was erroneously published as 11.9.

TABLE I.—(*Continued*)

Year	Acreage (*thousands*)				Yield per acre (*bushels*)			Production (*thousand bushels*)			
	Dept. of Agriculture		Census[c]	F.R.I. revision[d]	Dept. of Agriculture		Census[c]	Dept. of Agriculture		Census[c]	F.R.I. revision[d]
	Original[a]	Revised[b]			Original[a]	Revised[b]		Original[a]	Revised[b]		
1900	42,495	51,387	.....	54,580	12.3	11.7	....	522,230	602,708	.....	638,600
1901	49,896	52,473	.....	55,260	15.0	15.0	....	748,460	788,638	.....	828,900
1902	46,202	49,649	.....	50,540	14.5	14.6	....	670,063	724,808	.....	737,900
1903	49,465	51,632	.....	52,830	12.9	12.9	....	637,822	663,923	.....	681,500
1904	44,075	47,825	.....	46,480	12.5	12.5	....	552,400	596,911	.....	581,000
1905	47,854	49,389	.....	49,470	14.5	14.7	....	692,979	726,819	.....	727,200
1906	47,306	47,800	.....	48,080	15.5	15.8	....	735,261	756,775	.....	759,700
1907	45,211	45,116	.....	45,160	14.0	14.1	....	634,087	637,981	.....	636,800
1908	47,557	45,970	.....	46,750	14.0	14.0	....	664,602	644,656	.....	654,500
1909	46,723	44,262	44,263	45,110	15.8	15.8	15.4	737,189	700,434	683,379	712,700
1910	49,205	45,681	.....	46,800	14.1	13.9	....	695,443	635,121	.....	659,900
1911	49,543	.....[f]	.....	49,543[d]	12.5	....[f]	....	621,338	.....[f]	.....	621,338[d]
1912	45,814	.....[f]	.....	45,814	15.9	....[f]	....	730,267	.....[f]	.....	730,267
1913	50,184	.....[f]	.....	50,184	15.2	....[f]	....	763,380	.....[f]	.....	763,380
1914	53,541	.....[f]	.....	53,541	16.6	....[f]	....	891,017	.....[f]	.....	891,017
1915	59,898	60,469	.....	60,469	16.9	17.0	....	1,011,505	1,025,801	.....	1,025,801
1916	52,785	52,316	.....	52,316	12.1	12.2	....	639,886	636,318	.....	636,318
1917	45,941	45,089	.....	45,089	14.2	14.1	....	650,828	636,655	.....	636,655
1918	59,110	59,181	.....	59,181	15.5	15.6	....	917,100	921,438	.....	921,438
1919	73,243	75,694	73,099	75,694	12.8	12.8	12.9	940,987	967,979	945,403	967,979
1920	57,192	61,143	.....	61,143	13.8	13.6	....	787,128	833,027	.....	833,027
1921	62,408	63,696	.....	63,696	12.7	12.8	....	794,893	814,905	.....	814,905
1922	61,230	62,317	.....	62,317	14.0	13.9	....	856,211	867,598	.....	867,598
1923	58,308	59,659	.....	59,659	13.5	13.4	....	785,741	797,381	.....	797,381
1924	54,209	52,364	.....	52,364	16.1	16.5	....	872,673	862,627	.....	862,627
1925	52,200	.....	.....	52,200	12.8	....	....	669,365	.....	.....	669,365

[f] No revision.

TABLE II.—DOMESTIC RETENTION OF WHEAT, ANNUALLY, BASED ON ORIGINAL PRODUCTION ESTIMATES, 1866–1900, AND REVISED OFFICIAL ESTIMATES, 1901–24*

(Thousand bushels, except as noted)

Year July–June	Original production estimates[a]	Net exports including flour[b]	Calculated domestic retention[c]	Estimated seed requirements[d]	Calculated retention less seed	Population Jan. 1[e]	Per capita retention less seed (*bushels*)	
							Annual	5-yr. moving average
1866–67.....	152,000	10,437	141,563	27,117	114,446	35,840	3.19	....
1867–68.....	212,441	23,927	188,514	27,321	161,193	36,592	4.41	....
1868–69.....	224,037	27,585	196,452	28,388	168,064	37,364	4.50	4.16
1869–70.....	260,147	52,088	208,059	28,110	179,949	38,157	4.72	4.34
1870–71.....	235,885	51,106	184,779	29,517	155,262	39,056	3.98	4.27
1871–72.....	230,722	36,832	193,890	30,870	163,020	40,076	4.07	4.10
1872–73.....	249,997	49,936	200,061	32,815	167,246	41,136	4.07	4.07
1873–74.....	281,255	89,189	192,066	36,951	155,115	42,236	3.67	4.07
1874–75.....	308,103	71,653	236,450	39,045	197,405	43,374	4.55	4.11

* The per capita retention less seed as calculated here is shown graphically in Chart 2, p. 240. Its low values prior to 1901 can be explained only on the supposition that the production estimates are below the facts for these years.

