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ADEQUACY AND RELIABILITY OF CROP-YIELD ESTIMATES

BY

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RETURN AFTER FIVE DAYS
AGRICULTURAL STATISTICIAN
AGRICULTURAL EXPERIMENT STATION
PURDUE UNIVERSITY
WEST LAFAYETTE, INDIANA

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INTRODUCTION

Long-established theories in the field of economics are now being subjected to the searching light of quantitative analysis. The statistical approach is used to test theories derived by deductive reasoning as well as to form the basis of new inductive generalizations. Only in recent years have sufficient data been available for comprehensive statistical analysis. Practically all the publications of a statistical nature in this country have dealt either with the technic of analyzing quantitative data or with the results of such analysis when applied to a particular problem. Too little attention has been given to the problems involved in the collection and compilation of data and the making of estimates. A careful appraisal of the statistical data used in a given problem is fundamental if the conclusions based on the analysis of the data are to have validity.

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The tables appearing each year in the Yearbook of the Department of Agriculture contain two fundamentally different kinds of statistical data. First are those which result from enumeration of all items under a given category, such as the number of hogs slaughtered under Federal inspection, receipts of grain at primary markets, exports and imports of agricultural products, and the Federal census of agricultural production. Second, are estimates based on samples drawn from designated populations, such as the annual estimates of acreage, yield per acre, and production of various crops, number of livestock on farms, most of the market-price quotations, farm prices, farm wages, grain stocks on farms at specified dates, and agricultural income. Although the source of the material is pointed out in footnotes to the tables, many research workers, even some within the Department of Agriculture, fail to distinguish between the reliability of the different sources when drawing conclusions from the analysis of these statistics.

Any user of this large assortment of statistics would prefer data derived from enumerations rather than estimates based on sample data, provided that count be absolutely complete, or at least contain a uniform degree of incompleteness, throughout the entire series. It is conceivable that an estimate might be closer to the truth than an incomplete count or enumeration. The reliability of an estimate depends on several factors, including the homogeneity of the population from which the sample is drawn, the representativeness of the original sample data, freedom from bias, size of the sample, and the technical knowledge and common sense of the statistician making the estimate.

The research worker who uses the statistics compiled by the Department of Agriculture is entitled to know just how the data were gathered, and he should be given some basis for appraising their accuracy and reliability, whether they are results of enumeration or estimates based on sample data. Progress in the field of economics is being retarded at present because this type of essential information is not always available.

Statistics on agricultural production generally antedate those covering manufacturing and industry. The Sixth Federal Census, taken in 1840, contained items relating to agricultural production, but it was not until the Tenth Federal Census, in 1880, that both the acreage and the production of crops were enumerated. During the forties and fifties various agencies, including the Patent Office, trade journals, and newspapers, attempted to estimate production of the more important crops, such as cotton, wheat, corn, and oats, but the results were so unsatisfactory that when the office which eventually became the Department of Agriculture was organized in 1862 it was charged with the collection and compilation of agricultural statistics.

Official estimates of crop production must necessarily be both accurate and timely if they are to measure the annual supply of a given crop for the buyer and the seller, and thereby reduce the speculative fluctuations of the market price. The greatest accuracy could be obtained by means of a complete annual census or enumeration of the acreage, yield per acre, and production of each of the various crops. Such a census could not be taken until after the harvest was practically completed, and then it would require from several months to a year or more to tabulate its returns and make them available. It would also be very expensive in comparison with the cost of developing a crop-reporting service.

Not only are accurate estimates of the production of crops required immediately following the completion of harvest, but buyers and sellers demand forecasts of production of the various crops prior to harvest. "They could not do without them. Private agencies will supply them, and the government as a neutral crop reporting agency can not avoid its responsibility by omitting them" (*15, p. 320*).[1] Methods of forecasting are being steadily improved. With cotton, for example, on which there is an accurate check on production, the December estimate of production for 1928 was 99.3 per cent of the final ginnings. In 1927 the December estimate was 98.7 per cent of the final ginnings. The production forecasts of September, October, and November, during 1929, were each within 1 per cent or less of the December estimate, and the December estimate was 100.6 per cent of the final ginnings.

Forecasts and estimates of crop production are necessarily based on sample data rather than on enumerations. During June each year thousands of farmers report to the Department of Agriculture the acreages of the various crops growing on their farms, both for the current season and the year previous. From this and other information the percentage change in the acreage of each crop is estimated by the Crop Reporting Board. This percentage change in acreage is applied to the estimate of acreage for the previous year to produce an estimate of the acreage for the current year for each of the various crops. The decennial or quinquennial Federal agricultural census enumeration, with some adjustments for incompleteness, furnishes the base or starting point for estimates of acreage.

During the growing season forecasts of the probable yield per acre are made on the basis of the "condition of the crop in per cent of normal," actually on appearance, as reported by the regular crop correspondents. The relationship of condition to final yield per acre as a basis of forecasting is supplemented by weather and yield relationships.

After the harvest of a given crop is completed in practically all States, estimates of production for the crop are made by multiplying the estimate of acreage of the crop remaining for harvest after abandonment is deducted by an estimate of yield per acre. In late September an extensive survey of the current year's acreage of all crops is made with the help of the rural mail carriers of the Post Office Department. Results of this survey, with other information, form the basis of the estimates of the acreage of the various crops remaining for harvest. The crop correspondents, both regular and special, report on the average yield per acre of the various crops in their locality, and these returns are used as a basis for the crop estimate board's estimates of yield per acre. The forecast of production for a given crop in a particular State is the product of the acreage estimate multiplied by the forecast of probable yield per acre.

Accurate estimates of production require that methods of estimating all component factors be accurate and reliable.[2]

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[1] Italic numbers in parentheses refer to Literature Cited, p. 137.

[2] The reliability and adequacy of the farm price estimates of the department have been considered in U. S. Department of Agriculture Bulletin 1480 (*14*).

In the field of crop estimating, as in any other specialized field of knowledge, it has been necessary to develop a technic applicable to the problems involved. Many of these problems are similar to those now being encountered in the more general field of quantitative analysis of economic data. The general principles of statistics, especially as related to sampling, have been of material assistance in understanding the technic developed through many years of experience in crop estimating and in suggesting improvements that have already proven their worth.

The general problem of determining the reliability and adequacy of estimates of crop production must be considered from the standpoint of two specific problems—the accuracy of estimates of acreage and accuracy of estimates of crop yields per acre. The statistical principles related to the methods of sampling used in estimating crop yields per acre are much less complex and are of more universal application in the general field of quantitative procedure than are those related to the estimating of acreage. This study will be limited to the specific problem of estimates of crop yields per acre. A study similar to this has been made in connection with estimates of acreage, and many of the improvements in method that were developed have been incorporated in the procedure of estimating the acreage of crops.

PURPOSE AND PROCEDURE

The primary purpose of this bulletin is to report the results of a critical investigation of the sources of current information, the character of the information received, and the methods used in preparing the official estimates of yield per acre of crops. This investigation has been conducted over a period of several years, has served as a basis for determining the reliability and adequacy of estimates of crop yields per acre, and has resulted in improvement and refinement of methods used in preparing such estimates.

The procedure followed in the study was to examine the data regularly available to the Department of Agriculture in the light of statistical principles, related to sampling, that had been tried and proven in other fields. In the course of this examination the data basic to many of the official estimates for principal crops in related States were reworked, and accepted measures of reliability were applied. Official estimates were compared with the yields indicated by the reports received, considered alone without correction by the board.

The results are presented in the following order: (1) Description of the nature and sources of reports from farmers; (2) treatment of sample data to meet practical and theoretical requirements; (3) detailed critical analysis of the data for typical States and years for important crops; (4) comparison of yield estimates of the Department of Agriculture with yields derived from the census data; and (5) an appraisal of the historical series.

The first part, which deals with a description of the phenomena and methods is treated in summary fashion in view of available materials on the general subject.

The second part of this study, which adapts available sampling principles to the immediate problem of estimating the yields of crops, has resulted in a classification of the factors that cause samples to be misleading and estimates to be inaccurate. These generalizations,

which are based on experience in the field of estimating crops and livestock, have a definite application in the general field of making estimates and drawing conclusions from sample data. Every constructive worker in economics and related social sciences is forced eventually to utilize sample data, whether he collects them himself or not.

The detailed analysis of the sample data for typical States and years for important crops has involved an immense amount of labor both in actual performance, and in checking the accuracy of the work. A large part of this labor has been done by the staff of field statisticians in the various States and other workers of the Division of Crop and Livestock Estimates, in connection with courses of instruction in sampling and general statistics conducted by the author during the last three years.

In the fourth phase of this study, the sample data and estimates of yield have been directly checked against the yields per acre derived from census data. This is an entirely separate approach to the problem of the reliability of yield estimates. The conclusions of this study are based, therefore, on the results obtained by using two different methods of investigating the same general problem and are considered more dependable than if either had been utilized alone.

The brief evaluation of the yield estimates as a historical series will be helpful in explaining year-to-year variations in the yield of a given crop in a certain State on the basis of the weather and economic factors involved.

Scientific workers and students, especially those in the field of the social sciences, who are making and interpreting surveys and samples of social and natural phenomena will be particularly interested in the principles and methods of sampling as they have been developed by the United States Department of Agriculture over a period of more than 60 years. To this group the first part of this bulletin to and including the discussion of the reliability of the estimates for winter wheat will have greater significance than the remainder. Others, however, may be interested in the reliability of the yield-per-acre estimates for one or more particular crop. It is suggested that they consider the section on winter wheat as a basis for comparison with the particular crop of their interest. Those interested only in the general reliability of yield estimates made by the department will find most of their questions answered in the summary.

SOURCES AND KINDS OF INFORMATION

PHENOMENA OF CROP YIELDS

The phenomenon that the Department of Agriculture is called upon to measure and to estimate is the average yield per acre of a given crop for the United States, for a State, and for some subdivision of the State, such as a county or group of counties. The estimate of yield per acre for a State is theoretically the total production of a given crop in that State divided by the total number of acres of that crop harvested.

Although the term "average yield per acre" implies that the actual production on an acre of ground is the unit of observation, experience teaches that the smallest unit in actual practice undoubtedly is the average yield per acre for a field. If a farmer is asked how much corn he grows per acre on his farm, he is likely to say that on his 40-acre field on the river flat he produced 60 bushels to the acre and on his 20-acre field over on the hill, his average yield per acre was only 40 bushels. The production of a crop on a given field, divided by the area of that field, is about the smallest unit in which the farmer thinks of yield per acre. It is the rate of production per acre for any given area such as a field, several fields, or the locality.

Yields per acre of any given crop differ as between fields, between farms, between counties, between States, and between geographical areas. These differences result from difference in soils, cultural practices, seed selection, weather, farm management, and other factors. Since crop production is a natural phenomenon, it is reasonable to expect a fairly normal distribution of the observations if the samples are drawn from a reasonably homogeneous area.

Differences in soil fertility, topography, and climate are the fundamental causes of the variation in crop yields for the country as a whole. The Delta counties of Mississippi have on an average, much higher yields per acre of cotton than have the upland counties. The areas of high production per acre for the country as a whole are rather well determined and tend to be fairly homogeneous; areas on the margin of profitable production are less clearly defined geographically. Yields per acre not only differ, but so also do the geographic distribution and density of the acreage planted to a given crop. With the approach to the geographic margins of profitable production of a given crop, a smaller proportion of farm land is planted to that crop. In sampling for yields per acre of a crop it is necessary to consider not only geographic variations in yields but also geographic distribution of the acreage.

A political unit such as a State or county is not necessarily, and in fact is seldom, a homogeneous geographic district from the standpoint of either yield per acre or acreage distribution. If an approach to a normal distribution is to be secured in the observations of the sample of crop yields, a State should be divided into districts having natural conditions as nearly uniform as possible. In actual practice a State is usually divided into nine crop-reporting districts of about equal extent, on the assumption that the variation both in yields per acre and in the distribution of the acreage is greater over the entire State than within one of these districts. To the extent that this assumption holds true, the crop-reporting district is more homogeneous than the State as a whole. Homogeneity within the districts has been materially increased, in the case of several States, by giving more careful attention to natural geographic and climatic factors and the distribution of the acreage of the important crops when selecting the counties that are to be included within each district.

There are 41 State offices at present. There is one field office for the New England States, one for Maryland and Delaware, and one for Nevada and Utah. The two lists of crop correspondents, township and field aids, have now been merged in several States, including the New England States, New York, Pennsylvania, New Jersey, Maryland, Delaware, Virginia, West Virginia, Florida, and California. The combined list of crop correspondents reports to the field offices in these States. Generally speaking, these are States in which the crops of general speculative interest, such as wheat, corn, oats, and cotton, are relatively unimportant, or in which the agriculture is so

highly specialized that a sample has little significance unless interpreted by one familiar with the agricultural details of the State. It is deemed advisable, however, to continue this dual system of crop correspondents, in most important agricultural States, especially in those with highly speculative crops, as it insures that sample data will be available for the Crop Reporting Board. Reports from the State officers are sometimes lost or fail to reach the board by the morning of the day the report is released.

In some of the important grain States the returns from the regular crop correspondents of the department have been supplemented by special questionnaires to country mill and elevator managers, each of whom is asked to estimate the yield per acre for the more important grain crops in his locality.

In many States an additional "judgment inquiry" is sent out in the late fall to farmers who are not regular crop correspondents of the department. The returns from these inquiries, taken later in the season, supplement the regular returns and are especially helpful when estimates of yields are made on less than a State basis.

THE LISTS OF REPORTERS

The Department of Agriculture now maintains two lists of crop correspondents. Both lists are recruited from among farmers who are willing to serve without compensation and who are selected with the idea of having on each list at least one reporter from each agricultural township in the United States. The township list, which reports to Washington, has usually consisted of about 30,000 or more farmers. There are at present about 46,000 correspondents on the field-aid list, which reports to the field statisticians in each State. For any regular monthly report about 50 per cent of the correspondents return the questionnaires. The township list was first established in 1896 and the field-aid list in 1914, when the field force of the Bureau of Crop Estimates was reorganized. In 1925, the list of county correspondents was merged with the township list. The county correspondent was expected to provide himself with from three to five assistants living in different parts of the county, who reported to him the yields in their localities, while he in turn, made an estimate for the entire county.

JUDGMENT INQUIRIES

From the beginning in 1862 to 1930 the official estimates of crop yields per acre have been based primarily on what is called the judgment inquiry, in which the unit of observation for a given crop is the crop reporter's estimate of the average yield per acre in his locality. From 1862, when the county reporters were organized, until 1896, when the township list of crop correspondents was begun, the unit of observation was theoretically the average yield per acre for an entire county. It is obvious that, as a matter of fact, the average yield for the locality with which the reporter is familiar has always been the unit of observation.

In the generally used judgment inquiry of the department the crop reporter is asked to make an estimate of the average yield for his locality which, theoretically, would be the total production divided by the total acreage therein. In actual practice the crop reporter presumably starts with the knowledge of the average yield per acre on his own farm; then through contacts with other farmers, he obtains information concerning the average yields on other farms in his locality. Many reporters undoubtedly not only consider the yields obtained on farms with which they are familiar, but go even further and make an allowance for the poor appearance of some outlying farms for which they do not have accurate information. No effort is made to limit the locality that the crop reporter represents. It is possible that the influence of the higher yields on the reporter's own farm tends to result, in years of very low yields, in an estimate that is above the true situation.

After conversations with many crop reporters in Iowa, the writer is under the impression that most reporters do make an allowance for the low yields as well as for the high yields obtained in their immediate neighborhoods. Most of the reporters are better-than-average farmers and although they generally obtain better-than-average yields on their own farms, they do tend to discount their own yields in arriving at an estimate for their locality.

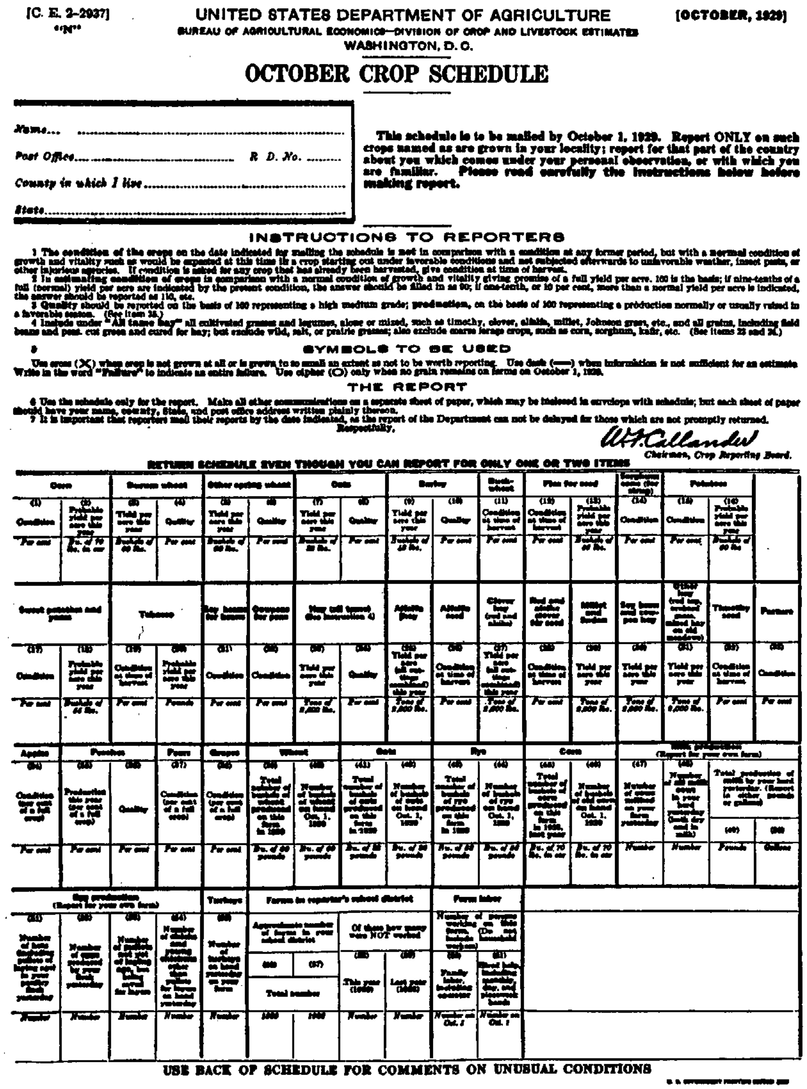
From 1883 to 1914, the returns from these voluntary crop correspondents, who reported directly to the department in Washington, were supplemented by the observations and estimates made by part-time State statistical agents, each of whom had a small group of crop correspondents. From about 1900 to 1914, full-time regional field agents were employed to travel continuously during the growing season and immediately after harvest over a territory comprising several States. They observed the condition and appearance of the growing crops and estimated the average yield per acre for each of their States on the basis of their observations, reports from a limited list of crop correspondents, and other information secured from operators of mills and elevators and informed persons with whom they came in contact during travel.

During the last few days of the month both lists of reporters receive a questionnaire which includes various items such as the condition in per cent of normal of the growing crop, yield per acre of different crops shortly after harvest, and miscellaneous questions on farm labor, farm wages, poultry and milk production, etc. The "probable yield" as well as the condition of wheat and rye is included on the June questionnaire for reporters in the Southern States. In July the questionnaire asks for the harvested yield of wheat and rye in the Southern States and the probable yield in the Northern States. The probable yield for the more important crops is requested about harvest time, and harvested yield is requested a month later, some allowance being made for the advancement of the season in the Southern and the Northern States. The October inquiry (fig. 1) includes the harvested yield of the spring-sown grains and the probable yields of corn and potatoes. The last inquiry on yield per acre for the season has been as of November 1; such late-harvested crops as corn, potatoes, and buckwheat were included. Beginning with 1928 in the Northern States the yield inquiry for corn was repeated on December 1, and this practice will be continued in the future. Early each year there is an announcement of the list of crop reporting dates for the year,[3] which shows what is to be published in connection with each crop report throughout the year.

[3] UNITED STATES DEPARTMENT OF AGRICULTURE, BUREAU OF AGRICULTURAL ECONOMICS. CROP REPORTING DATES FOR 1931 ANNOUNCED. U. S. Dept. Agr., Bur. Agr. Econ. Press Release. [1] p. January 31, 1931. [Mimeographed.]

REPORTS FOR INDIVIDUAL FARMS

In addition to these judgment inquiries, both regular crop reporters and other farmers are asked to report on the acreage and production of the crops on their own farms. From these reports a yield-per-acre



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UNITED STATES DEPARTMENT OF AGRICULTURE [OCTOBER, 1929]

BUREAU OF AGRICULTURAL ECONOMICS—DIVISION OF CROP AND LIVESTOCK ESTIMATES

WASHINGTON, D. C.

OCTOBER CROP SCHEDULE

Name ...

Post Office ... *R. D. No.* ...

County in which I live ...

State ...

This schedule is to be mailed by October 1, 1929. Report ONLY on such crops named as are grown in your locality; report for that part of the country about you which comes under your personal observation, or with which you are familiar. Please read carefully the instructions below before making report.

INSTRUCTIONS TO REPORTERS

1 The condition of the crops on the date indicated for mailing the schedule is not in comparison with a condition at any former period, but with a normal condition of growth and vitality such as would be expected at this time in a crop starting out under favorable conditions and not subjected afterwards to unfavorable weather, insect pests, or other injurious agencies. If condition is asked for any crop that has already been harvested, give condition at time of harvest.

2 In estimating condition of crops in comparison with a normal condition of growth and vitality giving promise of a full yield per acre. 100 is the basis; if nine-tenths of a full (normal) yield per acre are indicated by the present condition, the answer should be filled in as 90; if one-tenth, or 10 per cent, more than a normal yield per acre is indicated, the answer should be reported as 110, etc.

3 Quality should be reported on the basis of 100 representing a high medium grade; production, on the basis of 100 representing a production normally or usually raised in a favorable season. (See item 35.)

4 Include under "All tame hay" all cultivated grasses and legumes, alone or mixed, such as timothy, clover, alfalfa, millet, Johnson grass, etc., and all grains, including field beans and peas, cut green and cured for hay; but exclude wild, salt, or prairie grasses; also exclude coarse forage crops, such as corn, sorghum, kafir, etc. (See items 22 and 24.)