[a] Data as in Appendix Table I.

[b] Including shipments to possessions. Flour converted to wheat at 4.7 bushels per barrel (cf. p. 249). Data 1866–95, exports from *Monthly Summary of Foreign Commerce*, January 1900; imports and re-exports from U.S. Department of Agriculture Statistical Bulletins 74 and 75. Data 1895–1924 from the U.S. Department of Agriculture Statistical Bulletin 12.

[c] Production less net exports.

[d] Calculated, 1866–1900, at 1.48 bushels per acre harvested in following year, as shown by original official estimate (cf. Appendix Table I). Data 1901–24 from U.S. Department of Agriculture Statistical Bulletin 12, Table 43, based on requirement of 1.38 bushels per acre sown, as indicated by official revised estimates.

[e] Population in thousands. Data for 1867–1908 are means of successive census estimates for July 1, from U.S. Statistical Abstract, 1914; 1909–25 estimates of National Bureau of Economic Research, from National Bureau of Economic Research, *News Bulletin*, April 20, 1925.

TABLE II.—(*Continued*)

Year July–June	Original production estimates[a]	Net exports including flour[b]	Calculated domestic retention[c]	Estimated seed requirements[d]	Calculated retention less seed	Population Jan. 1[e]	Per capita retention less seed (*bushels*)	
							Annual	5-yr. moving average
1875–76	292,136	73,327	218,809	40,888	177,921	44,544	3.99	4.25
1876–77	289,356	56,145	233,211	38,891	194,320	45,745	4.25	4.45
1877–78	364,194	90,843	273,351	47,521	225,830	46,976	4.81	4.39
1878–79	420,122	148,564	271,558	48,168	223,390	48,232	4.63	4.59
1879–80	448,757	181,648	267,109	56,221	210,888	49,511	4.26	4.54
1880–81	498,550	187,851	310,699	55,809	254,890	50,736	5.02	4.71
1881–82	383,280	122,917	260,363	54,859	205,504	51,906	3.96	4.70
1882–83	504,185	149,540	354,645	53,955	300,690	53,094	5.66	5.03
1883–84	421,086	113,435	307,651	58,424	249,227	54,302	4.59	4.75
1884–85	512,765	134,769	377,996	50,600	327,396	55,530	5.90	4.80
1885–86	357,112	96,161	260,951	54,473	206,478	56,776	3.64	4.61
1886–87	457,218	156,184	301,034	55,710	245,324	58,042	4.23	4.58
1887–88	456,329	121,925	334,404	55,257	279,147	59,327	4.71	4.45
1888–89	415,868	90,562	325,306	56,424	268,882	60,632	4.43	4.45
1889–90	490,560	111,895	378,665	53,409	325,256	62,118	5.24	4.62
1890–91	399,262	108,487	290,775	59,077	231,698	63,396	3.65	4.50
1891–92	611,780	228,082	383,698	57,060	326,638	64,465	5.07	4.14
1892–93	515,949	194,841	321,108	51,251	269,857	65,718	4.11	3.87
1893–94	396,132	166,688	229,444	51,625	177,819	66,990	2.65	3.96
1894–95	460,267	146,978	313,289	50,390	262,899	68,283	3.85	3.57
1895–96	467,103	129,614	337,489	51,236	286,253	69,594	4.11	3.42
1896–97	427,684	147,995	279,689	58,408	221,281	70,923	3.12	3.93
1897–98	530,149	220,196	309,953	65,187	244,766	72,270	3.39	3.94
1898–99	675,149	226,376	448,773	65,998	382,775	73,632	5.20	3.71
1899–00	547,304	191,484	355,820	62,893	292,927	75,156	3.90	4.30
1900–01	522,230	220,823	301,407	73,846	227,561	76,804	2.96	4.73
1901–02	788,638	239,390	549,248	76,438	472,810	78,422	6.03	4.82
1902–03	724,808	209,000	515,808	72,631	443,177	80,040	5.54	5.20
1903–04	663,923	125,937	537,986	73,689	464,297	81,658	5.69	5.92
1904–05	596,911	44,871	552,040	70,246	481,794	83,276	5.79	5.96
1905–06	726,819	102,171	624,648	68,615	556,033	84,894	6.55	5.77
1906–07	756,775	151,979	604,796	67,436	537,360	86,512	6.21	5.67
1907–08	637,981	167,718	470,263	65,049	405,214	88,130	4.60	5.69
1908–09	644,656	118,203	526,453	63,755	462,698	89,357	5.18	5.43
1909–10	700,434	90,865	609,569	69,015	540,554	91,530	5.91	5.18
1910–11	635,121	72,650	562,471	73,180	489,291	93,165	5.25	5.32
1911–12	621,338	80,992	540,346	72,411	467,935	94,458	4.95	5.39
1912–13	730,267	146,605	583,662	71,427	512,235	96,144	5.33	5.14
1913–14	763,380	148,946	614,434	75,598	538,836	98,213	5.49	5.46
1914–15	891,017	337,648	553,369	84,997	468,372	99,710	4.70	5.21
1915–16	1,025,801	242,278	783,523	78,456	705,067	101,055	6.98	5.01
1916–17	636,318	183,614	452,704	77,544	375,160	102,590	3.66	4.93
1917–18	636,655	109,131	527,524	89,944	437,580	103,852	4.21	5.23
1918–19	921,438	283,965	637,473	105,226	532,247	104,524	5.09	4.63
1919–20	967,979	221,861	746,118	91,063	655,055	105,711	6.20	4.72
1920–21	833,027	315,321	517,706	90,952	426,754	107,412	3.97	4.90
1921–22	814,905	268,279	546,626	96,249	450,377	109,135	4.13	4.92
1922–23	867,598	207,985	659,613	91,413	568,200	110,688	5.13	4.59
1923–24	797,381	134,865	662,516	79,378	583,138	112,684[f]	5.17	....
1924–25	862,627	257,566	605,061	87,627	517,434	114,311[f]	4.53	....