5 SYMBOLS TO BE USED

Use cross (X) when crop is not grown at all or is grown to so small an extent as not to be worth reporting. Use dash (—) when information is not sufficient for an estimate. Write in the word "Failure" to indicate an entire failure. Use cipher (O) only when no grain remains on farms on October 1, 1929.

THE REPORT

6 Use the schedule only for the report. Make all other communications on a separate sheet of paper, which may be inclosed in envelope with schedule; but each sheet of paper should have your name, county, State, and post office address written plainly thereon.

7 It is important that reporters mail their reports by the date indicated, as the report of the Department can not be delayed for those which are not promptly returned.

Respectfully,

W. F. Callander
Chairman, Crop Reporting Board.

RETURN SCHEDULE EVEN THOUGH YOU CAN REPORT FOR ONLY ONE OR TWO ITEMS

Corn		Durum wheat		Other spring wheat		Oats		Barley		Buckwheat	Flax for seed		Sorghum cane (for sirup)	Potatoes	
(1) Condition	(2) Probable yield per acre this year	(3) Yield per acre this year	(4) Quality	(5) Yield per acre this year	(6) Quality	(7) Yield per acre this year	(8) Quality	(9) Yield per acre this year	(10) Quality	(11) Condition at time of harvest	(12) Condition at time of harvest	(13) Probable yield per acre this year	(14) Condition	(15) Condition	(16) Probable yield per acre this year

USE BACK OF SCHEDULE FOR COMMENTS ON UNUSUAL CONDITIONS

FIGURE 1.—Typical monthly schedule or questionnaire. The monthly questionnaires sent to crop reporters differ with the nature of the information sought as the season progresses. In October the inquiry chiefly concerns the yields of crops. For those crops not harvested prior to October 1, the reporter necessarily gives his idea of the "probable yield." In some of the States and for those crops the harvest of which has been virtually completed the report is on "yield per acre this year"

estimate can be derived by dividing production by acreage. This is known as an "individual farm" inquiry. Since the crop correspondents are generally better-than-average farmers, the individual-farm returns usually show a higher average yield per acre than do the judgment inquiries. These individual-farm inquiries are made usually in the late fall after harvest is over for practically all crops except corn.

In years of generally good yields the spread between the yield per acre on the farms of crop correspondents and the average for all farms in the State is probably not as great as in years of low average yields because the crop yields of the better farmers are not so likely to be affected by adverse conditions as are the yields on either marginal land or on the farms of less skillful farmers. The individual-farm inquiry was first developed and used as a check on the judgment sample during the eighties, but it has not been in continuous use, largely because of its obvious limitations.

The yields derived from the individual-farm sample may be used in a relative sense, when their limitations are understood, as indicating the relative change in yields from one year to the next; they are especially helpful with winter wheat in years of heavy acreage abandonment, serving as a means of estimating production independently of yield and acreage estimates. In 1928, for example, there was heavy abandonment of winter wheat in the eastern Corn Belt States, and considerable land on which winter wheat had been destroyed was allowed to remain unplowed because of the excellent stand of new grass seeding. Many fields were allowed to remain without being plowed up for some other crop, but were only partly harvested. This situation made extremely difficult the determination of both the actual acreage harvested and the yield per acre of harvested acreage. The individual-farm production schedules were especially helpful in supplementing the returns from the regular judgment inquiries.

CENSUS ENUMERATIONS

In the years for which a Federal census is taken, the census is available as a third source of information concerning the yield per acre of the various crops. These yields are derived from the census of acreage and production through dividing the latter by the former. Unfortunately the Federal census is not taken until so many months after harvest that this information is sometimes not available for a year or two after the specified harvest and can be used only as a basis for revising the yield estimates of the crop year to which the census applies. Should only the yields in the census year be revised on the basis of this information, which is available every 5 or 10 years, these estimates for the census year would not be comparable with the estimates for the intervening years.

It would appear on first thought that these yields as derived from the census data would serve as an excellent check on the accuracy of the estimates of yields made by the Department of Agriculture, and reveal the measure of the discrepancy between the results of an enumeration and estimates based on sample data. Subsequent investigation will show that several circumstances concerning the enumeration of acreage and production must be taken into consideration when closely comparing yields as derived from the census data with either the estimates of yield per acre or the averages of original sample data secured from the crop correspondents of the department.

COMMERCIAL CHECKS

The department has been obtaining commercial checks on production, such as figures showing cotton ginnings, car-lot shipments of fruit and vegetables, shipments and mill-door receipts of grain and flax in the spring-wheat States, and auction sales, which are useful as indicators of probable production during harvest and as a basis for estimating production after harvest. The field or State statistician gathers his summer information concerning acreage changes, production, yield per acre, and marketings, from farmers, county agents, elevator men, bankers, and others, for both the current and previous year.

PREPARATION OF THE ESTIMATES

The returns from township correspondents are tabulated and edited in the central office in Washington. The returns from the field-aid reporters, and from the combined list of correspondents in those States in which the two lists have been merged, are tabulated and edited in the respective State field offices.

The returned questionnaires (fig. 1) are usually entered on large sheets, by counties or by crop-reporting districts. This organization of the observations on a county basis is of material assistance in editing and checking and makes possible the computation of averages by counties. After the returns have been listed and carefully edited, averages are computed by counties in the field offices, and by crop-reporting districts in the central office in Washington. These averages of crop-reporting-district data are then weighted by acreage weights for the current year's crop to secure a weighted average yield per acre for the entire State. The unweighted or straight average (arithmetic mean) of all reports for the State is also calculated.

At harvest time the field statistician in each State carefully summarizes the sample data that he has received from his field-aid reporters and from such special correspondents as mill and elevator managers and cotton ginners. From observations and contacts made during travel over his State, and in the light of many years of experience in that State, he considers the representativeness of the sample, its size, and the possibility of bias, and arrives at an estimate of the yield per acre of a given crop for the State. This estimate usually does not differ materially from the weighted average of the returns from the field aids. The estimates of the field statistician, and the statement of the district and State averages from his crop correspondents are mailed to the Crop Reporting Board in Washington. Comments concerning the weather and other pertinent factors accompany these data.

These reports from the field statisticians to the board are divided into two classes, the A reports which deal with corn, wheat, and oats, and the B reports which include all other crops except cotton. The reports on corn, wheat, and oats, from States in which these crops are of very minor importance from a national standpoint, are included with B reports. The reports on cotton are handled separately from all other reports and are released a day or two prior to the general report, which by law must be issued not later than the 10th of the month. The B reports are mailed directly to the board prior to the mailing of the A reports, which are sent directly in a specially marked A envelope to the Secretary of Agriculture. The A envelopes are placed immediately in a safe where they remain locked up until the morning of the day the crop report is released, when they are opened in the board room.

The Crop Reporting Board makes its estimates of the A crops behind locked doors and screened windows, and under guard, on the day of the release of the general crop report. The cotton report is handled in the same manner throughout as is the report on the A crops. At a specified minute copies of the crop report are laid face down beside telephone or telegraph instruments through which newspaper reporters assembled for the purpose may, at the stroke of a bell, transmit the details. Through relays, the report is available almost instantaneously at any point in the world. In making this report the Crop Reporting Board considers the sample data from various sources, other information, and the estimates submitted by the field statisticians, and arrives at an estimate of yield per acre by States, which is applied to the current estimates of acreage to obtain an estimate of production by States and for the country as a whole.

In December, when the final estimates of acreage, yield, and production for the current year are made, the Crop Reporting Board reconsiders all information obtained since the harvesting of the various crops, that concerns the yield per acre. If a revision of the yield per acre is apparently justified, such a revision may then be made in connection with the final estimates for the year. The following year, in connection with the July report or the December report, further revisions may be made if convincing evidence of need has appeared in the meantime. The final check of car-lot shipments, mill-door receipts, ginnings, etc., sometimes justifies these later revisions of yield as well as of acreage.

ADEQUACY OF SAMPLE DATA

THE PROBLEM

Present-day economists are making use of statistical information to a greater extent than ever before in the history of economic thought. Research workers are compelled to base generalizations upon sample data of one kind or another. Even when statistical series that have been completely enumerated over a period of years are used as a basis for relationship studies or correlation analysis, the data for the years included in the study are a sample of only a few years taken from a universe of all years or an infinity of time. There are always the questions as to whether the results secured for the limited period under observation will continue to be applicable in future years, and whether the generalizations that apply to the sample really apply to cases not included in the sample. The statistician's basis for assuming that a generalization concerning the average yield per acre of a crop from sample data will apply to the cases not included in the sample must be logically developed.

The ordinary methods of inductive reasoning are used, basing the logical processes upon statistical data. The whole practical problem of statistics centers on the validity of the reasoning process; on the validity of the assumptions upon which this type of inductive reasoning, known as statistical induction, is based. The fundamental assumptions that underlie this type of inductive reasoning may be briefly stated, but they must be held constantly in mind.

(1) There is the general assumption of the orderliness and uniformity of nature, or that there is some finite degree of variation in nature. (2) A random sample with all observations free from bias is usually assumed. (3) The conclusions from sample data can not be absolute and must consequently be expressed in terms of probability, which, however, can be given assignable limits. Any development or adaptation of the general theory of sampling must center about these fundamental premises to statistical inductive reasoning. In actual practice it is soon discovered that a random sample is very difficult to obtain and may be actually quite misleading, and that the observations in the sample are subject to both wide errors of observation and bias.

Can a sample be so drawn or so handled that it will reflect the situation of the large group or universe of inquiry from which it is drawn? This is fundamentally a problem in "sampling" in its broadest and most practical application. It involves a comprehensive statistical description of the sample data upon which the estimates of yield per acre primarily depend, and a careful consideration of the problem of statistical induction which is involved when an estimate is made largely on the basis of sample data. It is always difficult in practice to differentiate sharply between these fundamental distinctions inherent in the theory of statistics. As Keynes says (*9, p. 377*):

> The first function of the theory of statistics is purely *descriptive*. It devises numerical and diagrammatic methods by which certain salient characteristics of large groups of phenomena can be briefly described. * * * The second function of the theory is *inductive*. It seeks to extend its description of certain characteristics of observed events to the corresponding characteristics of other events which have not been observed. This part of the subject may be called the Theory of Statistical Inference.

Later Keynes points out that the more complicated and technical the preliminary statistical investigation becomes, the more inclined is the statistician to mistake the statistical description for an inductive generalization. Inductive reasoning tells us that on the basis of certain evidence a certain construction is reasonable, not that it is true. Induction depends upon experience for its validity.

Theoretically the making of an estimate of crop yields involves, (1) the collecting of sample data concerning yields per acre. These data are tabulated and edited, and an average (which is one of the most important characteristics of a sample) is computed. (2) The making of an estimate of a particular crop for a given State involves statistical inference. The statistician must take the step from his sample to the universe of inquiry, that is, in this case, from the average yield per acre for a given crop as shown by his sample to an estimate of yield for the State as a whole. The reliability of the estimate will depend not only upon the reliability and adequacy of the basic sample data, but also upon the statistician's appreciation of the assumptions involved and his interpretation of the indications from the sample.

The statistician does not willingly accept the average of the sample and use it as an estimate of the yield per acre for the State unless he is satisfied (1) that the universe from which the sample was drawn is reasonably homogeneous, (2) that the sample is fully representative of the State as a whole, (3) that the individual observations are free from bias or cumulative error of any kind, and (4) that the sample itself was sufficiently large to insure a high degree of "precision" or stability in the average obtained. He may also be influenced by such objective information as cotton ginnings to date and car-lot shipments, which indicates to some extent the change in production from the previous year and by his own observation and contacts in evaluating the sample and in drawing inferences when generalizing from the sample to the estimate of the average yield for the entire State. A great deal of the information and experience needed for the most intelligent interpretation of the sample can be obtained from a careful statistical analysis of similar samples collected in the same manner from much the same list of crop correspondents in previous years. These samples can be tested for various kinds of representativeness, for the influence of size of sample, and even for bias, provided check data are available. This systematic analysis of several previously obtained samples, in combination with a full appreciation of the current situation, forms an excellent basis for properly evaluating the sample data and consequently insures a high degree of accuracy in the estimates themselves.

It is possible to select a sample that will reflect the situation of the large group from which it was drawn. The requirements change with the objectives or the purposes for which the results of the sample are to be used. Consequently one of the first considerations in obtaining a sample of any kind is to determine the particular objective that is sought. Of the four general objectives of sampling in the field of agricultural economics, as outlined by the advisory committee on research methods of the Social Science Research Council,[4] two seem to apply most definitely to the sampling of crop yields per acre.

The first is to obtain an accurate description of conditions existing in a given universe of inquiry. Ideally the sample should be a miniature or replica of the universe being sampled.

The second objective is to obtain a measure of the change in conditions taking place from time to time rather than an exact measure of conditions existing at any one time. The absolute level shown by the average of a sample may be too high, but the change shown by successive samples from month to month, or year to year, may accurately represent the change taking place in the universe of inquiry. Constant bias or constant lack of representativeness is eliminated when data from two samples are used relatively. Obviously a sample which would be a miniature of the whole, taken from time to time would also reflect accurately the change taking place in the universe of inquiry.

In sampling for crop yields, the purpose of all the judgment inquiries is to realize the first objective—a miniature or replica of the universe of inquiry. Each observation represents the reporter's judgment concerning yields in his locality. A sample is wanted that will give the true average yield for the State as a whole. The estimate of crop yield per acre is used in an absolute sense when it is multiplied by the estimate of acreage to obtain an estimate of production for a given crop. The requirements are much more rigid when a sample is to be used in an absolute sense, than if the objective is only to measure change—the second objective.

With the individual-farm sample, in which a derived yield per acre is obtained by dividing the production of a crop by the acreage

[4] SOCIAL SCIENCE RESEARCH COUNCIL, ADVISORY COMMITTEE ON SOCIAL AND ECONOMIC RESEARCH IN AGRICULTURE. RESEARCH METHOD AND PROCEDURE IN AGRICULTURAL ECONOMICS. v. 1, 196 p. 1928. [Mimeographed.]

on which it is grown for the farms in the sample, the purpose is primarily to measure change in conditions, and an absolute replica of the universe of inquiry is not required. Comparability between the two successive samples is essential if they are to be used in a relative sense. Complete comparability as to location and persons represented in the samples for two successive years, can be secured only when the returns from identical farmers are compared. Not only may higher yields be expected from the farms represented in the sample than from all farms in the State, but it may be expected that this spread will not be constant from one year to the next. This spread probably is smaller in years of high yields than in years of low yields. If it could be assumed that the necessary correction factor, which is needed to convert the yields from the sample into average yields for the State, would remain constant from one year to the next, then the two samples could be used in a relative sense, to indicate change.

There is the further difficulty of finding a satisfactory base from which to depart or to apply the indicated change, when the two samples are used in a relative sense. When last year's estimate of final yields is the result of other and better samples or better check data, then a relative indication of change in yield can be utilized with greater confidence. The individual-farm sample is at best only a check on the judgment inquiry and serves as a second line of defense when unusual conditions arise and the evidence is conflicting.

REPRESENTATIVENESS OF YIELD SAMPLES

In using the judgment-inquiry sample with the objective of obtaining a replica of the universe of inquiry, so that the average obtained from it may be used in an absolute sense, the sample must be thoroughly representative of the entire population from which it was drawn. If the individual-farm sample is used, in a relative sense, with the objective of measuring changes in the population by being applied to some base year and carried along from year to year, then the problem is not so much one of obtaining fully representative samples as of obtaining comparative representativeness as between the samples that are to be compared. In this case what is wanted is successive samples from year to year which, taken collectively, will be representative of the change taking place in the population of the universe from which they are drawn.

How to obtain a representative sample in the realm of living things, as of the yield per acre of various plants, is fundamentally a biological problem. The individual observation in the judgment inquiry is based on the crop reporter's locality; in the individual farm-yield inquiry it is based on his own farm. Evidently it is necessary that the sample contain observations from the full range of possible yields either by localities or by farms for a given crop. All known differentiations of the universe from which the sample is drawn should be given consideration, and provision should be made for their inclusion within the sample and in so far as possible in proportion to their occurrence in that universe.

Some measure of the geographic representativeness of a sample can be obtained from a map that shows in detail the local topography, geography, soils, etc., of the points at which the observations were obtained. On both the township and field-aid lists the reporters are distributed by townships, and it is possible to ascertain the townships not represented in the sample.

The importance of geographic representativeness depends on the extent of local differentiation in crop yields. If a county is made up of townships that differ considerably as to topography, soil fertility, and distance to shipping points, it is extremely important to have a report from each township in order to obtain a sample that will be representative of the county. On the other hand, if there is as great a range of yields within the township as over the county it is not necessary to be so particular concerning the distribution of reports by townships. The same reasoning would apply to counties within a crop-reporting district or in the State as a whole. Unless there is geographic differentiation in the universe of inquiry, a sample from one section is likely to show about the same yield as that from another.

When a county comprises two distinct types of soil, varying greatly in fertility, as may happen in any State in which there are broad rich bottom lands and less fertile uplands, it is of the utmost importance to have the sample include observations from localities on both types of soil and to obtain the observations in about the same proportion as the acreage of a given crop in these two localities. If a crop is grown on both irrigated and dry land in the same county or township it is necessary to consider the low, dry-land yields separately from the higher yields obtained on the irrigated lands. This differentiation is so extreme as actually to result in two different universes. If the observations from both dry-land and irrigated localities are handled as one sample it will be found that the observations arrange themselves into two distinct modal groups. Consequently there is no tendency toward a piling up of the observations at some central point, which is essential if the average, as computed, is to have statistical significance. A weighted average for the State can be obtained by using estimates of the acreage of the crop grown under irrigation and of the acreage grown on dry land as weights. This method was used in all the far Western States for the first time in 1929.

The crop-reporting districts (fig. 2) do tend to group the counties into districts that may differ considerably in the factors that influence yields per acre of a given crop. A number of State statisticians, have effected improvement in handling their sample data by regrouping the counties into more homogeneous crop-reporting districts than were obtained under the original rigid system of nine districts per State.[5]

It would be ideal if the sample could be selected in such a way that the number of reports would be proportional to the acreage of the crop, township by township within the county, and county by county within the State. The present system of distributing the reporters by townships tends to bring this about. The representativeness of the sample is further improved by the method of weighting the average yield obtained in each crop-reporting district by the acreage of that crop in that district, thus obtaining a weighted average yield for the State. The closeness with which the unweighted or straight average (arithmetic mean of all the reports) checks with the weighted average for a State indicates whether or not the sample is distributed as between crop-reporting districts in about the same proportion as thecrop.

[5] The original system was adopted from the grouping of counties made by the Post Office Department which divides a State into nine districts—northwestern district, north-central, northeastern, west-central, central, east-central, southwestern, south-central, and southeastern.

Under some conditions this method of weighting effects marked improvement in representativeness, as in the case of cotton yields in Mississippi, where it is much more difficult to obtain reports from the

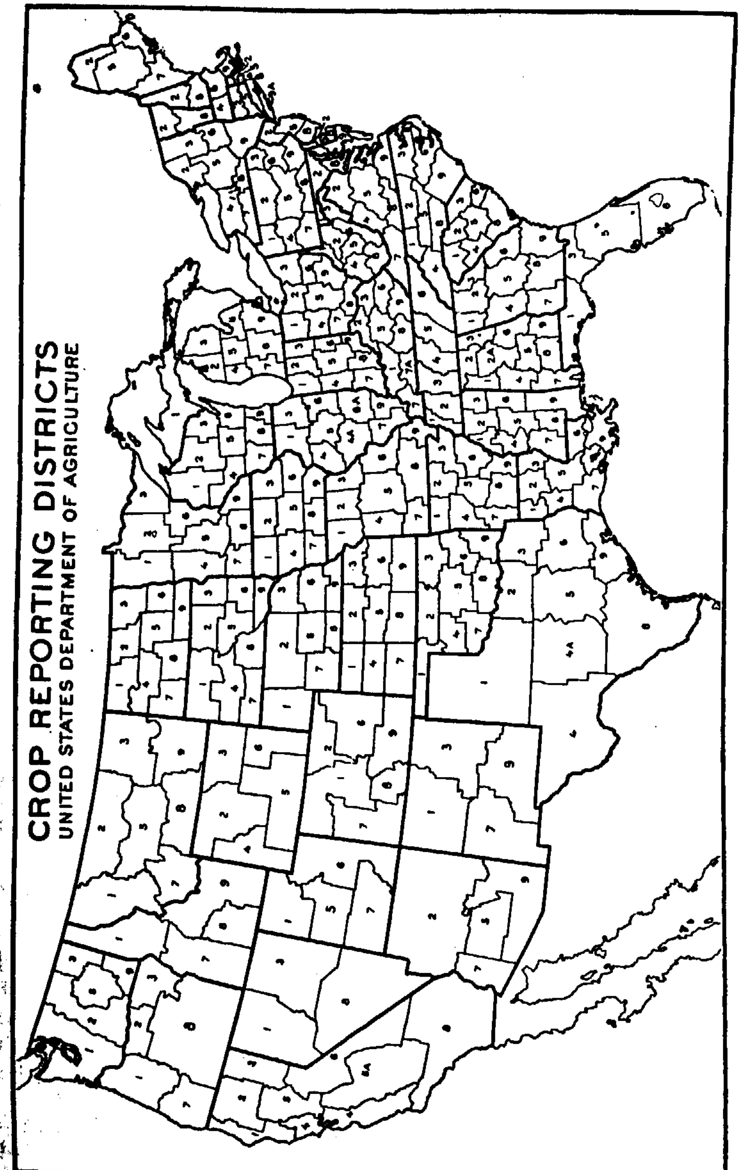

FIGURE 2.—Districting of States for crop-reporting purposes is a modification of the system used by the Post Office Department in handling the mails. The district boundaries follow county lines and include those contiguous counties which together make up the most homogeneous agricultural producing areas possible under the limitations of location. Shifts in the boundaries have been made from time to time, especially in the Western States. This map shows the present lines

large plantations in the Delta counties than from the farms in the much lower yielding counties on the upland. Weighting a crop by irrigated and dry-land acreage materially improves the representativeness of the yield-per-acre sample.

With highly localized crops, especially with fruits, commercial vegetables, and certain minor crops (such as potatoes, beans, peanuts, or tobacco in certain States), it is necessary to average and weight by counties; with a crop like beans it may be necessary to weight by varieties or types as well as by counties, in order to obtain a sample that is representative of the universe of inquiry. From the standpoint of geographic representativeness it is of the utmost importance that the State statistician be thoroughly familiar with the agriculture of his State in order that he may be in better position to evaluate the representativeness of his sample data. His travel over his State fits him to appraise reports that are not reasonable for a given locality.

Judgment inquiries require a sample selected in such a way that the reporting localities will represent the county, district, or State. So far as the representativeness of the crop reporters estimate for his locality is concerned, there is little opportunity to test the sample. Individual differences in yield exist as between fields on the same farm and farms in the locality. With this type of inquiry it is necessary to rely solely on the crop reporter's judgment concerning his locality, trusting that errors in all the judgment estimates may be compensating when the sample is of sufficient size. It is also possible that what is later designated in this study as "bias," in the observations themselves, is in fact due in part to the inability of the crop reporter under certain conditions to make an estimate that is truly representative of his locality.

With the judgment samples of yield per acre it is necessary to assume that (1) the reporter's estimate is representative of his locality, (2) the localities from which reports are received, are also representative, (3) the localities from which estimates are received do not overlap sufficiently to give undue weight to any one section of the State, and (4) the observations in the sample as reported are distributed proportionately to the acreage of the crop being sampled both within the county and in each crop-reporting district. Weighting yield-per-acre sample data of the major crops by counties changes the weighted average for the State so little from what it is when weighted by crop-reporting districts that the additional labor usually is not justified. With minor crops grown largely in certain counties (such as rye in Wisconsin and potatoes in many States) weighting on a county basis is necessary in order to obtain a representative sample.

With the individual-farm sample of yield the problem of representativeness applies to the farm as a unit and hence becomes a much more complicated problem than in the case of the judgment reports for whole localities. Not only is geographic representativeness just as fundamental as with the judgment inquiry, but there is the additional problem of selecting farms that are really representative of the different farms and farmers found in a county, district, or State.

When the individual farm is taken as the unit of observation, prior experience with agriculture suggests that there are many possible sources of differentiation. Yields may be higher on owner-operated than on tenant-operated farms, on small farms intensively operated than on large extensive farms, on farms where livestock is highly important than on farms where cash crops are grown. Better yields might also be expected on the farms of the more intelligent and public-spirited farmers such as those who are willing to serve as voluntary crop reporters. If weighting the sample by counties or crop-reporting districts improves its geographic representativeness, it is equally logical to divide the sample on the basis of other well-known differentiations (such as size of farms, method of farm operation, etc.) that may be associated with yield per acre. Averages can be computed for these subdivisions of the sample and weighted by the importance of the crop in each subdivision to obtain a weighted average either for the crop-reporting districts or for the State.

This division of the sample into subdistricts is called "stratification." To insure comparability between the averages of two samples made up of individual farms taken at different times and used as relatives to indicate change in the universe of inquiry from one inquiry to the other, it is important that the sample be stratified (on the basis of any factor that may be related to the yield per acre, such as size of farm,) and that the same weights be used in computing the average for each of the two samples. If there is a relationship between size of farm and yields per acre the sample should be weighted on the basis of size of farm. This is especially true with individual-farm reports on acreage used in a relative sense. The use of a relative indication from two samples obtained from the same farmers for both years insures comparability without the necessity of stratification. The interpretation of a relative indication of change from two samples that are comparable depends on the statistician's judgment concerning how well the sample reflects the change that has actually taken place for the State as a whole.

This is a somewhat different problem from the one presented by a definite shift in the geographic distribution of the crop. In case of such a shift it would be necessary to use new weightings in order to obtain an accurate estimate of yield for the whole area under consideration.

METHODS OF SELECTING A REPRESENTATIVE SAMPLE

The question of representativeness is of vital importance in sampling. Pearl (*12*) in considering the geographic selection of observations in sampling says:

> The whole universe dealt with covers a certain area. To get a representative sample it will, therefore, be necessary to lay down over the whole area an imaginary network, in which all the meshes are of equal and not too large area, and then draw a sample relative to the other differentiations from within each mesh.

The selection of a reporter from each township for the township list of crop correspondents and another for the field-aid list is practically what Pearl suggests doing. In most statements concerning the selection of a sample that will be representative of the universe of inquiry great emphasis is placed on obtaining a perfectly random sample. In fact, any departure from random selection is presumed to result in a sample that would be useless because it would not be representative. If the sample is not representative it would be biased and not trustworthy. The term "bias" is not used in this study to indicate a sample that is not representative of universe of inquiry, but it is reserved for the more specific use of referring to the non-compensating errors of the individual observations themselves.

Although random selection is the foundation of all sampling theory, certain departures or improvements can be effected that will insure a sample not only more representative, but more stable than one selected purely on the basis of randomness. The limitations of random selection are well illustrated in dealing four hands of cards in auction bridge. Each hand of 13 cards is a random sample made up of 25 per cent of the 52 cards and yet one player may get a hand worth several times as much as the hand of some other player from the standpoint of taking tricks. The composition of this especially good hand is not at all representative of the whole deck of cards. Bowley (*2*) suggests four methods that may be used in selecting a representative sample, beginning of course with random selection. These methods are:

RANDOM SELECTION

Random selection is usually known as "simple sampling." A sample is found in such a way that every one of the individuals in the universe of inquiry has the same chance of being selected in the sample, and that the selection of a particular individual does not influence the chance of selecting some other individual. This corresponds to selection on the basis of a lottery. There are various approaches to random selection that do not completely fulfill the requirements, such as every tenth farm along a road. Returns must be made compulsory, otherwise the sample is from only those who are willing to reply. With individual-farm returns from crop reporters the sample is selective of the better type of farmers.

STRATIFIED RANDOM SELECTION

For stratified random selection the universe is subdivided into districts, geographically as crop-reporting districts (or on the basis of some variable as size of farm, tenancy, nativity of farmers), and a number of observations are taken at random in each district. Bowley's original concept of stratified random selection implied that the same size of sample should be selected from each stratum or district and that all strata or districts should be of equal importance. When a sample is selected in this manner it is designated as a proportionately stratified sample to distinguish it from the samples obtained by the method used in crop-estimating work, in which it is impossible ordinarily to select in exact proportion to the acreage in each district or to have the districts all of equal weight. In obtaining a sample in crop estimating, the State is divided into districts, and the average of each district is weighted by the acreage of that crop in the district—a method which will be termed "weighted stratified selection."

PURPOSIVE SELECTION

> The term Purposive Selection denotes the method of selecting a number of groups of units in such a way that the selected groups together yield as nearly as possible the same averages or proportions as the totality with respect to those characteristics which are already a matter of statistical knowledge (*3*).

When a sample is secured by the "purposive method," groups of observations are deliberately selected by the statistician, the principle of randomness being entirely disregarded. The judgment of the statistician is substituted for impartial chance, or the mechanical principle, in the selection of the sample. The objective is to select a sample that will have the same characteristics as the whole universe of inquiry.

In selecting these areas or groups of units for the sample the statistician uses, as far as possible, criteria or controls which relate to the field of inquiry. Controls are factors which are known for both the

unknown quantities that are being investigated. Such areas are selected as will, in their aggregate, give the same results in respect to these control factors as does the universe.

STRATIFIED PURPOSIVE SELECTION

Purposive selection can be made on the basis of a stratified sample. Take for example the partial or sample census of agriculture, which has been proposed as a means of obtaining a reliable indication of change in acreage of the various crops from one year to the next. The selectivity of a voluntary sample, which covers only the farms operated by farmers who are willing to report, would be entirely overcome by a compulsory and complete enumeration, year by year, of all the farms within a number of specified enumeration districts distributed over the State. With the selectivity of the best farmers eliminated, the remaining problem is to select districts geographically representative of the differentiation existing over the entire State or county, constituting the universe of inquiry.

The objective would be to obtain a sample made up of a number of enumeration districts, which would be a replica of the universe of inquiry so far as important factors taken as controls are concerned.

The more nearly the sample is a replica of the universe of inquiry in the year of the census, the more it would tend if enumerated each year, to reflect the changes in acreage of the various crops from year to year. A tabulation by enumeration districts of selected control items from the census schedule would render these items available for both the enumeration districts and the universe as a whole in the year of the census. By a method of sorting and subsorting these enumeration districts, it would be possible to select a sample made up of such districts which would proportionately represent the differentiation of these control items throughout the universe of inquiry, and by the judicious use of "trial and error" in the selection of individual districts, the averages of the sample for these control items could be made to approach very closely to the averages for the universe of inquiry.

In choosing the control items from the census schedule, as a basis for rendering the sample a replica of the universe of inquiry in the year of the census, such factors as might have the highest correlation with changes in acreage and the least intercorrelation between themselves should be selected. This selection would be based on a priori reasoning until sample surveys for two or more years were available for determining just what factors in the farm organization are correlated with changes from year to year in acreages of various crops. The individual farms secured by the sample census for two consecutive years would be used as the units of observation in such a study of relationships. The factors, which might be determined tentatively, should include the acreage in the farm and in each of the various crops, as well as such factors as the number of milk cows and other classes of livestock, proportion of tenants, nativity of farm operators, value of land and buildings, and proportion of produce sold cooperatively.

A simple arithmetical test for representativeness may be applied to any sample when the totals for the entire district or State are known. The percentage relation of the sum of each of the items or control factors in the sample to the total of each for the complete census enumeration is determined. That is, if the sample contains 5 per cent of the land in farms in the State, does it also contain 5 per cent of the acreage of corn, wheat, oats, hay, and other crops grown as well as 5 per cent of the milk cows, of the number of tenants, of the native-born farm operators, and other factors? The more nearly all the factors approach a given percentage, the more nearly representative is the sample, provided the frequency distribution of these factors within the sample also approaches the distribution within the universe of inquiry.

If this test is satisfactorily met by a sample of individual farms selected at random, it is reasonable to assume that the frequency distribution of the sample corresponds closely to that of the entire universe. When applied to a sample of enumeration districts obtained by purposive selection, it is important that enumeration districts be selected in proportion to the frequency distribution of the universe of inquiry. This simple test is especially helpful in checking up on the representativeness of a sample regardless of the method of selection used.

If the county, rather than the State, is used as the basis for crop and livestock estimates, enumeration districts much smaller than those used by the census would be necessary in order to cover the differentiation that exists within a county. In Alabama, where a sample census has been taken for several years, several routes over each county have been selected, and the farms along these roads are enumerated each year.

This method of purposive selection has been used in several of the Scandinavian countries (*6*, *7*, *8*) for more than 20 years, with excellent results, as a means of estimating crop acreage and production. It is much more reliable than any system based on voluntary crop correspondents and much more timely and inexpensive than a complete enumeration.

With Bowley's classification of methods in mind, the judgment inquiry on crop yields may be designated a "stratified voluntary-judgment sample of crop yields per acre." The sample is not random, nor does it fall under the heading of purposive selection, as returns are only from those who are willing to reply. The statement applies equally well to the individual-farm yield sample. On the other hand, the samples may be considered as highly stratified, and with major crops the returns are closely proportional to the importance of the crop. The breaking up of the State into crop-reporting districts is a form of stratification. The use of the weighted State averages is an excellent and practical substitute for "proportional stratification." Instead of having a random sample within the district, the sample is further stratified because of the fact that the reports received are distributed by townships. The use of county or district weights helps to improve the geographic representativeness by distributing the influence of the sample in proportion to the acreage of the crop. The individual-farm sample by contrast may be designated a "stratified voluntary individual-farm sample of acreage and production," from which crop yields per acre may be derived.

Voluntary reporters may be influenced toward making high estimates of yield per acre by the higher yields obtained on their own farms. This tendency may be further accentuated by the fact that

it is always easier to secure reporters in the better farming localities than in the marginal localities of a county or crop-reporting district.

This limitation of lack of representativeness is serious with all the sampling work of the department. In making estimates this factor is considered and allowed for in so far as it is possible to do so without adequate check information. The use of purposive selection as a method of making a sample census would eliminate this kind of selectivity which is due to the voluntary nature of the reports, as a sample census of representative districts would include all of the farmers in a given district. It then would be a problem of selecting a sample that is geographically representative of the agriculture of a State. A careful and intelligent application of the principles of stratified purposive selection as suggested by Bowley and herein developed, would go a long way towards obtaining a really representative sample of American agriculture that would reflect changes in the acreage of various crops and numbers of livestock on farms from year to year and serve as a partial check on the yield-per-acre samples and furnish other valuable statistical data of high economic value.

ERRORS ENCOUNTERED AND THEIR TREATMENT

From a statistical point of view there is a distinction between mistakes and errors. Mistakes arise from carelessness or incompetency in transcribing and reading figures or from numerical mistakes in computation. The only safe assumption in regard to computation is that mistakes are bound to occur and a system of checking is always necessary. The general policy of the Division of Crop and Livestock Estimates is to have all original computations of sample data verified by a second computer and the corrections verified by the original computer. The calculations that are used on the day of the issuance of the report, in computing production from acreage and yield indications, are always carefully reviewed by one or more members of the Crop Reporting Board. Even with these precautions an occasional mistake is made; it is usually found soon after the release of the report, and the corrected figure is given wide distribution. In a field office there are times when the pressure of work for a crop report becomes so great that it is impossible to verify all computations. A comparison of county averages by the statistician who is thoroughly familiar with the State serves as an effective preliminary check. When the vast number of the calculations made under high pressure is considered it is surprising how few mistakes actually occur.

A comparison of the weighted and unweighted averages serves to show the presence of mistakes in computation. If the two check closely then the probability of a mistake is not high. If they do not check closely either there is a rational explanation of the difference or a mistake has been made. If the number of reports is not in proportion to the weights and there is considerable difference between district averages then a high district average with a large weight will tend to make the weighted average higher than the unweighted average; the opposite situation would result in a weighted average below the unweighted.

PREVENTABLE ERRORS

Errors are encountered in sample data; some types of error may be prevented, but all must be corrected in so far as possible. Misunderstanding of the question, or of the definition attached to the question, is a frequent source of error, especially in the case of questionnaires handled by mail; such mistakes may be serious even when a schedule is filled out by a paid but inadequately instructed enumerator. Carefully preparing the questionnaire and testing the inquiry in a limited way will enable the statistician to avoid many of these sources of misunderstanding. Frequently the condition or the quality of the crop is reported when yield has been requested. If the condition or quality is between 50 and 100 and yields per acre are not running over 25 to 40 bushels, it is comparatively easy to detect these mistakes or errors on the part of the crop reporter and delete the offending figures before the averages are calculated.

The yield of corn is measured and consequently reported in three different units: (1) By the standard bushel, equivalent to 56 pounds of shelled corn, in the Corn Belt States, (2) by the bushel basket of ear corn, actually one-half a standard bushel, in parts of New York, Pennsylvania, and New England, and (3) by the barrel of 5 standard bushels in sections of Maryland. The remedy for such a situation is to ask for the yield per acre of corn in all three units of measure, side by side on the same inquiry. Fundamentally the problem is to know in what terms the farmer usually thinks and then ask the question in those terms. Difficulty arises because the same questionnaire, for reasons of economy, must be used in several States.

When the yield of "all tame hay" is included on the schedule as one question, the average obtained in most States is likely to be lower than when the yield is asked by varieties and the average for each variety is weighted by the acreage of that variety. The farmer does not always include the higher per acre yield of alfalfa in his estimate for all tame hay. His definition of all tame hay is not the same as the one used by the department. During recent years this situation has been corrected by obtaining yields by varieties on a special questionnaire late in the fall after all the hay crops are harvested.

Asking questions concerning facts upon which the informer has no definite information is not only useless work, but it tends to create prejudice against the entire crop-reporting service. It is impossible, for example, to obtain accurate information in most States as to the total quantity of milk produced, or total number of eggs laid, during the previous year or of changes in acreage of the various crops in the locality from year to year. Unless the farmer has sold fluid milk and has a statement of what he sold each month he is likely to be influenced by the more recent production on his farm. It is better to repeat the inquiry periodically and limit the estimate to a day or a week.

It is surprising to observe in how many ways different individuals will reply to a question concerning their estimates of the yield per acre for a hypothetical case that is fully described to them as a group. It is small wonder that printed instructions are sometimes misread, especially if a man is tired from a hard day's work in the harvest field. The statistician must be able to devise a questionnaire that is direct, straightforward, and readily understood, and he must be on the alert to detect reported figures that are apparently the result of misunderstanding the question.

COMPENSATING ERRORS

The worker in the physical laboratory knows that there is no such thing as an absolutely exact measurement. When an object is measured repeatedly and with the greatest care the results are not identical. The most probable value may be obtained by averaging the results of a number of observations provided the errors, or differences, of the separate observations are accidental and tend to balance each other. These compensating errors are spoken of as errors of observation. As Pearson (*13*) says: "In most cases our knowledge does not wait upon certainty, but is described in terms of probability which may approach certainty."

Chaddock (*4, p. 212*) describes the origin of the probable error concept, as follows:

> Gauss made repeated observations of the same phenomenon, as the diameter of a heavenly body in order to increase the accuracy of the observations by averaging. He noted the distribution of these measurements to be in a symmetrical or bell-shaped form about the average or *most probable value*. Their distribution may be characterized as follows:
> (1) Small deviations from the mean were more frequent than large.
> (2) Positive and negative deviations were about equally frequent.
> (3) Extremely large deviations did not occur.
> He observed this arrangement to be in accord with the usual distribution of chance events and described the resulting frequency curve by a mathematical equation.

The standard error and probable error [6] were developed originally as measures of these accidental and compensating errors of observation. The standard error measures the distance, plus and minus, from the average, within which approximately two-thirds of the observations (measurements) fell; the probable error includes one-half of the observations.

Errors of observation are common in all scientific measurement. They occur in all statistical data whether in a complete enumeration, or a registration, or a sample from a universe of inquiry. Errors of observation are of much greater magnitude in social-science data than in data from the so-called exact sciences. It is difficult for a farmer to estimate accurately the average yield per acre of a given crop in his locality or the number of acres of corn or wheat harvested on his own farm. The grain drill is about the only available measure of acreage for many farmers. Established fields generally are assigned a specified area which is reported from father to son, and never verified. But mere lack of exactness on the part of different observers need not destroy the results of an inquiry, since an estimate made too high by one observer may be compensated for by an estimate made too low by another, and the average from a large number may closely represent the true value.

The errors of observation in either the judgment or the individual farm inquiry on yield per acre are undoubtedly large. Moreover crop correspondents tend to report yields for their locality in rounded numbers [7] that are divisible by 5, such as 5, 10, 15, 25, and 30 bushels.

[6] The terms, "standard error" and "probable error" are used here with reference to the dispersion of actual observations or the several measurements of a given object or distance, such as the diameter of the moon. This is done in order to explain the origin of the concept that is now used in statistics as a measure of the dispersion of the averages of a number of samples drawn from the same universe, each of which is made up of a number of observations.

[7] See Table 2, Number of reports at specified yields per acre received from township reporters, winter wheat, August, 1928; and Table 3, Number of reports at specified yields per acre received from township reporters, corn, November, 1928.

It is not unusual, with the judgment inquiry to have from 50 to 80 per cent of the reported yields in numbers divisible by 5. Figures divisible by 2 are also popular, but the figure 13 is avoided by most reporters. The reporter is only estimating, and it is reasonable to expect him to make his estimate in rounded numbers. Lack of accurate knowledge concerning yields is also a factor in the situation. *These errors need not affect the accuracy of the average, provided the sample is large enough to enable them fully to compensate.*

NONCOMPENSATING ERRORS, OR "BIAS"

The consideration of noncompensating errors in the sample data, commonly known as "bias," must of necessity be abstract because bias can be measured only when adequate check data for the universe as a whole (from some other source than the sample) are available for direct comparison, and no such information is available with crop yields per acre. The reporters' statements of yields are influenced by the time of year when the inquiry is made, and there are limitations to the use of census enumerations as checks on crop-yield information collected at harvest time. These facts have been discussed.

Bias in its several phases is a form of error found in sample data as well as in complete enumerations and registrations. Biased errors differ from errors of observation in that they are cumulative rather than compensating. They are constant and persistent. A very short person may read the thermometer hanging on the wall and every observation will be above the true reading. No matter how many observations are made by that person the average will never approximate the most probable degree of temperature. It is like using a short yardstick to measure a room. The prejudices, or personal equation, of the informer may influence him to observe only the phenomena that support his views. This personal bias may be intentional or unintentional, but the error becomes cumulative when any appreciable proportion of the observations are so affected.

The form of biased error most difficult to overcome or to make allowance for in making estimates for a universe of inquiry from a sample drawn from that universe is error, intentional or unintentional, resulting from the prejudices or the personal equation of the observer or informer. Such an error is the tendency to exaggerate that which is the center of attention. In years of propaganda of any kind concerning acreage changes or desirable kinds of crops, there is always a distortion of the samples in the direction that the propaganda suggests. Perhaps this is due to the reporters' actually making the suggested changes, while the man who expects to profit by his neighbors' adjustment is not likely to report at all—another example of the possibility of lack of representativeness in the sampling process.

When reporters are asked to give estimates of the acreage of crops harvested on their farms last year, along with the acreage for harvest this year, it is discovered that, when a sufficient number of these reports are compared with what was actually reported currently last year, the acreage of pasture and more important feed crops (such as corn, oats, and hay) check closely; thereby indicating that memory bias was largely compensating and should be classed under errors of observation. But with the minor crops the reporters seem to forget some of the acreage, and the figures taken historically may underestimate the acreage of these minor crops from 5 to 25 per cent, or possibly more. This is a form of memory bias that must be guarded against. With livestock, the reporter tends to forget the calves and other young stock rather than the adult animals. Although this type of error is unintentional it is cumulative, and no increase in size of sample will overcome it. It is really a form of unintentional psychological bias.

Intentional bias is deliberate understatement or overstatement by the observer. The usual example of this is the marked tendency of women to understate their ages. There is a marked tendency to underestimate the current year's acreage of cash crops, among farmers who report on acreage schedules. The same error exists in the reports on yield per acre or production of important cash crops such as cotton, until the crop has left the owner's hands. Intentional bias undoubtedly is prompted by motives of self interest regarding the effect that supply estimates will have on prices that will be received for the crop, and the tendency is to be over conservative in reporting supply factors to the agency that makes the official Government forecasts and estimates.