[f] Preliminary estimate.

TABLE III.—COMPUTATION OF THEORETICAL PRODUCTION AND ACREAGE, 1866–1914

Year July–June	Elements in domestic disposition estimated on per capita basis (bushels per capita)				Population Jan. 1[d] (millions)	Apparent domestic disposition less seed[e] (million bushels)	Estimated seed requirements[f] (million bushels)	Net exports[g] (million bushels)	Theoretical production (total apparent disposition) (million bushels)	Yield per acre[h] (bu.)	Theoretical acreage harvested[i] (million acres)
	Food[a]	Feed and waste[b]	Change in stock[c]	Total							
1866–67	5.600	0.4	−1.751	4.249	35.840	152.3	38.9	10.437	201.6	9.9	20.36
1867–68	5.600	0.4	+ .539	6.539	36.592	239.3	41.4	23.927	304.6	11.6	26.26
1868–69	5.600	0.4	+1.212	7.212	37.364	269.5	41.3	27.585	338.3	12.1	27.96
1869–70	5.600	0.4	+1.616	7.616	38.157	290.7	36.3	52.088	379.1	13.6	27.88
1870–71	5.600	0.4	− .404	5.596	39.056	218.6	34.6	51.106	304.3	12.4	24.54
1871–72	5.600	0.4	−1.212	4.788	40.076	191.9	42.7	36.832	271.4	11.6	23.39
1872–73	5.600	0.4	.000	6.000	41.136	246.8	49.2	49.936	345.9	12.0	28.83
1873–74	5.600	0.4	+ .808	6.808	42.236	287.6	45.3	89.189	422.0	12.7	33.23
1874–75	5.600	0.4	.000	6.000	43.374	260.2	44.6	71.653	376.5	12.3	30.61
1875–76	5.600	0.4	−1.212	4.788	44.544	213.3	48.2	73.327	334.7	11.1	30.16
1876–77	5.600	0.4	−1.078	4.922	45.745	225.2	60.3	56.145	341.6	10.5	32.53
1877–78	5.600	0.4	+2.829	8.829	46.976	414.7	60.7	90.843	566.2	13.9	40.74
1878–79	5.600	0.4	+ .808	6.808	48.232	328.4	59.2	148.564	536.1	13.1	40.99
1879–80	5.600	0.4	+ .269	6.269	49.511	310.4	59.7	181.648	551.8	13.8	39.98
1880–81	5.592	0.4	− .269	5.723	50.736	290.3	50.4	187.851	528.6	13.1	40.35
1881–82	5.584	0.4	−2.963	3.021	51.906	156.8	67.7	122.917	447.4	10.2	34.06
1882–83	5.576	0.4	+1.751	7.727	53.094	410.3	61.9	149.540	621.7	13.6	45.71
1883–84	5.568	0.4	− .269	5.699	54.302	309.4	62.2	113.435	485.1	11.6	41.82
1884–85	5.560	0.4	+ .404	6.364	55.530	353.4	58.0	134.769	546.2	13.0	42.01
1885–86	5.552	0.4	−1.751	4.201	56.776	238.5	72.9	96.161	407.5	10.4	39.19
1886–87	5.544	0.4	+ .674	6.618	58.042	384.1	70.3	156.184	610.6	12.4	49.24
1887–88	5.536	0.4	+ .674	6.610	59.327	392.1	60.8	121.925	574.9	12.1	47.51
1888–89	5.528	0.4	−1.078	4.850	60.632	294.1	71.7	90.562	456.4	11.1	41.12
1889–90	5.520	0.4	+1.212	7.132	62.118	443.0	70.2	111.895	625.2	12.9	48.46
1890–91	5.508	0.4	− .808	5.100	63.396	323.3	83.9	108.487	515.7	11.1	47.46
1891–92	5.496	0.4	+3.098	8.994	64.465	579.8	71.2	228.082	879.1	15.5	56.72