There is a pronounced tendency for the yield estimates of cotton to increase as the season advances from October to the following March. (Table 17.) This may be caused by the tendency to report conservatively prior to the final completion of harvest. It is interesting that the reported yields per acre of cotton tend to be higher after nearly all the crop has left the hands of the grower, whereas an opposite tendency is shown with grain crops in most States. In the case of special cash crops intentional bias is always expected, and some allowance is usually made for it.

A distinction should be made and kept in mind between bias due to errors in the data themselves and a discrepancy shown between the average of the sample and that for the universe because of the failure of the sample to be fully representative of the population of the universe of inquiry. The statistician can do a great deal toward improving the representativeness by stratification and weighting, but when the individual observations are subject to biased or cumulative errors, no way of handling the sample will correct for it. The only way to correct fully for bias is to compare the average of the sample with the average for the State as a whole for previous years if check data are available.

It is difficult in a given case to distinguish between lack of representativeness due to the voluntary nature of the sample (that is, the inclusion of the better farmers with the individual farm samples) and bias as herein described. With lack of representativeness the errors are not in the individual observations but appear in the average because the composition of the sample is not the same as the composition of the State as a whole.

There is this similarity, however, in handling the results from a sample that is not representative and a sample that is representative but in which the data are biased. When either type of sample is handled on a relative basis the change shown by the two samples does indicate the change taking place in the universe provided the bias or lack of representativeness is constant with the two samples. This was explained in the discussion of the representativeness of samples.

The importance of developing adequate check-data information on production by obtaining an accurate account of car-lot shipments mill-door receipts, etc., can not be overemphasized. Only by developing such check information will it be possible to allow adequately for bias in estimates of production. Unfortunately the bias so measured must be allocated as between acreage samples and yield samples, and there is no very satisfactory way of doing this; nevertheless, such a knowledge is of first importance if the accuracy of official estimates of crop production is to be increased. Already check information of this kind is being used with the cash grains in the spring-wheat States, with fruits and vegetables from commercial areas, and with cotton. With feed crops no such checks are available, and the best possibility for improvement lies in the use of the sample census. The sample census would not eliminate bias from the data, but would make it possible to secure a representative sample.

Through what is called statistician's bias, data may be so edited and handled by an unskilled or prejudiced statistician as to distort the picture. All the very high yields per acre may be eliminated from the sample as being improbable, when such a procedure would not be justified by facts. It is dangerous for the statistician to complete a schedule that has not been entirely filled by the reporter, and this is seldom if ever attempted by an experienced statistician. The State statistician is continually under pressure from the public, especially the agricultural public, and undoubtedly there is a tendency to be conservative in estimating the production of a cash crop, as higher estimates of production may cause lower prices and perhaps a storm of protest from the public. It is the function of the Crop Reporting Board to correct for this kind of bias in making estimates, and it is in better position to do this than is the State statistician, because the members are not so closely in touch with local agricultural affairs in a given State.

MEASURES OF PRECISION OF AVERAGES

PROBABLE ERROR OF THE MEAN

Inevitably the reliability of any conclusion is in some way a function of the number of cases on which it is based. Therefore the sample must be large enough to render the average significant within reasonable limits. If the sample is small and if there is a wide range of yields per acre over a given district, there will be a considerable fluctuation in the averages of samples drawn from this district at random and at the same time.

A conventional measure of the reliability of results, which takes into consideration both the variability in the sample and the number of observations is known as the "probable error of the mean." Pearl (*12, p. 213*) says:

> It is a constant so chosen that when its value is added to and subtracted from the result obtained, or the numeric conclusion reached, it is exactly an even chance that the true result or conclusion lies either inside or outside the limits set by the probable error [of the mean] in the plus and minus direction. * * * The significance of any result is to be judged by its relation to its probable error.

The words included in the brackets were added to Pearl's statement and need amplification. The term "probable error" has been used both for the purpose of the statistical description of a frequency distribution of sample observations and for the purpose of indicating the precision of some generalization, such as the average of a sample. When used for describing the dispersion in a sample it is merely 0.6745 times the standard deviation of the frequency distribution formed by the observations of the sample and should, in fact, be called "probable deviation." When used for the purpose of indicating the precision of some generalization, such as an average, it should be designated as the "probable error of the mean," in order to distinguish it from its use as probable deviation. In this bulletin, for convenience, probable error will be used for the "probable error of the mean," and in no case hereafter will it signify probable deviation.

Keynes (*9, p. 74*) defines probable error "as the name given * * * to an expression which arises when we consider the probability that a given quantity is measured by one of a number of different magnitudes." The average yield per acre from the sample is the most probable measure of the yield for the State, assuming that the sample is fully representative of the universe of inquiry and that the individual observations are free from bias. The amount that the difference between the actual average yield for the entire State and the average yield for the sample is as likely as not to exceed (chances of 1 to 1, or 50 out of 100) is the probable error. The smaller the probable error the greater confidence the statistician has in the average of a sample.

The probable-error concept is ordinarily used to compare the average of the sample with the average for the universe from which the sample is drawn.

> * * * The standard error can be assumed to measure only the errors arising from the fluctuations of simple sampling. * * * Fluctuations due to bias, due to the absence of random selection in the sampling process, due to persistent errors of any sort, quite elude this method of determining probable stability. * * * So serious are these limitations to the employment of the usual measures of probable error in connection with economic data that it would seem generally advisable to subordinate such measures to actual statistical tests of stability. By the study of successive samples, and by the testing of the subordinate elements in a given sample when broken up into significant subgroups, much more may be learned as to the reliability of a given measure and as to the possibility of applying it generally than by unquestioning acceptance and uncritical employment of the usual mathematical formulas for probable error (*10, p. 560–561*).

A comparison of the samples of crop yields received from the field aids and township correspondents such as is made in connection with this study, is in fact a study of successive samples which Mills suggests.

When the several assumptions underlying the ordinary usage of probable error are tested in connection with many kinds of yield-per-acre samples, it is obvious that the ordinary interpretation can not be made with all samples, for all crops, in all States. Consequently in this study the probable-error concept will be used for comparing the average of the sample with the more stable average which would have been obtained from an infinitely large sample taken at the same time and under the same conditions. (See Yule (*18, p. 336, par. 2*).) It also measures the range plus or minus the average of the given sample, within which the probability is 50 out of 100 that the average of a similar sample taken at the same time and under the same conditions is likely to fall. It is an inverse measure of the "precision" of the average as it measures the influence of the fluctuations of sampling.

This somewhat restricted interpretation is a most useful expedient, as it furnishes information concerning a fundamental and universal question in sampling, namely, "is the sample of sufficient size to render the average stable and reasonably free from the influence of the fluctuation of sampling?" When the statistician, through check information (such as cotton ginnings) for previous years, has knowledge of the universe from which the sample was drawn, and when he knows that the underlying assumptions will not hold universally for all samples of crop-yield data, he is not justified in making the ordinary interpretation of probable error. With the large amount of bias that is usually present in the observations of the crop correspondents concerning cotton yields per acre, the ordinary interpretation of probable error is totally inadequate in dealing with estimates of the yield of that crop.

The assumptions that underlie the ordinary use of the probable error concept are as follows:

(1) There is a reasonable degree of homogeneity in the population from which the sample is drawn.
(2) The sample is representative.
(3) The observations in the sample are exact measurements of the phenomena, that is, not subject to errors of observation or compensating errors.
(4) The observations are free from bias or noncompensating errors.
(5) The standard deviation of the sample measures the amount of dispersion in the universe from which the sample is drawn.

Since samples of crop yields per acre are samples of natural phenomena, the first assumption, that of homogeneity, may be conceded, except in those cases in which a State is made up of a number of homogeneous districts that show marked interarea differentiations. Homogeneity is often greatly improved by proper stratification of the sample.

The second assumption, that of representativeness, can be accepted with crop-yield samples in most States when one takes into consideration the methods of minute stratification by townships and crop-reporting districts and the weighting of the returns by counties or districts. In fact this departure from random selection tends to improve the representativeness of the sample.

The third assumption, that the observations are free from compensating errors, never has held in any sample ever taken. Accuracy is a matter of refinement of measurement. Fortunately, even wide errors of observation are not serious, provided the sample is sufficiently large to enable the errors to compensate. The influence of these errors is measured at the same time the influence of the fluctuations of sampling is measured, that is, by the probable error, when the standard deviation of the sample is used to measure the dispersion of the universe.

The fourth assumption, that the individual observations are free from bias, can never be made. Freedom from bias must be established as fact. A complete census does not obviate the difficulty of bias.

The fifth assumption, that the standard deviation of the sample is equal to the standard deviation of the universe, except as it may be influenced by the fluctuation of sampling, is seldom valid with samples collected by means of schedules or questionnaires, where the errors of observation are likely to be large and the measurements contain a large subjective element. At best it can be equal only to the standard deviation of an infinitely large sample taken under similar conditions and subject to the same general limitations as the sample, including errors of observation.

Unless the statistician can use one of Bowley's four methods of selecting a sample and can be sure that the observations are the result of unbiased measurement, he is not justified in using the probable-error concept in the ordinary manner. When the probable error of

the mean is used in this more precise manner the statistician using the material is placed on guard against the possibility that the sample may not be fully representative or that the observations may be biased. The statistician can not afford to take anything for granted, and the assumptions involved must be carefully tested in every way possible. Is the universe reasonably homogeneous? Is the sample fully representative? Are the observations free from noncompensating errors? Is the sample large enough to render the average reasonably stable and free from the fluctuations of sampling? The probable error concept answers only the last of these questions.

That samples subject to as much bias as are cotton yields are of considerable use is evidenced by the high degree of accuracy of the cotton estimates of production during the last three years. When check data are available, as with cotton, the bias of the samples for past years can be determined with considerable accuracy. This bias varies as the result of variations of such factors as the percentage of the crop picked or sold by the time the inquiry is made, the price of the crop, etc. Fortunately bias is much more likely to occur in the case of cash crops for which commercial checks can be obtained, than of crops fed on the farm. Only on the basis of some measurement of bias in past years is it possible to use such samples as cotton yields per acre for estimating purposes. Otherwise it would be impossible to bridge the gap between the average of the infinitely large sample which can be inferred from the current sample to the average for the universe from which the sample was drawn.

This restricted interpretation of probable error eliminates all assumptions concerning representativeness of the sample and of bias in the individual observations, and permits the statistician to proceed on the practical assumption that the infinitely large sample would be subject to the same limitations as the one in hand. With crop-yield data it would continue to be a "voluntary stratified sample" and not a random sample.

The selection of a stratified sample results in greater precision of the average than does the selection of the sample at random. The more homogeneous the districts or subdivisions of the universe, the greater is the precision. Bowley (*3, p. 12, 20*) says:

> Thus increased accuracy is always attained by stratification, unless the attribute is evenly distributed throughout the district, and in some cases the improvement is considerable. * * * If the averages of the districts differ considerably from the general average, or if the standard deviations in the districts are considerably smaller than in the population as a whole, the gain in accuracy by stratification may be considerable.

Not only is the State divided into crop-reporting districts that tend to show less dispersion than does the State as a whole, but the data within the districts are obtained from reporters distributed by townships; this constitutes, in effect, further stratification of the sample. The improvement in accuracy of the district average may be considerable if there are actual differences between the counties and townships that comprise the crop-reporting district. In practice, the matter of increased precision in district averages depends on whether the dispersion of the error of observation of the individual reports is less than the dispersion in the district caused by actual differences in crop yields between localities or townships. This could be tested on the assumption that the extent of the correlation between two series of judgment-yield estimates obtained at the same time from two correspondents each reporting for the same township would tend to measure the amount of differentiation between townships; or the lack of correlation would indicate that the dispersion due to errors of observation is larger than the dispersion caused by the differentiation that might actually exist between townships.

This test is possible because of the two separate lists of crop correspondents; it is a matter of bringing together two reports from the same township. This test would assume that the locality and township are synonymous; this is not necessarily true, for the reporters may live on opposite sides of a township and each be estimating for a locality centered at his farm; neither of these two men would be estimating for the same locality. In the few samples from a highly homogeneous area in the Corn Belt so analyzed, the correlations have been generally low, about plus 0.40 or 0.50, indicating that the errors of observation are large in comparison with the slight differentiation in average yields per acre for townships. In districts that show greater differentiation higher correlations would be expected.

Bowley (*2, p. 337*) has worked out a method which makes it possible to calculate the effect of stratification on the probable error of the average when the data are drawn in proportion to the importance of the strata, "proportional stratification." Since in practice it is impossible to obtain this type of sample, the system of weighting by crop-reporting districts or by counties is used as a substitute for proportional stratification.

Therefore Bowley's formula for proportional stratification is not fully applicable to crop-yield samples. He has also devised a formula (*2, p. 316*) for ascertaining the probable error of a weighted average which allows the dispersion of the weights to increase materially the size of the probable error. This influence of the dispersion of weights is difficult for the writer fully to rationalize in all cases. Neither of these formulæ seems to apply directly to the problem of measuring the probable error of an average secured from crop-yield samples, especially as neither makes allowance for the increased precision due to the distribution of the crop reporters by townships within the districts.

The probable errors calculated in this study from the usual formula will tend, therefore, to exceed the true probable errors that actually exist, provided allowance could be made for the stratification of the observations by townships and the handling of the sample so as to secure a weighted average for the State. They will not always be strictly comparable as between States or even between different years in the same State because the effectiveness of stratification depends in part on the extent to which the individual districts are more homogeneous than the State as a whole. But an analysis of sample data on a district basis will throw light on the influence of stratification on the precision of the average of the sample. Even with these reservations concerning the instrument that is to be used in the analysis of yield-per-acre samples, such an analysis will be valuable in helping to appraise the reliability and adequacy of crop-yield sample data.

INTERPRETATION AND SIGNIFICANCE OF PROBABLE ERROR

The probable error has already been defined and its use limited to the immediate problem of testing the sample to determine whether it is large enough to be useful as a basis for an estimate of crop yields.

This probable error that is calculated tends to be larger than the true probable error. The more homogeneous the crop-reporting districts as compared with the whole State and the greater the difference between communities and localities within the district the greater will be the effect of stratification and the smaller will be the probable error of the weighted average as compared with the probable error of an unweighted average on the assumption of random selection.

To go a step further, an attempt must be made to visualize the significance of the term probable error or standard error when applied to the average of a sample. Let it be assumed that a large number of samples can be collected that are identical in size to the one already available, and taken at the same time and under similar conditions, from the same universe. All of the samples are to be subject to the same general limitations of the sampling (such as bias, representativeness, selectivity, etc.) as the sample in hand. A sample from the township reporters and another from the field aids constitute an approach to this idea of more than one sample, from the same universe, under similar conditions.

If the averages of all these separate samples were calculated and plotted, it would be found that these averages would form a frequency distribution much more normal in form than that formed by the original observations in an ordinary yield-per-acre sample. If the standard deviation of this frequency distribution of all these means is calculated and multiplied by 0.6745, it will be found that it approaches closely in value to the probable error of the original single sample calculated by the formula

$$\text{Probable error} = \frac{0.6745\sigma}{\sqrt{n-1}}$$

The combined average of all the many samples would be equivalent to the average of an infinitely large sample.

Another demonstration of this principle of the influence of fluctuation of sampling as related to the size of the sample is to draw a sample from a universe, compute an average, draw another sample under precisely the same conditions and observe the averages of the two samples combined; add to these a third sample, and so on, until the average approaches, not continuously, but with some fluctuations, closer and closer to some stable figure. This stable average that would be obtained in a very large sample is thought of as the average of an infinitely large sample.

Knowing the variation in the samples obtained and the number of reports, the probable error can be calculated, and from this it can be determined within what limits improvement in the stability of the average may be expected by increasing the size of the sample.

With a probable error of 1 bushel with an average yield for the sample of 40 bushels it can be said that the chances are equal, or 50 out of 100, that the average of an infinitely large sample taken at the same time and under similar conditions would not differ by more than plus or minus the probable error from the average of the sample—in this case 1 bushel—or that it would fall between 39 and 41 bushels. If, instead, a range of plus or minus 2 bushels (twice the probable error) is taken, the chances are 4.64 to 1 or about 18 out of 100. With three times the probable error the chances are 22.24 to 1 or 4.30 out of 100.

With four times the probable error the chances are 142.3 to 1, or 7 out of 1,000. When the standard error of the mean is used instead, a range of plus or minus three times the standard error indicates that the chances are about 370 to 1 or 27 out of 10,000. These probabilities are computed on the basis of the area of the normal frequency distribution. To approximate the reasonable limits of the possible influence of the fluctuations of sampling, either 3.8 times the probable error or 2.6 times the standard error is used. In either case it can be said that the chances are at least 99 out of 100 that the average of the infinitely large sample will not differ by more than 3.8 times the probable error or 2.6 times the standard error plus or minus from the average of the sample.

The mathematical assumptions underlying these statements are clearly and concisely explained by Pearl (*12, p. 214–215*) as follows:

> Now such statements as these derive whatever meaning they may possibly have from the following simple mathematical considerations. Assuming that the errors of random sampling are distributed strictly in accordance with the normal or Gaussian curve, * * * it is a simple matter to determine from any table of the probability integral the precise portion of the area of a normal curve lying outside any original abscissal limits, or, in other words, the probability of the occurrence of a deviation as great as or greater than the assigned deviation. To say that a deviation as great as or greater than three times the probable error is "certainly significant" means, strictly speaking, that the area of the normal curve beyond 3 P. E. on either side of the central ordinate is negligibly small. As a matter of fact this is not true, unless one chooses to regard 4.3 per cent as a negligible fraction of a quantity. There are certainly many common affairs of life in which it would mean disaster to "neglect" a deviation of 4 per cent of the total quantity involved.

Table 1 (*12, p. 218*) gives the value of the probability and odds for different magnitudes relative to the probable error, and is presented here as an essential part of the above explanation of the significance of the probable-error concept.

TABLE 1.—*Value of probability and odds for different magnitudes relative to probable error*

Deviation ÷ probable error	Probable occurrence of a deviation as great as or greater than designated one in 100 trials	Odds against the occurrence of a deviation as great as or greater than the designated one	Deviation ÷ probable error	Probable occurrence of a deviation as great as or greater than designated one in 100 trials	Odds against the occurrence of a deviation as great as or greater than the designated one
1.0	50.00	1.00 to 1	3.3	2.60	37.42 to 1
1.1	45.81	1.18 to 1	3.4	2.18	44.80 to 1
1.2	41.83	1.39 to 1	3.5	1.82	53.82 to 1
1.3	38.06	1.63 to 1	3.6	1.52	64.89 to 1
1.4	34.50	1.90 to 1	3.7	1.26	78.53 to 1
1.5	31.17	2.21 to 1	3.8	1.04	95.38 to 1
1.6	28.05	2.57 to 1	3.9	.853	116.3 to 1
1.7	25.15	2.98 to 1	4.0	.698	142.3 to 1
1.8	22.47	3.45 to 1	4.1	.569	174.9 to 1
1.9	20.00	4.00 to 1	4.2	.461	215.8 to 1
2.0	17.73	4.64 to 1	4.3	.373	267.2 to 1
2.1	15.67	5.38 to 1	4.4	.300	332.4 to 1
2.2	13.78	6.25 to 1	4.5	.240	415.0 to 1
2.3	12.08	7.28 to 1	4.6	.192	520.4 to 1
2.4	10.55	8.48 to 1	4.7	.152	520.4 to 1
2.5	9.18	9.90 to 1	4.8	.121	828.3 to 1
2.6	7.95	11.58 to 1	4.9	.0950	1,052. to 1
2.7	6.86	13.58 to 1	5.0	.0745	1,341. to 1
2.8	5.89	15.96 to 1	6.0	.0052	19,300. to 1
2.9	5.05	18.82 to 1	7.0	.00023	427,000. to 1
3.0	4.30	22.24 to 1	8.0	.0000068	14,700,000. to 1
3.1	3.65	26.37 to 1	9.0	.0000013	730,000,000. to 1
3.2	3.09	31.36 to 1	10.0	.0000000015	65,000,000,000. to 1

If the statistician wishes to set a limit at which he can say that the probabilities of an occurrence of a deviation as great as the one in hand or greater, is 1 in 100, he will find, by reference to Table 1, that about 3.8 times the probable error will establish this limit. If he is working with the standard error, about 2.6 times the standard error will set this same limit.

CALCULATION OF PROBABLE ERROR AND STANDARD ERROR

The standard error and the probable error are both used to measure the precision of an average. The probable error is equal to 0.6745 times the standard error. Most formulæ are developed in terms of the standard error, but the application of the theory of probability is frequently made in terms of probable error, because the probabilities are 1 to 1, instead of approximately 2 to 1 as with the standard error. The standard error is converted into probable error by multiplying the standard error by 0.6745.

The standard error [8] is calculated by dividing the standard deviation of the population of the universe being sampled by the square root of the number of observations in the sample less one, or

$$\text{Standard error} = \frac{\text{Standard deviation}}{\text{Square root of number of observations less one}} = \frac{\sigma}{\sqrt{n-1}}$$

The probable-error formula is:

$$\text{Probable error} = \frac{0.6745\sigma}{\sqrt{n-1}}$$

These formulæ measure the errors that are likely to occur as a result of the fluctuations of sampling with random selection. The upper limit of this type of error in the sample is set approximately by a figure that is three times the standard error or about four times the probable error.

As soon as a sample has 25 or 30 observations the $(n-1)$ becomes, for all practical purposes, the same as n hence the minus one is disregarded as most of the samples analyzed contain more than 25 observations. Since it is impossible to obtain the standard deviation of the universe we must be content with an approximation of it from the sample. The standard deviation which is calculated from the sample with 25 or more observations will tend to approximate the standard deviation of that part of the universe from which the sample was obtained (*5*). The more representative the sample the more closely will the standard deviation calculated from the sample approximate the true standard deviation of the universe of inquiry. This standard deviation also assumes that the observations are true observations,

[8] The full formula also provides for the effect of having in the sample a larger or smaller proportion of the total number of observations in the universe of inquiry, by adding the term $\sqrt{1-K}$ where K is equal to the number of observations in the sample divided by the number of observations in the universe. The complete formula is therefore,

$$\text{S. E.} = \frac{\sigma}{\sqrt{n-1}} \cdot \sqrt{1-K}$$

If the sample included all the observations in the universe this last term would become zero, and consequently the standard error would also be zero. In samples of crop-estimating data either the universe is considered as infinity or the number of observations is so small that K would be very small indeed (*10*).

which is impossible as all known observational measurements are subject to some error of observation; observations of economic and natural phenomena are likely to be subject to large errors of observation. Consequently the standard deviation used in calculating probable or standard error includes (in addition to the dispersion caused by actual differences in the universe of inquiry), dispersion due to errors of observation. As a result the probable-error concept in practical use really covers the matter of precision in the average of the sample whether the instability is caused by large errors of observation or by differences existing in the universe of inquiry. Yule says (*18*, p. 211) "The effect of errors of observation is, consequently, to increase the standard deviation above its true value." The probable-error formula can be used to indicate how large a sample is needed to give a certain degree of precision when the combined dispersion due to differences in the population of the universe and the errors of observation of the sample data is known approximately and expressed as the standard deviation of the sample.

STATISTICAL INDUCTION

The fundamental importance of the distinction between statistical description and statistical induction has been mentioned. The results of statistical description can be applied only to events actually observed in the sample, but the statistician must go further; he must make an estimate for the universe of inquiry. Mills (*11*) says:

> He seeks generalizations which will apply to a wider group, to events not observed, to cases not included in his sample. He seeks, that is, to employ the ordinary methods of induction, basing the logical processes upon materials of a particular kind—statistical data.

The premises are subject to considerable doubt, as the individual observations are frequently only crude approximations. Complete knowledge of all the observations in a sample of any size is impossible. A multiplicity of causes operate to determine the yield per acre of a given crop. Variation in yields per acre over a given locality, township, county, district, or State is usually pronounced, and even with a representative sample free from bias, an element of probability attaches to every estimate. The calculation of the probable error is a method of measuring the approximate degree of probability in a given case.

The conclusions of all inductive reasoning must be expressed in terms of probability. No average based upon sample data, no matter how numerous these data, is likely to be absolutely identical with the average of the universe from which the sample was drawn. If an average of a sample is to fall within certain prescribed limits of the true average of the universe of inquiry with any finite degree of probability, some assumption must be made about the nature of the universe from which the observations were drawn. The step from a particular sample to an estimate must proceed from some premise about the orderliness of nature, in addition to that premise which takes account of the instances studied. That there should be a reasonable degree of probability in favor of the accuracy of the estimate—the inductive conclusion—it is necessary to make an assumption concerning the finite degree of variation in nature. This general premise of the uniformity of nature in some form is essential in all statistical induction.

So far as the yield per acre of any crop is concerned, there is a limitation to the degree of independent variation possible in the universe of inquiry. Only in exceptional cases does the yield of wheat in Kansas exceed 40 bushels per acre, or the yield of corn in Iowa exceed 80 or 90 bushels per acre. Experience in the field of agriculture justifies the statistician in assuming that the yield per acre for a given crop falls within definite assignable limits. It is extremely important that the statistician have an understanding of the fundamental pattern of the phenomena of the yields per acre for a given crop in a particular State if any considerable weight is to be attached to inductions that he may make in the way of estimates. Mills (*10*) says:

> Quantitative inference of this type differs in no wise from the ordinary process of induction, except in that one of the premises is in quantitative form, and that the conclusion * * * extends an average value, which may or may not hold in any given case. Both evidence and conclusion deal with only probable and approximate relationships or average values, and in this respect accord more closely with actual experience than do the premises and conclusions of universal inductions.
>
> The problem at issue in the discussion of the validity of this process relates to the reliability of the results, to the stability, when applied beyond the sample, of the averages, ratios, or equations computed. The whole practical problem of statistics centers about the stability of such results, and the limits to such stability when the results are generalized in this way.

When the average of a sample of yield-per-acre data is used beyond that sample as an estimate for a definite geographical area, some idea of the limits within which the statistical measure is likely to fluctuate is a practical necessity. The problem involves the theory of inverse or empirical probabilities. "The very foundation of statistical induction, in so far as an attempt is made to measure the stability of the conclusions, rests upon the validity of determining probabilities empirically" (*10*).

The validity of computing probabilities from the results of experience is a controversial subject. Formulæ of probable errors have been developed for computing, from the results obtained from a limited sample, the probability of securing similar results in a study of the larger groups from which the sample was drawn. The controversy centers about the question whether empirical evidence alone is sufficient. Keynes (*9, p. 384*) maintains that the application of mathematical methods to the general problem of statistical inference is invalid.

> To apply these methods to material, unanalyzed in respect of the circumstances of its origin, and without reference to our general body of knowledge, merely on the basis of arithmetic and of those of the characteristics of our material with which the methods of descriptive statistics are competent to deal, can only lead to error and delusion.

Most of the activities of life, however, are based on probabilities that are primarily empirical. Decisions concerning business, engineering operations, industry, life and fire insurance, farming operations, etc., rest upon probabilities that are based on experience—empirical. Pearson (*13*) states that this principle of inverse probabilities rests on the foundation of common sense. In the actual application of statistical methods, empirical probabilities play a dominant part, but this application must necessarily be made in the light of sound reason. The statistician can not place all of his trust in mere mathematical computations of the average of the sample and the probable error of the average. Unfortunately, basic knowledge of the phenomena that are being sampled is often limited. Men who have worked extensively with crop yields and other samples can go practically all the way with Keynes (*9*) when he says:

> The commonly received opinions as to the bearing of the observed frequencies in a random sample on the constitution of the universe out of which the sample is drawn, though generally stated too precisely and without sufficient insistence on the assumptions they involve, our actual evidence not warranting in general more than an approximate result, are not, I think, fundamentally erroneous. The most usual error in modern method consists in treating too lightly what I have termed above the inductive problem, i. e., the problem of passing from the series S_1, S_2, etc., of which we have observed samples, to the series S of which we have not observed samples.

Accepting the average of a sample of any kind as an absolute figure to represent the true average of the universe from which the sample was drawn, undoubtedly is not scientific procedure. Use of its probable error as the sole basis for interpreting the average of a sample is an important forward step in statistical technic, but appraisal of the reliability and adequacy of the sample can not stop at this point. The statistician must assure himself that the sample in hand actually is meeting the assumptions involved in the concept of statistical induction and in the application of the theorem of inverse probabilities.

Although an array or frequency distribution of the sample data will throw much needed light on the validity of the assumption of the uniformity of nature as applied to yield-per-acre phenomena it does not settle the question. In all of the samples analyzed in this study a frequency distribution of the reported yields per acre of a given crop for the crop-reporting districts and for the State was first made. These distributions were reasonably symmetrical with a tendency to skewness toward the upper limits. This skewness is due to the existence of a positive lower limit of yields per acre below which either the crop is not harvested in any manner or is a failure. The upper range of yields have no such definite limit, as the yields per acre vary considerably over a State and in a few localities may be several times larger than the average for the State. The method of grouping the reports by crop-reporting districts tended to isolate these high yields into a few districts, thereby decreasing the range and dispersion in the remaining districts and rendering the district sample somewhat more homogeneous than the sample for the State as a whole.

In the far western group of States, where there is a great variety of natural conditions even within parts of the same county, the samples showed the least tendency toward symmetry and the normal curve. The regrouping and weighting of the yield samples on the basis of irrigated and nonirrigated acreages, initiated generally for the first time during 1929, will undoubtedly do much to render the samples more homogeneous in these States and strengthens the assumption of uniformity in nature. It suggests the desirability of improving the homogeneity of the crop-reporting districts by a somewhat more logical regrouping of the counties.

The assumption that the observations were selected at random must of course be qualified in the field of voluntary crop reporting. The departure from randomness known as stratification, as practiced by the department in selecting the sample data in reality increases the stability of the average of the sample and results in a probable error somewhat smaller than that resulting from random selection.

The possibility of bias or noncompensating errors in the individual observations makes it necessary to limit the application of the theory of probability to a comparison of the average of a given sample with that of an infinitely large sample of observations similar to the data in the sample. This suggests the imperative need of developing statistical information concerning the universe as a basis for checking the sample data in order that a reliable measure of bias may be determined, that can be used to true-up samples collected in the future. With bias definitely measured, it next becomes a problem to determine the factors that cause bias to vary from year to year, as a basis of ascertaining the most probable amount of bias under a given set of circumstances.

The departure from the principle of pure random selections brings to the foreground the important question of the representativeness of the sample—something that is usually taken for granted when random selection is employed. Representativeness should be tested by the statistician in all the ways his ingenuity can devise, even if he is so situated that he can use random selection.

Years of experience in observing the close agreement of the averages of reports on yields per acre for a given State from the two separate lists of crop correspondents have justified a belief in the stability of these yield-per-acre samples in important producing States. The difficulties involved in attempting to make satisfactory estimates of yields per acre on the basis of available sample data in the far Western States and in some of the minor States and with highly localized crops has led to the analytical work upon which this study is based.

RELIABILITY OF THE ESTIMATES FOR SELECTED CROPS

The analysis of the official estimates of crop yields per acre was undertaken for the purpose of appraising the reliability and adequacy of these estimates and the methods employed in making them. Such an appraisal points out the limitations and the strength of these official estimates for separate crops in various parts of the country. The resulting practical method of analysis can be readily adapted to other types of estimates based on sample data, and to the general use of quantitative data as a basis for inductive generalization and inductive reasoning in the field of economics and related sciences.

Many of the improvements that have been suggested in consequence of this analysis have already been incorporated as a part of the methods now in use by the Department of Agriculture.

This part of the study will be confined to estimates of crop yield per acre for recent years. Many are primarily interested in the reliability and adequacy of current estimates, and especially in the reliability of a comparison of the latest estimates with the yield the previous year or with the 5-year or 10-year average. Others are interested in evaluating the yield-per-acre estimates as a continuous historical series. Some research workers are using these estimates for correlation studies with weather factors as a basis of forecasting crop yields and in other connections. An appraisal of the historical series of estimates of crop yields per acre has been included (p. 129). It is necessarily largely qualitative because of the scarcity of material and information. It consists of a brief résumé of the significant developments in sources of data, methods used, and personnel as they might be expected to affect the representativeness and size of sample and the possibility of bias.

In the more important agricultural States, where agricultural conditions are not extremely varied, the regular judgment sample as obtained from the regular township and field-aid correspondents has always been, and continues to be, the primary basis of the estimates of crop yields per acre. The individual-farm samples are used to supplement the judgment samples and can be evaluated more advantageously in connection with the estimates of acreage and numbers of livestock, which are based almost entirely on individual-farm returns. The judgment type of inquiry is used also in obtaining sample data on crop yields per acre from business men in agricultural communities. These "special inquiries" as they are called, to distinquish them from the regular monthly inquiries, are limited to the more important cash crops, and their use in a particular State is largely optional with the State statistician. Field observation on the part of trained agricultural statisticians, special samples, individual-farm samples, and check data on production have all been used to supplement the judgment sample from regular crop reporters.

The objective of sampling with the judgment inquiry is to secure a sample that can be used in an absolute rather than a relative sense. It is to secure a yield-per-acre figure which, when multiplied by acreage harvested, will give the total production of a crop for a given State. When experience has shown bias to be present, the average of the sample must be corrected for this bias in so far as possible before it can be utilized as an estimate of yield per acre.

PROCEDURE

The presentation followed in the analysis of the estimates of yields per acre for each of the several crops is as follows:

(1) A general appraisal of the geographic representativeness of the sample is made largely on the basis of a comparison of the straight average (arithmetic mean of all the reports for the State) and the weighted average (district or county averages weighted by estimates of current acreage) of both the township and field-aid samples taken at the same time. A table for each crop is given. These tables, presenting this comparison for each crop, show the two types of averages (from the two corps of crop reporters) for each of two years, by States, along with the official estimates of yields, and the estimates of acreage of the crop harvested.

(2) For two crops, wheat and corn, the frequency distribution of the original observations from the township sample are shown for several States. The distribution of the sample and the tendency of the reports to be made in figures divisible by 5 or by 2 are typical of practically all crops, consequently this type of material was not included for the others. These two tables indicate the possibility of large errors of observation, or errors that are largely compensating, and due to the correspondent's making estimates for his locality in figures divisible by 5 or 2.

(3) The matter of bias (noncompensating errors) in the individual observations of the sample is given consideration. Unfortunately an analysis of the sample itself furnishes no reliable measure of the extent of bias. Bias can be measured only when check information of some kind is available for the State. The ginnings of cotton, for example, as determined by actual count by the Census Bureau, furnish a check on the estimates of production of cotton, but no very satisfactory method has been developed for allocating the existing bias between sample data of acreage changes and sample data of yields per acre. An understatement bias is always expected, but not always found, with all sample data concerning important cash crops. If the sample is to be used in an absolute sense, as with the judgment samples of yields, this is a serious difficulty in making accurate estimates, but if the successive samples are to be used on a relative basis to indicate change as with individual-farm samples of yields or acreage, this difficulty vanishes entirely, provided there is a constant degree of bias and a closely similar degree of selectivity in the successive samples. Any shift in the degree of bias or selectivity invalidates the use of sample data on a relative basis unless adequate allowance can be made for the change in bias or the samples can be stratified and weighted in such a way as to eliminate the shift in selectivity, as is now done with individual-farm samples of acreage. The experience of the Department of Agriculture in discovering the presence of bias with individual crops is briefly stated in connection with each crop. It is also possible to observe to what extent the Crop Reporting Board has made allowance for bias and selectivity by comparing the final estimates with the sample indications in the tables mentioned above as appearing in connection with the first step of this analytical procedure.

(4) Consideration is given to the experience of the department with the so-called preventable errors, which are due to misunderstanding of the questionnaire, wherever this type of error has been found to have any material influence on the reliability of the sample indications. Customary units of measure vary in different sections of the country. Spring-wheat farmers do not always include durum wheat under the caption of "all spring wheat" on a questionnaire.

(5) The fifth step in this procedure deals with the problem of stability of the sample or the precision of the averages of the sample data. From a study of the sample itself it is possible to gain some idea as to the homogeneity of the universe from which it is drawn and to ascertain whether a given sample is of adequate size and the observations sufficiently concentrated about some central value to give significance to the average of the sample.

The matter of stability and precision is approached in two ways: (1), Somewhat empirically by a comparison of the averages of the two separate samples of township and field-aid reports, taken at the same time and under similar conditions, and (2), by the more technical method of probable error analysis. The tables, previously mentioned under the phase of analysis which treats of the representativeness of the sample, make this comparison possible for both the 1927 and 1928 crops. These comparisons are for all States that grow 10,000 or more acres of a given crop and where the two lists have not been combined. For each of the 14 different crops, usually in several different States, yield-per-acre samples have been subjected to statistical analysis and some of the results are shown in one or more tables for each crop. These tables give illustrations of size of sample, measures of dispersion, and probable error, by States; and in some of the more important States by crop-reporting districts.

A satisfactory distribution of crop reporters by agricultural townships is maintained by eliminating those reporters who fail to report with reasonable regularity and by recruiting new crop reporters promptly to take the places of those who are eliminated. In Iowa, a waiting list is maintained for farmers who wish to serve as crop correspondents. It is extremely difficult to maintain a satisfactory distribution of voluntary correspondents in States that have a scattered agricultural population, as in many of the far Western and Mountain States, or where the farmers speak a foreign language or receive little schooling.

Reports concerning a given crop are received from those districts in which that crop is commonly grown, and consequently with such crops the reports tend to be distributed in about the same pattern as the acreage of the crop, and the straight and weighted averages of a given sample do not differ widely. When the returns are not distributed between districts in proportion to the acreage of the crop, the weighting of the district samples by the acreage of the particular crop for the current year tends to improve the geographic representativeness of the sample and makes the weighted average more representative for the entire State than the unweighted or straight average. Weighting within the crop-reporting districts is considered unnecessary except for those crops the acreage of which is highly localized within limited areas, as is likely with fruit and vegetable crops. With the yields per acre is usually much greater over a territory as extensive as a State than over a territory approximately only one-ninth of the State.

Even with generally distributed crops, however, in important producing States the final estimates of yield per acre are frequently derived from county estimates made at the close of the season on the basis of a vast amount of supplementary information. That is, the State statistician makes an estimate of acreage and yield per acre and production of a crop for each county on the basis of all available information. When the total production of all the counties for the State is divided by the total acreage, a derived estimate of yield per acre is obtained for the State. This method is feasible when an assessor's enumeration of the acreage devoted to each crop is made each year, as in Kansas, Nebraska, Iowa, and Wisconsin, or where an annual sample census of a representative locality in each county is made each year, as in Alabama.

The tables for each crop by States, for 1927 and 1928, showing the averages obtained from the separate samples from township and field-aid correspondents permit a practical and nontechnical approach to the problem of the stability of the sample and the precision of the averages obtained from the samples of yields per acre. If, for a large group of States in two different years, the weighted averages of the two samples are in close agreement, the observer would be satisfied to conclude that such samples are reasonably stable and that these averages would not be materially altered by increasing the size of the State samples, provided the larger samples were taken at the same time and under similar conditions. It is likely that when such samples are analyzed it will be found that the probable errors are not excessive and that the averages have a high degree of precision.

Such conclusions are justified on the assumption that the two samples for each State, one obtained from township correspondents and one from field aids, are two separate samples taken under practically similar conditions as to time, distribution of reporters, and the system of stratification and weighting used. Some differences between the averages of two such samples do exist in particular States and in certain years. The most important single cause of such differences lies in the method of editing the returns after they are received (either in the State office or in Washington). Generally speaking, the editing of the township returns in the Washington office is a more mechanical and probably a more uniform process as between States than is the editing of the field-aid returns in the various State offices, where the State statistician usually has some direct knowledge of the situation existing in his State.

Take, for example, the problem of editing the yields per acre of a crop when a few correspondents report a zero yield. Zeros should be retained or eliminated, depending on whether the abandonment of acreage has been allowed for in the estimates of acreage. If the estimate of acreage includes only land that was actually harvested, then the zeros should be eliminated before the calculation of the averages for the districts or the State average. But if the estimate of yield per acre is to be made prior to the final revision of the acreage estimates, and there has been more abondonment than usual in a particular season, then some of the zeros should undoubtedly be retained in the sample in order that the estimate of yield can be applied

tion. In seasons in which abandonment and crop failure are greater than usual, differences in editing are easily possible and differences between the computed averages of the reports from the two lists of correspondents will tend to reflect greater differences than might be expected merely from the fluctuations of sampling.

The statistical description of the individual sample used in this analysis results in a reduction of the mass phenomenon of yields per acre to several highly significant and important measurable characteristics such as the number of observations, the average, the standard deviation, coefficient of variation, probable error, and relative probable error. Other characteristics of the sample, such as the type of distribution of the observations and skewness, are not quantitatively measured, but are evaluated graphically by inspection.

The yield data for a given crop year and State were tallied by districts so arranged as to form frequency distributions for crop-reporting districts and for the State as a whole. From this tally of the frequency distribution it was possible to determine in a general way the homogeneity of the sample, type of distribution, and skewness, both by districts and for the entire State. Typical frequency distributions for selected States are shown in Tables 2 and 3. From the frequency distribution the average of the sample, the standard deviation and the coefficient of variation are computed by methods described in standard text books on statistical methods. The probable error (of the mean) is computed by the usual formula for samples exceeding 30 observations.[9] The relative probable error is secured by expressing the probable error as a percentage of the average yield.

TABLE 2.—*Number of reports, at specified yields per acre, of winter wheat, received from township reporters, August, 1928*

Reported yield (bushels)	Oregon	Kansas	New Mexico	Washington	Colorado	Utah	Pennsylvania	Illinois
2							1	
3			1					
4		1	2				1	
5					3		14	15
6		1	1		1		3	10
7							7	3
8		5	1		3		16	17
9		3						1
10		16	2	1	7		33	37
11		4					2	2
12	1	30	3	2	2		23	27
13		9			1		5	3
14	1	19	1	1			6	8
15	5	58	2	10	5	3	35	27
16		21		2	1	1	11	9
17		17		1			8	4
18	3	36		3		2	21	23
19		2						4
20	11	76	3	13	11	4	37	46
21		4					4	4
22	1	10		1	2		7	9
23		5		1			4	1
24				1	1		5	3
25	6	33	2	14	4	5	19	16
26		3					3	4
27	1	1		1			5	2
28							8	1
29								
30	8	5	2	15	13	9	4	5
31		1				1		2
32	1						2	
33								
34				1				
35	5		1	2	5	1	1	
36								

0.6745 times standard deviation

TABLE 2.—*Number of reports, at specified yields per acre, of winter wheat, received from township reporters, August, 1928*.—Continued

Reported yield (bushels)	Oregon	Kansas	New Mexico	Washington	Colorado	Utah	Pennsylvania	Illinois
37								
38								
39								
40	5			6	6	2	1	
41								
42								
43	1							
44								
45	1			1				
46								
47								
48								
49								
50				1				
Total	50	360	21	77	65	28	281	283

TABLE 3.—*Number of reports, at specified yields per acre, of corn, received from township reporters, November, 1928*

Reported yield (bushels)	Indiana	Iowa	Georgia	Oklahoma	Wyoming	Colorado	Utah	New York
2			1					
3			5					
4			2					
5	1		26	1	1	5		1
6			10			2		1
7			16			2	1	
8	1		32	1		2		
9			3		1			
10	8		61	13	2	7		4
11			5			1		
12	2		27	8	1	5		
13			1	1	1			1
14			4			1		
15	12		37	32	3	17		4
16			3	3				
17			3	6				1
18	5		8	13		2		1
19	1							
20	32	2	19	88	9	16	1	10
21				2				
22	3			10	1			
23				4				
24	1			4	1			
25	55	3	8	44	7	4	1	13
26	2	1		1	1	1		1
27	1	1		2				
28	4	6		5				
29		1						
30	91	26	2	35	3	6	1	20
31				1				1
32	4	7		2				
33	1	1						1
34		5		1				1
35	66	59	3	14	4	4	1	19
36	1	12						4
37		4						1
38	14	19						18
39		1						
40	92	97	1	6		9	2	40
41	1	1						
42		18						1
43	1	3						
44		4						1
45	36	93		3		1	1	13
46	1	5						
47	1	4						
48	3	18						
50	31	62	1	2	1	4	3	28
52	1	5					1	1
55	7	17						1
58		3						1
60	5	19				3	1	14
65	1	3						2
Total	485	500	278	302	36	92	13	204

One purpose of computing the probable error is to determine whether the sample is of sufficient size to give a reasonable degree of stability to the average yield as calculated for the State. Unless there is reasonable stability or precision in the average of the sample obtained from crop correspondents, there is no point from which to measure the bias of the observations or the lack of representativeness of the sample.