1892–93	5.484	0.4	.000	5.884	65.718	386.7	58.4	194.841	640.0	13.3	48.12
1893–94	5.472	0.4	−2.829	3.043	66.990	203.9	75.5	166.688	446.1	11.3	39.48
1894–95	5.460	0.4	+ .674	6.534	68.283	446.1	75.4	146.978	668.6	13.1	51.03
1895–96	5.448	0.4	+1.482	7.330	69.594	510.1	68.9	129.614	708.6	13.9	50.98
1896–97	5.436	0.4	− .943	4.893	70.923	347.0	81.9	147.995	577.0	12.4	46.53
1897–98	5.424	0.4	+ .135	5.959	72.270	430.6	85.5	220.196	736.3	13.3	55.36
1898–99	5.412	0.4	+2.020	7.832	73.632	576.7	69.1	226.376	872.2	15.1	57.76
1899–00	5.400	0.4	−1.886	3.914	75.156	294.2	79.5	191.484	565.2	12.1	46.71
1900–01	5.388	0.4	−1.751	4.037	76.804	310.0	97.7	220.823	628.6	11.7	53.73
1901–02	5.376	0.4	+2.829	8.605	78.422	674.8	76.4	239.390	990.6	15.0	66.04
1902–03	5.364	0.4	+1.078	6.842	80.040	547.6	72.6	209.000	829.2	14.6	56.80
1903–04	5.352	0.4	−1.751	4.001	81.658	326.7	73.7	125.937	526.3	12.9	40.80
1904–05	5.340	0.4	−1.078	4.662	83.276	388.3	70.2	44.871	503.4	12.5	40.27
1905–06	5.320	0.4	+1.751	7.471	84.894	634.3	68.6	102.171	805.0	14.7	54.76
1906–07	5.292	0.4	+2.020	7.712	86.512	667.2	67.4	151.979	886.6	15.8	56.12
1907–08	5.256	0.4	−1.078	4.578	88.130	403.5	65.0	167.718	636.3	14.1	45.12
1908–09	5.212	0.4	− .808	4.804	89.357	429.3	63.8	118.203	611.2	14.0	43.66
1909–10	5.160	0.4	+1.616	7.176	91.530	656.9	69.0	90.865	816.7	15.8	51.69
1910–11	5.108	0.4	− .943	4.565	93.165	425.4	73.2	72.650	571.1	13.9	41.09
1911–12	5.064	0.4	−2.155	3.309	94.458	312.5	72.4	80.992	465.9	12.5	37.28
1912–13	5.028	0.4	+2.425	7.853	96.144	755.0	71.4	146.605	973.0	15.9	61.20
1913–14	5.000	0.4	+ .943	6.343	98.213	623.0	75.6	148.946	847.5	15.2	55.76
1914–15	4.980	0.4	+ .943	6.323	99.710	630.5	85.0	337.648	1,053.1	16.6	63.44

[a] Apparent consumption of wheat in the form of flour, based on census milling statistics, exports, and changes in stocks. Cf. pp. 241 and 246.

[b] Average difference between trend of per capita domestic disappearance of wheat in the form of flour and trend of per capita disappearance of wheat (for food, feed, and waste). Cf. p. 242 and Chart 2.

[c] Estimated from yield per acre, cf. pp. 246–48.

[d] Cf. Appendix Table II, note *e*.

[e] Derived by multiplying figures in two previous columns. In performing the computations for this table the figures were carried to a larger number of places than shown here, and then rounded off; in some cases, therefore, the last digits will not appear to agree in the figures shown.