The sample analyzed is usually either the township sample or the field-aids sample. If the sample is a combination of the returns from both lists of correspondents or from a special list, it is so designated by a footnote to the table in which it occurs. Consequently, in considering the possible influence of the fluctuation of sampling on the estimate of yield per acre for a given crop in a particular State, allowance should be made for the fact that the basic sample data were composed of two samples, the sample analyzed—perhaps the field aids—and another similar one from the township correspondents of about the same size. Doubling the size of the sample will reduce the probable error nearly 30 per cent. In many States the supplementary sample data on which the final estimate of yield is based are several times as numerous as either the township or field-aids data.

The standard deviation and coefficient of variation both serve as means of describing the dispersion found in the sample, which in turn approximates the dispersion in the universe of crop yields from which the sample is drawn, whether it be the State or the crop-reporting district. The dispersion of the districts is of special interest from the standpoint of the possible influence of stratification of the sample into crop-reporting districts. The smaller the dispersion of the sample within districts as compared with the sample on a State basis measured by the standard deviation, the more effective is the influence of stratification in increasing the precision of the weighted State average above that shown for the straight average.

The probable error of the straight average may be considered as a maximum measure of the influence of the fluctuation of sampling in practically all samples of crop yields per acre. The extent to which the true probable error of the weighted average of yield samples is actually smaller than the probable error of the straight average (as calculated in this study) depends upon the dispersion pattern of yields over a given State. If there is fully as much dispersion in the reports from a county or crop-reporting district as from the entire State, no decrease in probable error is to be expected when the sample is stratified by counties or districts and a weighted average is computed by weighting the averages of these strata. The same reasoning would apply when the universe is stratified by townships and one or more reports are secured from each township. That is, if there is as great dispersion in yields in the townships as for the entire State there is no possibility of reducing the probable error by selecting the crop correspondents by townships. The more homogeneous and uniform the universe of inquiry, the smaller is the reduction in probable error effected by stratification.

The influence of the stratification of the sample into crop-reporting districts may be detected in either of two ways, (1) by comparing the average dispersion of the observations in each district with the dispersion of all the observations on a State basis, or (2) by computing the dispersion of the district averages for the State. The larger this dispersion of these district averages, the greater the influence of stratification. This is true because the sum of these two measures of dispersion expressed as variance [10] is equal to the dispersion of all the observations for the entire State when the districts all have equal weights and the samples have the same number of observations from each district. When the weights of the strata are not equal, as is the case with crop-reporting districts, the improvement resulting from stratification tends to be offset by any high degree of dispersion in the weights themselves.

The analysis of the estimates of the yields per acre of winter wheat are made in greater detail than for other crops and forms a standard with which other crops may be compared.

WINTER WHEAT

REPRESENTATIVENESS

The acreage of the winter-wheat crop is generally well distributed over a State geographically; consequently with a sample of the yields per acre as large as that obtained in most States, it is not difficult to obtain geographic representation. In only a few States of importance in winter-wheat production east of the Rocky Mountains is there a difference of more than 1 bushel between the straight average (arithmetic mean of all the reports for the State) and the weighted average (district or county averages weighted by estimates of current acreage) of yields per acre of winter wheat computed from the same sample of reports of crop correspondents. (Table 4.) Rather wide differences exist between the straight and weighted averages of the yield samples in the Mountain and Pacific Coast States. It is difficult to obtain a representative sample in these States. The reports are frequently concentrated in the areas of greatest agricultural population, usually in irrigated sections farmed intensively and growing less wheat than the dry-land areas of the State, from which it is difficult to secure crop reporters. Although weighting county or district averages of yield by acreage tends materially to improve the representativeness of the wheat-yield samples in most States, it is necessary further to stratify and weight the sample within each district on the basis of irrigated and nonirrigated land. As the samples of crop yields in these far Western States have been weighted on the basis of irrigated and nonirrigated land in addition to weighting by crop-reporting districts, since 1929 it is expected that the representativeness of the yield-per-acre samples in these States will be improved.

[10] This concept is used by R. A. Fisher in connection with the explanation of total dispersion in the dependent variable due first to covariation in the independent variable, and second to other factors not associated with the independent variable (5).

TABLE 4.—*Winter wheat: Averages of yields per acre computed from reports of crop correspondents, and the official estimate, by States, 1927 and 1928*

State	1927						1928					
	Acreage	Reported by the township list		Reported by the field-aid list		Official estimate	Acreage	Reported by the township list		Reported by the field-aid list		Official estimate
		Average (arithmetic mean)	Weighted average [1]	Average (arithmetic mean)	Weighted average [1]			Average (arithmetic mean)	Weighted average [1]	Average (arithmetic mean)	Weighted average [1]	
	1,000 acres	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*1,000 acres*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*
New York	289	21.9	21.8	22.0	21.5	21.0	306	17.6	16.7	17.6	17.7	14.8
New Jersey	60	23.8	23.2	23.8	22.5	23.0	60	------	------	19.5	19 0	20.0
Pennsylvania	1,090	18.5	18.1	17.9	18.2	18.5	1,101	16.0	15.6	15.1	15.2	15.5
Ohio	1,610	18.1	18.6	17.2	17.8	18.0	864	11.9	11.6	11.4	12.0	10.8
Indiana	1,782	16.0	15.5	16.1	15.8	15.5	900	11.1	11.1	10.2	10.3	10.5
Illinois	2,293	13.9	12.3	14.2	13.2	13.5	1,261	15.6	16.3	14.4	14.5	14.0
Michigan	891	20.9	21.3	21.3	22.0	21.5	882	16.8	16.1	16.1	15.9	16.0
Wisconsin	73	22.5	22.2	23.7	24.1	23.5	42	19.2	18.0	18.1	18.0	18.5
Minnesota	155	21.2	21.6	20.8	21.2	21.4	165	17.3	16.7	16.3	16.0	16.0
Iowa	400	20.1	19.0	19.3	19.3	19.0	411	19.5	19.4	19.5	19.7	19.5
Missouri	1,558	10.2	9.5	10.1	9.9	10.0	1,496	13.4	13.0	13.1	12.5	12.7
South Dakota	105	18.1	17.6	18.6	18.2	18.0	105	14.0	12.1	13.2	11.7	12.0
Nebraska	3,457	20.1	19.5	20.3	19.9	20.5	3,492	18.7	18.4	19.3	19.6	19.1
Kansas	9,936	12.1	10.7	11.5	10.6	11.2	10,433	17.4	16.7	17.5	17.3	17.0
Delaware	98	19.3	------	18.4	21.8	19.0	102	------	------	18.0	------	18.0
Maryland	525	------	------	17.2	17.5	17.5	530	------	------	16.1	16.6	16.5
Virginia	687	11.6	12.0	12.0	12.4	12.2	673	14.0	14.1	14.2	14.8	14.5
West Virginia	135	13.7	13.5	13.5	13.1	13.3	122	12.7	12.4	13.6	13.5	13.0
North Carolina	483	10.7	10.6	11.3	10.8	10.7	444	11.5	11.4	12.4	12.2	11.6
South Carolina	80	11.2	11.1	11.0	10.8	11.0	64	12.3	12.3	13.1	12.6	12.5
Georgia	125	9.7	9.7	9.1	8.8	9.2	94	11.4	11.1	11.4	11.3	11.0
Kentucky	296	10.5	10.0	10.3	9.5	9.5	125	10.9	9.9	9.2	9.4	8.0
Tennessee	528	8.1	8.0	6.6	6.4	7.0	422	9.8	9.8	9.2	9.2	8.8
Arkansas	28	10.9	10.7	15.9	11.8	11.5	22	15.1	13.9	12.0	10.0	11.5
Oklahoma	3,708	9.6	9.1	9.3	9.0	9.0	4,413	12.6	13.6	12.6	13.4	13.5
Texas	1,850	10.2	10.0	11.1	9.4	9.7	2,016	11.8	9.8	11.2	10.1	11.0
Montana	648	18.4	18.8	20.1	19.8	22.0	810	14.9	12.8	15.8	16.0	15.0
Idaho	501	25.5	23.4	26.9	24.0	24.5	456	23.0	21.6	24.9	24.5	23.0
Wyoming	54	21.7	16.1	22.9	22.5	17.0	62	17.8	------	22.3	17.9	15.0
Colorado	1,086	20.5	17.5	18.2	14.4	13.0	923	22.1	19.4	21.2	17.0	12.0
New Mexico	25	15.2	13.4	10.1	3.1	6.0	150	15.7	7.2	16.4	9.9	10.0
Arizona	58	20.0	20.0	23.0	22.5	25.0	47	28.7	------	25.8	21.9	27.0
Utah	152	21.3	20.5	24.9	22.5	19.0	162	25.8	24.6	24.9	24.4	23.0
Nevada	4	27.5	27.5	25.4	25.4	24.0	4	25.7	------	26.4	------	26.0
Washington	1,228	26.6	25.4	28.4	27.6	29.5	1,424	24.6	23.3	28.0	26.2	25.0
Oregon	900	24.0	25.9	26.1	28.6	26.0	837	26.2	28.5	25.4	25.0	24.0
California	812	------	------	18.1	16.8	16.8	780	------	------	21.6	21.0	21.0

[1] Crop reporting district or county averages weighted by acreage weights.

ERRORS OF OBSERVATION

Errors of observation, due to an inaccurate knowledge of the production of a given field, are undoubtedly smaller with a crop like wheat that is threshed and sold than with a feed-grain crop like oats, which is often fed to livestock without being threshed. The tendency to estimate yield per acre in rounded figures divisible by 5 also results in errors of observation. In the group of States shown in Table 2, about 68 per cent of the reports were in figures divisible by 5. The figures divisible by 2 were more popular than odd numbers. Errors of observation are not serious with large samples. Since they tend to increase the standard deviation of the sample beyond that of the universe of inquiry, their influence is inseparable from that of the fluctuation of sampling.

BIAS

Since winter wheat is an important cash crop in many areas, some "cash-crop bias" or understatement in the crop reporter's estimate of yield per acre for his locality might be expected. In no winter-wheat State have the shipments and mill-door receipts of wheat been sufficiently complete to form a reliable check on the accuracy of the estimate of wheat production; consequently no measure of bias is available at present. Such a check is needed and will be obtained eventually when time and funds permit. It is difficult to eliminate duplication of shipments and receipts of out-of-State wheat when milling has grown into an industry of considerable importance in a State consequently, obtaining adequate check data involves more than a mere tabulation of car-lot shipments from the railroads.

In past years the estimates of total wheat production in the United States have frequently been smaller than the supply of wheat that can be accounted for on a national basis from reported grindings, exports and imports of wheat, and estimates of wheat used for feed, seed, and wheat wasted. This fact, combined with the tendency for "cash-crop bias" to appear with crops sold from the farm, leads the statistician to be on his guard against such a bias with winter wheat, especially in instances in which winter wheat is relatively important in comparison with other sources of agricultural income.

There is, however, the long-established impression that crop reporters tend to report yields above the true facts, either because of local pride or because they may be unduly influenced by the higher-than-average yields on their own farms or in their immediate neighborhood. The yields on reporters' farms, as shown by the individual-farm survey, are generally considerably higher than the estimates made by these same reporters for their locality.

With such cash crops as cotton, potatoes, tobacco, peanuts, and fruits and vegetables grown on a commercial scale, for which satisfactory check data on production are obtained, there is a definite and pronounced tendency for understatement on the part of the crop reporter, at least until the crop has left the grower's hands. With winter wheat, however, there is a marked tendency for the yields to be reported lower and lower the further the time of reporting is removed from threshing time. There is no conclusive evidence that cash-crop bias is present in winter wheat yield samples. The Crop Reporting Board showed no appreciable leaning toward the higher of the weighted averages from the two samples in either 1927 or 1928, as might be expected if cash-crop bias were considered by them to be an important factor.

In New York State the official estimate of 21 bushels in 1927 was about 0.6 bushel less than the average of the two weighted averages obtained from the field aids and township reporters. In 1928 the official estimate of 14.8 bushels was 2.4 bushels smaller than were the sample indications. The regular inquiry regarding wheat yield is made the first of August each year. This is before harvest is well under way and entirely too early a date to secure reliable estimates of yields of wheat in New York. The official estimates as they appear in Table 4 were made in December on the basis of a later inquiry.

In New Mexico the official estimate in 1927 was 6 bushels, whereas the township sample showed 15.2 bushels for the straight average and 13.4 bushels for the weighted. The field aids indicated 10.1 bushels straight and 3.1 bushels weighted. The sample from New Mexico is seldom very trustworthy except in an occasional year when yields are fairly uniform over the State. It is necessary to depend almost entirely on the State statistician's appraisal of the situation in his State, based on meager sample data and direct personal observation and information secured by field travel and correspondence. The ordinary methods of sampling break down in a State like New Mexico. Only 25,000 acres of winter wheat were harvested in 1927; this acreage is scattered over one of the largest of the States. A very small population of farmers, including a high proportion of foreigners who do not read or write the English language easily, makes it impossible to secure an adequate and representative sample. Conditions are so varied over the State, because of differences in topography, elevation, rainfall, and irrigation that the fundamental assumption of uniformity in nature is not valid. It is only by careful stratification of the State and direct personal observation and contact of the State statistician that it is possible to make an estimate of yield per acre in most of these far Western States.

The acreages of winter wheat are small in these States as compared with those in the heavy producing States of Texas, Oklahoma, and in the Corn Belt. The combined acreage of winter wheat for the States of New Mexico, Arizona, Utah, Nevada, and Wyoming, where it is most difficult to secure reliable sample data, is usually less than for such relatively unimportant wheat-producing States as North Carolina and Tennessee.

PRECISION OF THE SAMPLE AVERAGES

One rather practical test of the stability of the yield samples and the precision of the averages is obtained by comparing the weighted averages from the two samples—township and field aids—obtained at the same time, under similar conditions and handled in much the same manner. In Table 4 it can be observed how closely these averages actually correspond in the case of the winter-wheat samples. In 1927 Wisconsin, Tennessee, and Arkansas were the only States east of the Rocky Mountains where the weighted averages of the two samples differed by more than 1 bushel. Winter wheat is of minor importance in Wisconsin and of even less importance in Arkansas. In 1928 Illinois, Nebraska, and Arkansas showed a difference of more than 1 bushel. The closer deletion of the very low yields in the township list, due to heavy abandonment, was responsible for most of the difference between the averages from the two samples for Illinois in 1928.

In the far Western States conditions are more diverse, and the size of sample is necessarily small; the difference between the two samples, exclusive of California, averaged about 3 bushels in 1927. In two of these States, Montana and Idaho, the difference did not exceed 1 bushel, and in five more it did not exceed 3 bushels. Only in Wyoming and New Mexico did the difference exceed 5 bushels, and in these two States the actual dispersion in the universe of wheat yields is extremely wide and the samples unusually small. In 1928 the average difference between the two samples ranged from 0.2 bushel in Utah to as much as 3.2 bushels in Montana and 3.5 bushels in Oregon. It is difficult to obtain a satisfactory sample of wheat yields in these far Western States, and consequently the estimates of wheat yields per acre have less precision than they have elsewhere in the country.

For most practical purposes this comparison of the weighted averages from the two samples for a large group of States is sufficient to justify the assumption that in States east of the Rocky Mountains the samples of winter-wheat yields are generally stable and have a high degree of precision. But in the far Western States, considerable improvement is needed in the sampling methods of the Department of Agriculture if really dependable averages are to be reached from sample data.

Table 5 presents for comparisons (1) the size of winter wheat yield-per-acre sample, (2) the average yield, (3) the dispersion, (4) variation, and (5) the probable error of the average yield obtained for several different States and for crop-reporting districts in some States. The dispersion of a winter-wheat yield-per-acre sample for an entire State, as measured by the standard deviation of the sample, varies from 3 to 4 bushels in some of the Middle Western and Southern States, in certain years, to as much as 7 to 10 bushels in some of the far Western States; but the average yield per acre is usually so much larger in these far Western States that the coefficient of variation is sometimes no higher than in some of the Central States. In Missouri in 1927 the standard deviation was 3.44 bushels and the coefficient of variation about 35 per cent; in Washington in 1927 the standard deviation was 9.03 bushels and the coefficient of variation only 33 per cent, due to the fact that the average yield in Missouri had been 9.94 bushels and in Washington 27.5 bushels. The coefficient of variation is sometimes more satisfactory as a basis for comparing the dispersion in different samples than is the standard deviation, as it takes into consideration both the standard deviation and the average. It also makes possible a comparison of different crops, some of which are measured in bushels and others in tons or pounds.

TABLE 5.—*Winter wheat: Yields per acre. Selected illustrations of size of sample, measures of dispersion, and probable error*

State, year, and district	Reports	Average yield (arithmetic mean)	Standard deviation of reported yields	Coefficient of variation	Probable error of the average yield, or mean	Relative probable error
	Number	*Bushels*	*Bushels*	*Per cent*	*Bushels*	*Per cent*
Kansas:						
1928	360	17.22	4.43	25.7	0.16	0.9
1	18	16.64	4.10	24.6	.65	3.9
2	53	15.61	4.03	25.8	.37	2.4
3	51	19.51	3.75	19.2	.35	1.8
4	16	16.88	6.18	36.6	1.04	6.2
5	48	17.19	3.78	22.0	.37	2.2
6	40	20.56	4.43	21.5	.47	2.3
7	17	16.76	5.35	31.9	.88	5.3
8	54	15.05	3.88	25.8	.36	2.4
9	63	15.04	4.23	28.1	.36	2.4
1926 [1]	645	14.70	6.50	44.2	.17	1.2
1	36	4.40	1.90	43.2	.21	4.8
2	100	7.50	4.30	57.0	.29	3.9
3	86	16.40	4.90	29.9	.36	2.2
4	36	7.80	3.80	48.7	.43	5.5
5	82	15.00	3.50	23.3	.26	1.7
6	88	18.60	4.50	24.2	.32	1.7
7	51	17.60	6.10	34.7	.58	3.3
8	90	18.60	4.10	22.0	.29	1.6
9	76	19.60	4.50	23.0	.35	1.8

[1] [illegible] combined to constitute the sample.

TABLE 5.—*Winter wheat: Yields per acre. Selected illustrations of size of sample, measures of dispersion, and probable error*—Continued

State, year, and district	Reports	Average yield (arithmetic mean)	Standard deviation of reported yields	Coefficient of variation	Probable error of the average yield, or mean	Relative probable error
	Number	*Bushels*	*Bushels*	*Per cent*	*Bushels*	*Per cent*
Illinois:						
1927	414	13.90	5.67	40.8	0.19	1.4
1	30	19.50	5.35	27.4	.66	3.4
3	30	20.80	5.36	25.8	.66	3.2
4	39	11.80	4.63	39.2	.50	4.2
4a	72	11.20	3.77	33.7	.30	2.7
5	45	16.20	4.53	28.0	.46	2.8
6	60	18.20	3.57	19.6	.31	1.7
6a	63	12.70	3.58	28.2	.30	2.4
7	34	8.40	3.32	39.5	.38	4.5
9	41	9.10	3.00	33.0	.32	3.5
Nebraska:						
1928	232	19.17	4.53	23.6	.20	1.0
1	5	22.80	4.05	17.8	1.22	5.4
2	4	10.50	1.50	14.3	.51	4.9
3	24	20.01	4.37	21.8	.60	3.0
4	15	20.01	4.20	21.0	.73	3.6
5	23	17.10	4.05	23.7	.57	3.3
6	54	19.95	3.63	18.2	.33	1.7
7	33	19.47	4.80	24.7	.56	2.9
8	32	16.71	3.30	19.7	.39	2.3
9	42	20.22	3.77	18.6	.39	1.9
Missouri:						
1927	395	9.94	3.44	34.6	.12	1.2
1	51	13.02	3.05	23.4	.29	2.2
2	36	11.11	2.33	21.0	.26	2.3
3	20	11.33	2.69	23.7	.41	3.6
4	52	11.75	3.20	27.2	.30	2.6
5	85	9.41	3.52	37.4	.26	2.8
6	47	9.32	2.74	29.4	.27	2.9
7	36	7.99	3.07	38.4	.35	4.4
8	52	8.77	2.36	26.9	.22	2.5
9	16	6.75	2.44	36.1	.41	6.1
Michigan:						
1927	407	21.50	5.77	26.8	.19	.9
1925	398	16.50	6.28	38.1	.21	1.3
1922	461	14.70	5.27	35.9	.17	1.2
1920	416	14.90	5.55	37.3	.18	1.2
1919	529	20.00	5.59	28.0	.16	.8
Ohio:						
1929	582	20.40	5.75	28.2	.16	.8
1928	286	12.16	4.77	39.2	.19	1.6
Pennsylvania:						
1927 [2]	799	19.14	6.60	34.4	.16	.8
1927	326	18.02	4.91	27.2	.18	1.0
1926	321	19.05	5.81	30.5	.22	1.2
1925	270	19.69	5.88	29.9	.24	1.2
New York: 1928	126	17.62	5.98	33.9	.36	2.0
New Jersey:						
1928 [3]	56	19.86	5.04	25.4	.45	2.3
1928	115	21.95	5.70	26.0	.36	1.6
2	41	18.93	4.54	24.0	.48	2.5
5	48	21.50	4.93	22.9	.48	2.2
8	26	27.61	3.88	14.1	.51	1.8
Maryland:						
1927	314	16.8	4.66	27.7	.18	1.1
1	12	18.8	5.30	28.2	1.03	5.5
2	230	17.0	4.00	23.5	.18	1.1
3	29	14.0	3.60	25.7	.45	3.2
4	43	18.2	3.50	19.2	.36	2.0

TABLE 5.—*Winter wheat: Yields per acre. Selected illustrations of size of sample, measures of dispersion, and probable error*—Continued

State, year, and district	Reports	Average yield (arithmetic mean)	Standard deviation of reported yields	Coefficient of variation	Probable error of the average yield, or mean	Relative probable error
	Number	*Bushels*	*Bushels*	*Per cent*	*Bushels*	*Per cent*
Virginia:						
1927	270	11.50	3.90	33.9	0.16	1.4
1926	288	16.00	4.38	27.4	.17	1.1
2	62	17.50	4.17	23.8	.36	2.1
4	25	17.50	3.68	21.0	.50	2.9
5	66	16.40	3.38	20.6	.28	1.7
6	22	17.00	5.90	34.7	.85	5.0
7	56	16.00	3.71	23.2	.33	2.1
8	46	14.10	3.41	24.2	.34	2.4
9	11	11.60	1.87	16.1	.38	3.3
1924	257	12.70	3.94	31.0	.17	1.3
1921	301	9.20	3.18	34.6	.12	1.3
South Carolina:						
1927	80	11.30	4.53	40.1	.34	3.0
1926	81	15.60	4.61	29.6	.35	2.2
1925	61	11.50	3.92	34.1	.34	3.0
1924	84	12.50	4.38	35.0	.32	2.6
Georgia:						
1927	202	8.40	3.80	45.2	.18	2.1
1925	158	10.20	3.44	33.7	.18	1.8
1924	228	10.20	3.79	37.2	.17	1.7
Oklahoma:						
1927	337	9.60	3.32	34.6	.12	1.3
1	17	9.30	5.56	59.8	.91	9.8
2	82	8.70	2.86	32.9	.21	2.4
3	44	10.00	4.08	40.8	.42	4.2
4	61	10.00	2.64	26.4	.23	2.3
5	45	9.40	2.60	27.7	.26	2.8
7	60	10.60	2.88	27.2	.25	2.4
8	28	8.90	3.10	34.8	.40	4.5
1926	261	15.60	4.08	26.2	.17	1.1
1925	197	8.40	3.09	36.8	.15	1.8
1924	288	15.60	4.97	31.9	.20	1.3
Texas:						
1928	150	10.60	4.56	43.0	.25	2.4
1927	119	9.90	4.64	46.9	.29	2.9
1926	92	17.10	4.54	26.6	.32	1.9
1925	99	6.00	4.10	68.3	.28	4.7
Montana:						
1927	55	21.72	6.49	29.9	.59	2.7
1926	111	11.89	7.59	63.8	.49	4.1
1925	79	16.07	8.15	50.7	.62	3.9
Utah:						
1928	27	25.28	7.12	28.2	.92	3.6
1927	43	21.80	6.66	30.6	.68	3.1
1926	46	25.38	7.75	30.5	.77	3.0
Washington: [1]						
1927	205	27.50	9.03	32.8	.43	1.6
5a	48	23.00	7.05	30.7	.69	3.0
6	49	30.00	4.79	16.0	.46	1.5
1926	174	23.30	9.18	39.4	.47	2.0
5a	34	15.70	6.20	39.5	.72	4.6
6	30	25.20	6.39	25.4	.79	3.1
1925	116	26.70	9.36	35.1	.59	2.2
1924	233	16.50	11.37	68.9	.50	3.0
5a	67	6.90	4.95	71.7	.41	5.9
6	49	20.20	6.14	30.4	.59	2.9
California:						
1927 [1]	135	18.11	6.99	38.6	.41	2.3
1926 [1]	123	17.48	7.67	43.9	.47	2.7
1925 [1]	127	18.70	7.73	41.3	.46	2.5
5	34	18.83	6.19	32.9	.72	3.8
5a	29	18.28	1.57	8.6	.20	1.1

[1] Reports from township and field-aid lists combined to constitute the sample.
[2] Return from a special list of crop correspondents.

The coefficient of variation for winter-wheat yield samples is frequently lower than 30 per cent in important wheat States such as Kansas, Nebraska, Oklahoma, Texas, Michigan, Ohio, Pennsylvania, and Maryland, and even in Montana in 1927. On the other hand, it may reach 40 to 50 per cent in practically these same States in a year when the average yield per acre is low, as in Kansas in 1926, and Illinois, Georgia, and Texas in 1927. Some of the highest coefficients of variation were 68 per cent in Texas in 1925, when the average yield was 6 bushels per acre; 64 per cent in Montana in 1926; and 69 per cent in Washington in 1924. Practically one-half of the samples of wheat yield per acre, analyzed on a State basis, showed a coefficient of variation between 30 and 40 per cent, and more than a quarter of them were samples with less than 30 per cent dispersion.

The standard deviation in the same State from year to year seems to be more constant than the coefficient of variation because the latter is affected by the variation in the average yield of the sample from year to year. The greatest dispersion in the samples of winter-wheat yields per acre is found in the large Western States, such as Texas, Montana, and Washington, where conditions are extremely varied.

The probable error of the average from the samples is less than 0.2 bushel in most important winter wheat States east of the Rocky Mountains. It is as high as 0.35 bushel in South Carolina, where the sample is small. In the far Western States the probable error is seldom less than 0.4 bushel and in a few cases exceeded 0.8 bushel in the States where the sample was analyzed. In such States as New Mexico and Arizona the dispersion is so large and the sample so small that computation of the probable error is not worth while.

The majority of the winter-wheat samples from the important winter-wheat States east of the Rocky Mountains have a relative probable error of from 1 to 1.5 per cent. The samples from far Western States generally have a relative probable error as low as about 2 per cent in some years, and as high as 4 or 5 per cent in years of low average yields. The small size of sample in South Carolina causes the relative probable error to be as high as 2 or 3 per cent.

The results shown in Table 5 are from the township or field-aid samples, except for Kansas in 1926, Washington, and California, for which the reports from the two lists were combined for analysis. At least two samples similar in size to most of those shown in the table are used as the basis for the Crop Reporting Board's estimate of yields per acre. This doubling of the size of the sample would of course decrease the probable error by nearly 30 per cent from that shown for the single sample for a State. Many of the States have returns on yields from other lists of reporters which supplement the samples received from the regular crop reporters. The individual-farm sample of acreage and production on the reporter's own farm is also used on a relative basis to indicate the change in yields from one year to another in some States.

STRATIFICATION

If the crop-reporting districts in Table 5 show considerably less dispersion than does the State as a whole, there is a reduction in the actual probable error or a gain in the precision of the average. The greater the dispersion in the district averages, the greater the gain in precision. Kansas wheat in 1926 is an example of wide dispersion in yields over a State, as the lowest average yield, 4.4 bushels, with a standard deviation of 1.9 bushels, was in district 1, and the highest yield, 19.6 bushels, with a standard deviation of 4.5 bushels, was in district 9. When Bowley's formula (*2, p. 337, formula 83*) for the standard error of the mean of a proportionately stratified sample is applied to these data the standard error of the straight average of 0.26 bushel is reduced to 0.16 bushel as the standard error of the stratified sample, a reduction of more than a third. Although the formula does not strictly apply to the weighted stratified sample, it does serve to illustrate the importance of stratification when the individual districts are more homogeneous than is the State as a whole, or when the district averages show marked dispersion.

In the same State in 1928 the effect of stratification was small as compared with that in 1926, for the district averages all fall between 15 and 21 bushels and the standard deviations of the districts averaged about the same as for the State as a whole. It is to be noted, however, in comparing the two years that in 1926 the standard deviation for the State was 6.5 bushels because of the low yields in certain districts, while in 1928 it was only 4.43 bushels. In 1926, when there was wide dispersion in yields of wheat per acre over Kansas, stratification of the sample by crop-reporting districts helped to stabilize the sample and undoubtedly greatly increased the precision of the average.

In Illinois, in 1927, there was a range in district averages from 8.4 to 20.8 bushels. The standard deviation for the State was 5.67 bushels, and yet there were five districts with standard deviations falling below 4 bushels. Stratification by crop-reporting districts reduced the actual probable error materially as the districts were all more homogeneous than the State; that is, they each had a smaller standard deviation.

The two most important winter-wheat districts in the State of Washington show a material difference in their averages, and the standard deviations for the districts were much smaller than for the State as a whole. In 1926 the State standard deviation was 9.18 bushels, whereas in district 5a it was only 6.2 bushels and in district 6 it was 6.39 bushels. In 1927, the standard deviation for the State was 9.03 bushels with 7.05 bushels as the standard deviation of district 5a and only 4.79 bushels in district 6.

In practically every State for which district samples have been analyzed the dispersion in the crop-reporting district tends to be considerably less than for the sample on a State basis.

SIGNIFICANCE OF THE DIFFERENCE BETWEEN TWO AVERAGES

Frequently it is important in the field of economics and statistics to draw conclusions concerning the significance of the difference between two estimates, such as production or yield per acre of a crop in a given State for two successive years. Since conclusions based on sample data must always be in terms of probabilities, it is obvious that the significance of the difference between the averages of two samples must be considered in the same manner.

If the problem of the significance of the averages of samples is approached from the standpoint of the *probable error of the difference between the averages of two samples* for successive years, it is found that in most of the important States a difference of one-half to 1 bushel, or more, may be considered a significant difference. The probable error of the difference with unmatched data (or data from reporters

who do not report for each of the two years) is obtained by adding the square of the two probable errors and extracting the square root. But the two samples contain reports from fully 50 per cent of the same reporters from one year to the next, and there is usually considerable correlation between these paired reports from identical reporters which reduces the probable error of the difference materially. The probable error of the difference in a State like Kansas on the basis of unmatched samples would be about 0.3 bushel. On the basis of reports for the two years that have been brought together or matched, with a correlation of plus 0.60, the probable error of the difference would be less than 0.2 bushel. The correlation of matched data on yields has been, however, as high as plus 0.80 in some instances.

When the proportion of identical reporters is considered, along with other allowances for weighting and stratification of the sample, the statement is well justified that in important States east of the Rocky Mountains a difference between the yield reported one year and the next from the same list of reporters will usually be significant if it exceeds one-half of a bushel. In the far Western States the probable error of the difference might easily reach 1 bushel on the basis of an unmatched sample and probably not less than 0.5 bushel even when allowance for identical farms in the sample is made. In these States the difference between the average yield reported one year and the next from the same list of crop reporters would have to exceed 2 or 3 bushels before it could be assumed that the difference was significant and not due merely to the fluctuation of sampling.

SUMMARY FOR WINTER WHEAT

The probable error of the straight or unweighted average of reported winter-wheat yields in Central and Eastern States on the basis of random selection is around 0.2 of a bushel, or 1 to 1.5 per cent of the average. When allowance is made for the possible effect of the stratification of the sample, it is not likely that the average of a very large sample of wheat yields, taken under similar conditions, would differ from the average of the sample in these States by much more than a half bushel and certainly not by more than a bushel. In the far Western States, where the dispersion in the universe of inquiry is much greater and samples are smaller than in the more populous Central States, the probable error falls between 0.5 to 0.9 bushel, and consequently it is highly probable that the average of a given sample would not differ by more than 1.5 to 3 bushels or 5 to 10 per cent from the average of a very large sample taken under similar conditions.

The conclusions concerning the stability of the sample averages reached from a comparison of the averages from the two lists of crop correspondents shown in Table 4 are practically the same as the conclusions obtained from the more detailed analysis of size of sample, dispersion, and probable error. In the far Western States the yield-per-acre estimates of winter-wheat yields are much less dependable than in the Central and Eastern States, where more uniform conditions prevail and larger and better-distributed samples are obtainable. In these Central and Eastern States "check data" on the commercial movement and utilization of wheat are needed in order that the estimates of the crop reporter may be checked for bias. No increase in the size of sample or change in the method of weighting to secure a higher degree of representativeness would change the averages of these samples materially, perhaps not more than 1 bushel under ordinary circumstances.

The reliability of the estimates of the yields of winter wheat in the far Western States could be improved somewhat by securing larger and better-distributed samples, by a more careful stratification of the State into districts as homogeneous as possible, and by weighting these more homogeneous districts to obtain more complete representativeness. The sample census would undoubtedly be helpful in the far Western States and would serve as a valuable check on present methods in all other States that grow any appreciable acreage of winter wheat. The method of voluntary sampling breaks down completely in some of these States. In practically all of the Rocky Mountain and Pacific Coast States, extensive field travel, observation, and direct personal contacts with the growers and agencies that handle the crop, are necessary if the State statistician is to make a reasonably satisfactory estimate of yield per acre for winter wheat.

SPRING WHEAT

REPRESENTATIVENESS

Although the acreage of spring wheat is not generally as uniformly distributed over the States in which it is grown as is that of winter wheat, the yield-per-acre sample of spring wheat is apparently nearly as representative geographically as is the yield-per-acre sample of winter wheat. Except in the important spring-wheat States of North Dakota, South Dakota, and Minnesota, there is only a relatively small acreage in the States on the Central West. Even with this small scattered acreage, the differences between straight and weighted averages of the same sample (Table 6) generally fall within a range of 1 bushel or less. In fact, some of the greatest differences occur in the important States of South Dakota and Minnesota. In the far Western States the differences are much greater, as with winter wheat, and in about one-half the cases the difference between the straight and weighted averages exceeds 1 bushel and reaches a maximum of from 4 to 6 bushels in the State of Washington.

TABLE 6.—*Spring wheat: Averages of yields per acre computed from reports of crop correspondents, and the official estimate, by States, 1927 and 1928*

State	1927						1928					
		Reported by the township list		Reported by the field-aid list				Reported by the township list		Reported by the field-aid list		
	Acreage	Average (arithmetic mean)	Weighted average [1]	Average (arithmetic mean)	Weighted average [1]	Official estimate	Acreage	Average (arithmetic mean)	Weighted average [1]	Average (arithmetic mean)	Weighted average [1]	Official estimate
	1,000 acres	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*1,000 acres*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*
New York	12	22.0	21.2	20.3	20.1	18.5	10	16.5	17.0	20.2	21.3	17.3
Illinois	216	16.9	18.3	17.8	18.8	18.0	302	18.1	19.0	17.7	17.6	17.5
Wisconsin	72	20.4	19.7	19.9	19.6	19.8	62	22.2	21.4	21.4	21.1	22.0
Minnesota [2]	1,340	11.9	10.7	11.9	10.8	10.5	1,086	15.7	14.9	15.5	14.6	14.5
Iowa	41	16.5	16.2	15.6	15.7	15.5	41	17.2	17.1	17.6	17.6	17.3
Missouri	10	14.9	13.3	12.7	------	12.0	15	15.4	15.5	12.0	------	13.0
North Dakota [2]	6,024	12.0	12.2	12.4	11.8	11.8	5,301	13.4	13.1	13.3	13.4	13.2
South Dakota [2]	1,953	14.4	14.1	15.0	14.9	14.0	1,875	11.2	9.5	11.5	10.6	10.3
Nebraska	173	15.5	16.2	16.4	16.2	17.1	180	16.7	17.3	17.8	19.9	17.9
Kansas	10	11.8	12.5	4.6	5.1	4.4	40	13.7	15.4	11.4	11.9	11.8
Montana [2]	3,187	20.3	19.9	20.7	20.4	20.6	3,410	18.3	18.5	18.2	18.8	19.0
Idaho	670	27.5	27.1	34.8	32.6	30.0	704	27.5	27.9	32.6	30.3	26.0
Wyoming	172	21.9	18.7	23.3	21.9	19.0	181	21.2	18.9	21.1	20.4	17.5
Colorado	333	22.8	21.7	22.0	21.0	18.0	416	22.1	20.6	21.6	21.2	18.0
New Mexico	30	10.9	9.9	21.0	17.1	14.0	36	16.9	15.3	18.0	16.8	15.4
Utah	90	31.6	33.0	32.6	34.2	31.0	95	31.8	33.5	32.5	33.1	32.0
Nevada	14	30.1	27.3	29.3	25.2	26.0	14	26.7	32.1	26.1	26.5	27.0
Washington	1,033	24.7	19.4	25.0	20.5	21.5	847	20.1	13.8	20.8	16.3	15.4
Oregon	165	21.4	23.5	20.7	19.7	20.5	200	20.4	21.3	19.8	16.9	17.0

[1] Crop-reporting district or county averages weighted by acreage.
[2] Exclusive of durum wheat.

BIAS

In the important spring-wheat States of Minnesota, North Dakota, South Dakota, and Montana railroad shipments and mill-door receipts have been used as a check on the production of all wheat. If there were any evidence of cash-crop bias, this check information would have made it possible to detect it as present in either the acreage or the yield-per-acre reports of the correspondents. But since acreage is involved also, no exact measure can be obtained separately for either yield bias or acreage bias. Apparently there was no justification in either 1927 or 1928 for assuming cash-crop bias in the sample, as the final estimates are below the mean of the two weighted averages in Minnesota and North Dakota for both years, and below for one year in South Dakota. It is possible, however, that the estimates of acreage are on too high a level and that consequently the estimates of yield are held low in order that total production may be in line with utilization estimates based primarily on check information. Apparently some bias was allowed for in Montana as the estimates are above either the field-aid or township weighted average in Montana for both years.

PREVENTABLE ERRORS

Only since 1927 have the yields of durum wheat been obtained from the crop reporters separately from "other spring wheat" or "bread wheat" in Minnesota, North Dakota, South Dakota, and Montana. The differences between the straight and weighted averin 1928, range from 0.2 bushel with both wheats in North Dakota to 0.8 bushel for bread wheat in both Minnesota and South Dakota.

There is a tendency on the part of the crop reporter to consider only bread wheat and not the durum wheat when asked to report on spring-wheat yields. Since durum wheat usually yields more per acre, the estimates of yield per acre for all spring wheat in past years have been lower than they would have been had the yields of the two kinds of wheat been ascertained separately in the three States of Minnesota, North Dakota, and South Dakota. In Montana the acreage of durum is such a small part of the total of all spring wheat that the results could not be appreciably affected.

The two kinds of wheat are now being handled as separate crops, designated as "durum wheat" and "other spring wheat." Anyone combining the two estimates of yield per acre to secure the average yield of all spring wheat in any of these three States should appreciate the lack of comparability between the estimates of the last year or two, and those for previous years. This reporting for bread wheat only is an excellent illustration of what has been designated as a "preventable error"—one that can be avoided by the proper construction of the questionnaire in line with the manner in which the correspondents are most likely to interpret it in answering.

PRECISION OF THE SAMPLE AVERAGES

The spring-wheat yield samples are surprisingly stable when the relatively small acreage in many of the States is taken into consideration. When a comparison is made between the weighted averages of the township and field-aid correspondents, (Table 6) about 80 per cent of the two samples check within a bushel or less in the Central and Eastern States, whereas in the far Western States only about 40 per cent of the samples check as closely as that. The extreme differences are about as large as with sample yields of winter wheat.

Table 7 presents for comparisons (1) the size of spring-wheat yield-per-acre sample, (2) the average yield, (3) dispersion, (4) variation, and (5) probable error of the average yield obtained for several States. The dispersion of a State spring-wheat yield-per-acre sample, as measured by the standard deviation of the sample, varies from as low as 2.42 bushels in North Dakota in 1920 and 1923, to more than 12 bushels in some of the far Western States such as Idaho and Washington.

The coefficient of variation differs greatly from one year to another, partly because the standard deviation varies and because of differences in the average yield. In North Dakota, the coefficient of variation was 26 per cent in 1920, and 28 per cent in 1927, whereas in 1926 it was 57 per cent. In Montana it was as low as 33 per cent in 1927 and reached 68 per cent in 1925. The greatest variation was found in the State of Washington, when in 1924 it was 77 per cent, a year when the yield per acre was unusually low.

TABLE 7.—*Spring wheat: Yields per acre. Selected illustrations of size of sample, measures of dispersion, and probable error*

State, year, and district	Reports	Average yield (arithmetic mean)	Standard deviation of reported yields	Coefficient of variation	Probable error of the average yield, or mean	Relative probable error
	Number	*Bushels*	*Bushels*	*Per cent*	*Bushels*	*Per cent*
North Dakota:						
1927	405	12.37	3.48	28.1	0.12	1.0
1	74	12.70	3.05	24.0	.24	1.9
2	41	13.30	2.94	22.1	.31	2.3
3	77	10.70	2.73	25.5	.21	2.0
4	37	14.40	2.89	20.0	.32	2.2
5	31	9.50	2.30	24.2	.28	2.9
6	29	10.20	3.01	29.5	.38	3.7
7	35	13.40	3.46	25.8	.39	2.9
8	33	15.00	2.90	19.3	.34	2.3
9	48	10.70	2.69	25.1	.26	2.4
1926	334	8.54	4.86	56.9	.18	2.1
1923	223	7.18	2.42	33.7	.11	1.5
1920	326	9.30	2.42	26.0	.09	1.0
Minnesota:						
1927	404	11.84	3.98	33.6	.13	1.1
1926	446	13.18	4.80	36.4	.15	1.1
1924	437	21.75	5.40	24.8	.17	.8
Montana:						
1927	188	20.74	6.84	33.0	.34	1.6
2	28	24.82	5.74	23.1	.73	2.9
3	37	18.24	6.28	34.4	.70	3.8
5	35	18.86	5.98	31.7	.68	3.6
6	23	18.69	3.96	21.2	.56	3.0
9	20	19.50	5.22	26.8	.79	4.1
1926	223	12.92	7.98	61.8	.36	2.8
1925	237	11.97	8.13	67.9	.36	3.0
Idaho:						
1927	113	34.90	12.70	36.4	.81	2.3
6	32	40.20	9.90	24.6	1.18	2.9
8	31	44.20	7.94	18.0	.96	2.2
1926	80	26.20	10.70	40.8	.81	3.1
1925	131	31.40	10.60	33.8	.62	2.0
1	27	22.00	5.82	26.5	.76	3.5
6	40	35.10	8.97	25.6	.96	2.7
8	33	40.70	10.80	26.5	1.27	3.1
Washington:						
1927	262	24.40	11.33	46.4	.47	1.9
5a	63	18.20	5.07	27.9	.43	2.4
6	42	20.70	6.04	29.2	.63	3.0
1926	250	21.20	11.44	54.0	.49	2.3
5a	55	12.70	4.14	32.6	.38	3.0
6	50	20.90	6.38	30.5	.61	2.9
1925	200	21.90	12.02	54.9	.57	2.6
5a	45	11.90	4.25	35.7	.43	3.6
6	42	19.60	5.92	30.2	.62	3.2
1924	176	15.00	11.50	76.7	.58	3.9

In North Dakota and Minnesota the probable error of the averages of samples is usually less than 0.2 bushel; in Montana it is slightly higher or between 0.3 and 0.4 bushel, and in the State of Washington the probable error was between 0.47 and 0.58 bushel in the four years analyzed. In Idaho, with fully as large a standard deviation and with a smaller sample, the probable error was about 0.8 bushel in both 1926 and 1927.

The relative probable error of the averages of the samples of yield per acre of spring wheat in the important spring-wheat States of North Dakota and Minnesota was between 1 and 2 per cent in the samples analyzed, but in the far Western States it was usually between 2 and 4 per cent.