[f] Calculated, 1866–1900, at 1.48 bushels per acre harvested (theoretical acreage) in following year; 1901–24, from U.S. Department of Agriculture Statistical Bulletin 12, Table 43, based on requirement of 1.38 bushels per acre sown as indicated by official revised estimates.

[g] Cf. Appendix Table II, note *b*.

[h] Latest estimates of U.S. Department of Agriculture.

[i] Theoretical production divided by estimated yield per acre.

TABLE IV.—CALCULATION OF FOOD RESEARCH INSTITUTE REVISION OF ACREAGE ESTIMATES, 1866–1910, FROM "TRUE" TREND OF ACREAGE AND INDICATED DEVIATIONS*

Year	Ordinates of "true" trend[a] (million acres)	Ratio of original estimates to "true" trend[b] (per cent)	Ordinates of trend of ratios[b] (per cent)	Deviations of ratios from trend[c] (per cent)	F.R.I. revised acreage estimates (million acres)	Year	Ordinates of "true" trend[a] (million acres)	Ratio of original estimates to "true" trend[b] (per cent)	Ordinates of trend of ratios[b] (per cent)	Deviations of ratios from trend[c] (per cent)	F.R.I. revised acreage estimates (million acres)
1866.....	24.2				24.2	1889.....	47.7	79.9	79.4	+0.5	47.94
1867.....	24.8				24.8	1890.....	48.3	74.7	78.5	−3.8	46.46
1868.....	25.4				25.4	1891.....	48.5	82.3	77.6	+4.7	50.78
1869.....	26.0	(The	official esti	mates	26.0	1892.....	48.6	79.3	74.0	+5.3	51.18
1870.....	26.6	appea	r to throw	no light	26.6	1893.....	48.6	71.3	73.1	−1.8	47.73
1871.....	27.2	on th	e deviatio	ns of	27.2	1894.....	48.7	71.6	72.2	−0.6	48.41
1872.....	28.0	acrea	ge from it	s trend	28.0	1895.....	49.0	69.5	71.3	−1.8	48.12
1873.....	29.0	durin	g this peri	od, and	29.0	1896.....	49.9	69.4	70.4	−1.0	49.40
1874.....	31.1	our r	evised esti	mates	31.1	1897.....	51.6	76.5	76.7	−0.2	51.50
1875.....	33.2	can s	how only t	he trend	33.2	1898.....	54.8	80.4	79.9	+0.5	55.07
1876.....	34.8	of the	acreage)		34.8	1899.....	56.1	79.5	79.0	+0.5	56.38
1877.....	36.6				36.6	1900.....	55.3	76.8	78.1	−1.3	54.58
1878.....	38.5				38.5	1901.....	53.7	92.9	90.0	+2.9	55.26
1879.....	39.8				39.8	1902.....	52.1	88.7	91.7	−3.0	50.54
1880.....	40.6	93.6	93.0	+0.6	40.84	1903.....	50.7	97.6	93.4	+4.2	52.83
1881.....	41.0	92.0	92.1	−0.1	40.96	1904.....	49.5	89.0	95.1	−6.1	46.48
1882.....	41.2	90.0	91.2	−1.2	40.71	1905.....	48.5	98.7	96.7	+2.0	49.47
1883.....	41.5	87.8	90.3	−2.5	40.46	1906.....	47.6	99.4	98.4	+1.0	48.08
1884.....	42.3	93.3	89.4	+3.9	43.95	1907.....	46.8	96.6	100.1	−3.5	45.16
1885.....	43.3	79.0	83.0	−4.0	41.57	1908.....	46.1	103.2	101.8	+1.4	46.75
1886.....	44.4	82.9	82.1	+0.8	44.76	1909.....	45.7	102.2	103.5	−1.3	45.11
1887.....	45.5	82.7	81.2	+1.5	46.18	1910.....	45.7	107.6	105.2	+2.4	46.80
1888.....	46.6	80.1	80.3	−0.2	46.51						

* The theoretical basis for these computations is found in the fact that the actual level and trend of production (and thence acreage) may be calculated from data on disposition of wheat and the deviations from this trend calculated by a refinement of the original acreage estimates.

[a] Ordinates of the smooth curve of Chart 4, p. 249.

[b] Shown graphically in Chart 5, p. 252. The equations of the trend lines appear in notes on p. 255.

[c] Obtained by subtraction, leaving the figures still in percentages of the "true" trend, representing indicated deviations which may be multiplied into the ordinates of the "true" trend to obtain the final revised estimates shown in the last column of the table.

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