The spring-wheat yield samples are rather similar to winter-wheat samples from the standpoint of stability and geographic representa-tiveness and bias. In the far Western States the estimates of yield per acre are based on nonrepresentative and inadequate sample data, which must be supplemented by the field statistician. Larger and better-distributed samples, careful stratification of the State, and weighting on the basis of these more homogeneous districts in order to secure a more nearly representative sample would be helpful. The use of check data on the utilization of wheat has brought a high degree of accuracy in the revised estimates of spring-wheat production in the four most important spring-wheat States—Minnesota, North Dakota, South Dakota, and Montana. Dividing the inquiry into questions regarding durum wheat and other spring wheat, and the weighting of the sample by irrigated and dry-land acreage are both forward steps now under way.

RYE

Rye is grown principally in the Northern States, but also as far south as North Carolina, Georgia, Texas, and Oklahoma. More than a third of the rye acreage in the United States is in North Dakota, and Minnesota had about 400,000 acres in 1927 and 1928. Except in these States, rye is of minor importance in the States in which it is produced and is much less generally grown in the far Western States than is either spring or winter wheat. As a result of the small importance of rye and its use for soil-building purposes and for pasture, it is difficult to maintain satisfactory acreage weights that keep up with the changes in acreage. Under these conditions the straight average of yield per acre of rye may be fully as representative as is the weighted average.

REPRESENTATIVENESS

A comparison of the straight and weighted averages from the two samples of township and field-aid reporters for 1927 and 1928 as shown in Table 8 brings out the interesting fact that even with a crop of such minor importance as rye, in 75 per cent of the samples the two types of averages differ by less than 1 bushel. In only a few scattering cases does this difference exceed 2 bushels.

TABLE 8.—*Rye: Averages of yields per acre computed from reports of crop correspondents, and the official estimate, by States, 1927 and 1928*

State	1927						1928					
		Reported by the township list		Reported by the field-aid list				Reported by the township list		Reported by the field-aid list		
	Acreage	Average (arithmetic mean)	Weighted average[1]	Average (arithmetic mean)	Weighted average[1]	Official estimate	Acreage	Average (arithmetic mean)	Weighted average[1]	Average (arithmetic mean)	Weighted average[1]	Official estimate
	1,000 acres	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*1,000 acres*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*
New York	21	17.8	17.7	17.6	17.7	17.5	20	15.6	15.8	16.1	16.6	15.7
New Jersey	36	18.5	18.9	18.0	21.0	20.0	41	-----	-----	20.0	19.0	18.5
Pennsylvania	86	16.2	16.3	16.4	16.4	17.0	103	15.3	15.1	15.5	15.6	15.5
Ohio	35	15.7	15.7	15.9	16.3	16.0	30	13.2	13.4	13.4	13.3	13.3
Indiana	119	13.1	13.7	13.6	13.9	13.6	86	11.0	11.1	11.1	11.2	11.0
Illinois	62	13.9	15.4	11.6	14.2	14.5	62	14.8	15.8	14.9	14.6	14.5
Michigan	178	15.3	14.7	15.3	14.7	14.7	182	13.3	13.3	14.0	13.5	13.0
Wisconsin	238	17.5	16.3	17.6	16.8	17.0	167	15.3	13.9	13.8	12.8	13.0
Minnesota	383	18.5	18.4	18.5	18.1	18.3	402	16.0	15.5	14.6	14.6	14.8
Iowa	43	19.3	19.1	17.7	17.6	15.0	49	17.7	17.8	18.3	19.0	18.0
Missouri	16	10.2	10.2	10.6	11.2	11.0	19	12.0	11.4	12.3	12.2	12.0
North Dakota	1,381	16.2	15.8	16.9	17.5	16.7	1,271	10.0	10.2	10.3	10.5	10.0
South Dakota	154	16.7	16.9	19.1	19.0	18.0	162	10.1	8.6	10.4	9.5	9.0
Nebraska	274	16.3	15.5	16.1	14.6	15.0	249	15.7	15.1	15.3	14.6	14.0
Kansas	45	13.0	12.8	14.3	12.7	12.8	32	16.5	16.1	18.0	17.0	16.2
Maryland	14	-----	-----	15.0	15.3	15.3	15	-----	-----	14.9	15.0	15.0
Virginia	42	11.3	11.5	11.9	11.8	11.8	46	13.0	13.5	13.0	13.5	13.5
North Carolina	94	13.0	12.6	14.1	13.1	12.0	89	-----	-----	-----	-----	11.5
Georgia	26	13.3	11.8	10.2	9.5	10.0	22	-----	-----	-----	-----	10.0
Kentucky	14	11.4	11.3	10.6	11.0	11.0	-----	-----	-----	-----	-----	-----
Tennessee	26	8.4	8.3	8.2	8.1	8.0	25	-----	-----	-----	-----	8.2
Oklahoma	22	15.7	13.6	15.6	10.9	9.0	26	-----	-----	-----	-----	12.0
Texas	14	23.2	21.1	25.0	-----	7.0	15	-----	-----	16.0	-----	12.0
Montana	134	15.1	15.4	16.4	16.2	18.0	154	10.5	10.7	15.5	14.1	14.0
Wyoming	54	13.0	10.9	13.7	12.5	12.5	40	15.6	12.4	13.3	12.4	11.0
Colorado	76	12.1	11.7	11.4	9.9	10.5	74	13.8	12.0	12.8	12.2	11.0
Washington	22	15.6	15.3	17.9	18.0	16.0	18	16.3	14.4	20.8	20.6	15.5
Oregon	10	19.7	21.6	17.1	15.4	16.0	-----	-----	-----	-----	-----	-----

[1] Crop reporting district or county averages weighted by acreage weights.

BIAS

In North Dakota, South Dakota, Minnesota, and Montana the railroad shipments and mill-door receipts form the basis for estimates of the utilization of rye that are used as a check on rye production. Only in Montana has it been necessary for the Crop Reporting Board to exceed the averages of the samples in making an estimate of yield per acre. This indicates cash-crop bias in the sample data. This is not clearly defined evidence, however, because errors in acreage as well as yield must be considered when a production check is utilized in this way. No cash-crop bias is expected in States in which rye is a minor crop.

PRECISION OF THE SAMPLE AVERAGES

The rye-yield sample is remarkably stable considering the small acreage in most States, as in only about 35 per cent of the States does the weighted average of the township differ by more than 1 bushel from the weighted average of the field-aid sample. Table 9 presents for comparison (1) the size of rye yield-per-acre sample, (2) the average yield, (3) dispersion, (4) variation, and (5) probable error of the average yield obtained for several States. The dispersion of a rye-yield-per-acre sample for a State, as measured by the standard deviation of the sample varies from 4 to 6 bushels in the States where the samples were analyzed, while the coefficient of variation showed a range extending from about 27 per cent to as high as 56 per cent. Only in years of low average yields did the coefficient of variation exceed 45 per cent. This is about the same amount of variation as was shown for samples of wheat yield in these same States.

TABLE 9.—*Rye: Yields per acre. Selected illustrations of size of sample, measures of dispersion, and probable error*

State, year, and district	Reports	Average yield (arithmetic mean)	Standard deviation of reported yields	Coefficient of variation	Probable error of the average yield, or mean	Relative probable error
	Number	*Bushels*	*Bushels*	*Per cent*	*Bushels*	*Per cent*
North Dakota:						
1927	299	15.97	5.28	33.1	0.21	1.3
1	59	15.50	4.85	31.3	.43	2.8
2	33	15.50	3.65	23.5	.43	2.8
3	45	16.20	6.03	37.2	.61	3.8
4	34	16.30	3.87	23.7	.45	2.8
5	38	14.90	3.88	26.0	.42	2.8
6	21	19.60	7.35	37.5	1.08	5.5
7	27	13.90	4.99	35.9	.65	4.7
8	29	15.70	4.28	27.3	.54	3.4
9	13	20.90	6.05	28.9	1.13	5.4
1926	107	7.59	4.29	56.5	.28	3.7
1	13	7.80	4.62	59.2	.86	11.0
2	12	5.00	2.16	43.2	.42	8.4
3	23	8.70	3.60	41.4	.51	5.9
4	10	4.10	1.47	35.9	.31	7.6
5	9	7.00	3.99	57.0	.90	12.9
6	23	12.30	5.25	42.7	.74	6.0
7	5	5.00	2.15	43.0	.65	13.0
9	12	6.40	3.21	50.2	.63	9.8
1923	187	7.29	3.96	54.3	.20	2.7
1920	199	10.49	4.68	44.6	.22	2.1
Minnesota:						
1927	364	18.74	5.31	28.3	.19	1.0
1926	367	13.82	6.14	44.4	.22	1.6
1924	337	19.48	5.37	27.6	.20	1.0
Pennsylvania:						
1927[1]	399	17.28	4.94	28.6	.17	1.0
1927	176	16.33	4.42	27.1	.22	1.3
1926	176	16.26	4.94	30.4	.25	1.5
1925	177	16.97	4.69	27.6	.24	1.4
Ohio: 1929	174	17.63	5.32	30.2	.27	1.5
Illinois:						
1927	91	11.61	4.97	42.8	.35	3.0
1	13	16.00	3.72	23.3	.70	4.4
3	10	16.60	3.54	21.3	.76	4.6
4	12	10.50	5.73	54.6	1.12	10.7
4a	13	10.00	4.41	44.1	.82	8.2
5	10	10.00	4.02	40.2	.86	8.6
6	7	13.43	3.38	25.2	.86	6.4
6a	14	9.79	2.40	24.5	.43	4.4
7	6	9.00	4.11	45.7	1.13	12.6
9	6	7.00	2.46	35.1	.68	9.7
1927[2]	94	13.80	5.30	38.4	.37	2.7
1926[2]	158	14.60	5.41	37.1	.29	2.0
1925[2]	147	13.80	5.99	43.4	.33	2.4
1924[2]	109	14.52	6.10	42.0	.39	2.7

[1] Return from a special list of crop correspondents.
[2] Reported in August.

The probable error of the averages did not exceed 0.4 bushel in any of the States analyzed, and in 13 of the 17 samples it did not exceed 0.3 bushel. The relative probable error was as low as 1 per cent in three samples and exceeded 3 per cent in North Dakota in 1926 when the average yield was low. Since the estimates of rye yields were based on at least two different samples of this size, the township and the field-aid samples, the combined average from the two samples would have a probable error about 30 per cent smaller than for either taken separately because of the doubling of the size of sample. Although the rye acreage is scattered and the crop is of minor importance in most of the States in which it is grown, the sample indications are nearly as significant as with wheat, and the estimates of yield are nearly as reliable.

CORN

Corn is grown in every State, and in only one State—Nevada—does the acreage fall below 10,000 acres. This makes possible a comparison of samples between a large number of States. There are, however, certain limitations to such comparisons.

Corn is used largely as forage in the northern tier of States. In the Southern States the early planted corn ripens in late summer or early fall, and, in many sections there is a second, late-planted crop, that matures in late fall. When the inquiry regarding corn yield is made on November 1 the southern farmer tends to have the late-planted crop in mind rather than the earlier crop. In 1928 the late crop yielded much better than the early; as a result the estimates of yield per acre covering both crops was reduced below the November 1 sample indications. In many sections of the Northern States corn husking is not sufficiently advanced by November 1 to justify a final estimate of yield at that time. Beginning with 1928 the corn-yield inquiry has been repeated on the December 1 schedule. The estimated yield of corn is not strictly for "grain only" in all States, although the schedule specifies "corn for grain." During the last three years an effort has been made to distinguish between the yield of corn for grain and the yield for other purposes, and as a result, supplementary estimates have been made of the yield for grain, that are separate from the regular grain-equivalent basis.

REPRESENTATIVENESS

The samples of corn yield usually come from points that are distributed over a State in about the same proportion as is the acreage of corn, so a high degree of geographic representativeness is generally attained, except in some of the far Western States, and some of the smaller States where the small number of reports sometimes leads to distortion when district averages are weighted. The straight and weighted averages (Table 10) checked within 1 bushel in over 80 per cent of the samples for the States, exclusive of the far western group where only about 20 per cent of the samples checked as closely as 1 bushel. The acreage of corn is relatively very small in the Western States—7 of the 11 far Western States have less than 100,000 acres of corn each.

TABLE 10.—*Corn: Averages of yields per acre computed from reports of crop correspondents, and the official estimate, by States, 1927 and 1928*

State	1927						1928					
	Acreage	Reported by the township list: Average (arithmetic mean)	Reported by the township list: Weighted average[1]	Reported by the field-aid list: Average (arithmetic mean)	Reported by the field-aid list: Weighted average[1]	Official estimate	Acreage	Reported by the township list: Average (arithmetic mean)	Reported by the township list: Weighted average[1]	Reported by the field-aid list: Average (arithmetic mean)	Reported by the field-aid list: Weighted average[1]	Official estimate
	1,000 acres	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*1,000 acres*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*
Maine	14	------	------	44.0	46.6	37.0	13	------	------	40.1	39.6	40.0
New Hampshire	15	------	------	48.0	46.7	41.0	14	------	------	44.2	45.3	40.0
Vermont	84	------	------	47.0	44.3	39.0	80	------	------	46.0	46.7	44.0
Massachusetts	46	------	------	49.0	47.4	41.0	45	------	------	43.0	45.0	42.0
Rhode Island	10	------	------	47.0	47.8	38.0	10	------	------	43.3	44 4	39.0
Connecticut	55	------	------	48.0	48.1	38.0	55	------	------	48.5	45.6	42.0
New York	663	36.8	36.7	38.3	38.2	34.0	650	38.0	37.0	38.0	37.2	34.0
New Jersey	179	43.3	42.4	44.0	40.0	40.0	181	------	------	39.0	38.0	38.5
Pennsylvania	1,270	39 1	40.1	39.1	40.0	39.5	1,283	38.8	39.3	39.7	40.5	39.0
Ohio	3,376	36.8	36.6	34 0	34.0	32.5	3,646	37.9	37.8	38.0	38.0	37.5
Indiana	4,205	33.8	33.4	33.6	33.8	31.5	4,440	35.7	36.0	35.4	36.3	35.2
Illinois	8,469	31.4	31.5	31.7	31.7	30.0	9,570	37.3	38.7	38.6	38.8	38.4
Michigan	1,418	28,6	28.8	27.3	27.8	27.5	1,461	33.5	34.3	33.2	33.4	35.0
Wisconsin	2,100	32.8	34.0	33.7	33.4	32.5	2,121	40.6	43.4	44.6	45.2	43.0
Minnesota	4,172	30.8	31.2	30.5	31.3	30.5	4,089	34.5	35.7	34.5	34.7	35.0
Iowa	10,901	35.7	36.4	36.2	36.7	35.5	11,202	43.1	42.9	42.2	42.4	42.6
Missouri	5,796	28.9	28.8	29.5	29.4	29.0	6,260	37.8	30.1	29.1	29.5	29.0
North Dakota	959	26.0	26 0	27.8	27.1	25.0	997	25.8	25.1	25.7	25.6	24.5
South Dakota	4,655	28.3	29.7	29.8	31.6	29.0	4,469	21.8	22.3	22.6	21.8	21.0
Nebraska	8,805	31.8	32.5	31.7	33.1	33.1	8,937	22.8	22.1	21.9	21.4	23.8
Kansas	5,897	31.5	31.8	30.2	29.4	30 0	6,634	27.7	28.2	26.6	26.1	27.0
Delaware	135	34.8	------	34.0	35.0	35.0	136	------	------	29.5	29.9	33.0
Maryland	515	------	------	43.3	42.3	44.0	530	------	------	37.7	36.3	36.5
Virginia	1,626	30.8	29.9	29.1	29.0	29.5	1,626	------	------	27.5	27.6	27.5
West Virginia	441	32.9	32.7	37.4	36.4	33.5	459	------	------	38.6	37.9	36.0
North Carolina	2,352	22.9	22.8	23.1	23.2	22.8	2,305	19.7	19.6	19.0	18.8	18.5
South Carolina	1,497	17.4	17.3	16.4	16.8	17.0	1,422	13.1	12.9	12.3	12.1	12.0
Georgia	3,893	15.3	14.5	14.2	13.8	14.0	3,620	11.9	10.8	10.6	10.1	10.5
Florida	573	------	------	------	------	13.0	607	------	------	------	------	13.0
Kentucky	2,885	26.4	25.7	28.7	27.2	26.0	3,029	24.5	22.8	26.2	23.6	22.0
Tennessee	2,944	26 7	25.9	24.3	23.7	24.0	2,915	22.8	22.4	19.5	19.7	19.5
Alabama	2,800	16.1	15.7	17.0	16.0	16.0	2,650	14.1	13.5	14.0	14.0	11.5
Mississippi	1,918	18.0	17.9	17.6	17.8	17.8	1,765	14.9	15.0	14.3	14.3	13.0
Arkansas	1,925	21.0	20.7	18.0	18.2	19.0	2,002	18.3	18.4	17.7	17.5	16.5
Louisiana	1,161	18.1	18.7	16.2	16.7	17.5	1,242	16.7	17.6	17.5	17.5	17.0
Oklahoma	3,177	25.0	26.0	25.1	25.1	26.5	3,050	22.5	22.8	21.7	21.9	23.0
Texas	5,189	23.2	22 9	24.0	23.0	23.0	4,722	22.1	21.8	22.8	22.3	21.0
Montana	305	24.1	24.2	23.4	23.6	23.5	274	22.2	20.8	18.3	18.0	19.0
Idaho	76	39.0	39.3	42.3	43.0	41.0	53	44.4	40.9	50.4	49.4	46.0
Wyoming	176	26.2	23.4	23.4	23.4	20.0	167	21.4	20.8	21.4	21.0	18.0
Colorado	1,284	24.6	19.0	22.6	19.5	15.5	1,438	22.2	19.6	22.1	17.4	13.0
New Mexico	166	19.2	17.5	20.5	17.4	15.0	199	24.0	22.4	21.0	23.0	17.5
Arizona	44	40.0	41.8	39.5	43.6	32.0	39	36.7	31.8	42.5	30.9	26.0
Utah	19	35.6	32.9	32.7	31.0	27.0	18	35.5	37.0	30.7	34.3	29.0
Washington	43	41.1	40.4	40.8	34.0	37.0	46	43.8	40.0	44.5	42.0	39.0
Oregon	81	31.8	33.7	34.0	36.0	36.0	82	36.6	37.0	36.3	38.3	36.0
California	77	------	------	39.0	33.0	32.0	75	------	------	31.2	35.3	32.0

[1] Crop reporting district or county averages weighted by acreage weights.

ERRORS OF OBSERVATION

Table 3 shows the reports from the township reporters for the inquiry of November, 1928, grouped by specified yields per acre of corn. The tendency to report in figures divisible by 5 is pronounced; even in Georgia where the average yield was very low, 57 per cent of the yields were so reported. This tendency is common to all crops, as explained in discussing winter wheat, and is more pronounced in samples of the yield of corn than is the case with wheat. About 68 per cent of the reports in the wheat samples were in such figures,

whereas with corn 78 per cent of the reports in Indiana, 87 per cent in Iowa, and 82 per cent in Colorado were in figures divisible by 5. This practice results in a relatively smaller error of observation on corn than on wheat, because corn yields are generally much higher than wheat yields.

BIAS

Cash-crop bias with corn is ordinarily expected only in States that sell corn, where some bias may be expected, especially in years when the price is very low and there is much discussion in the newspapers about the size of the corn crop and the relation of large and small crops to the price. In Iowa, where the accessors' annual enumeration, taken from January to April, reports the acreage and production of corn for the preceding year, the average yield of corn can be derived and used as a check against the yield samples obtained in November.

In 1925, which was a year of a large corn crop in this country with prices much lower than for the previous year's small crop, the assessors' enumeration showed an average yield of corn of 43.9 bushels which was slightly higher than the weighted average of the township reports of 43.5 bushels and the 43 bushels reported by the field aids. This would seem to indicate the presence of some cash-crop bias in that year. In 1926, although the Iowa crop was nearly 12 per cent less than the year before, the farm price in November of 58 cents per bushel was also lower than the price the year before—61 cents. The assessors found a yield of corn husked or snapped of 39.1 bushels, while the weighted average of the township reports was only 36.3 bushels and that of the field-aid reports was 36.9 bushels, a difference of more than 2 bushels. In both 1927 and 1928 the assessors reported yields of corn lower than the yields reported by the crop reporters. The Iowa farm price in November, 1927, was 69 cents and in November, 1928, was 66 cents. In 1927 the assessors showed 35.2 bushels, as compared with the 36.4 bushels reported by the township list and 36.7 bushels reported by the field-aid list. In 1928 the assessors' report of yield of grain was 41.3 bushels, while the township-list report was 42.9 bushels and the field-aid report was 42.4 bushels.

In 1924, Iowa corn was soft, and only 5 per cent of the crop was reported as having been husked by November 1. Yield of corn for grain in that year as derived from the Federal census enumeration of acreage and production, was 28.3 bushels, whereas the assessors' enumeration for the same year resulted in an average of 28.2 bushels. In the November yield-inquiry 31.6 bushels was reported by the township reporters and 31.2 bushels by the field-aid reporters, whereas on December 1 the field-aid correspondents reported 28.5 bushels.

In Iowa there is apparently a tendency for the crop reporters to overestimate the crop in years of soft corn and to underestimate it in years of well-matured corn. The greater shrinkage in years of soft corn may cause the farmers to report a lower figure late in the winter to the assessor than they estimated on November 1. The present policy of having the yield inquiry repeated in December will undoubtedly greatly improve the estimates of corn yields in the important Corn Belt States.

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PREVENTABLE ERRORS

In parts of New York, Pennsylvania, and New England, the fact that farmers measure the yield of corn in bushel baskets which are equivalent to about one-half a standard bushel has led to the action reported on page 24. It is because of this difficulty that the recent estimates of corn yields in New York and New England are not entirely comparable with estimates of former years. In so far as possible the estimates are now on a standard-bushel basis.

PRECISION OF THE SAMPLE AVERAGES

The samples of corn yield are remarkably stable. Averages of the township and field-aid reports in States east of the Rocky Mountains checked within 1 bushel or less in about 60 per cent of the States in 1927, and in 80 per cent in 1928. The averages from the two samples checked within 2 bushels in the reports from nearly 80 per cent of the States in 1927 and in 97 per cent in 1928. Since corn yields are so much higher than wheat or rye yields, the check of 2 bushels for corn is comparable with 1 bushel for wheat or rye. Even in four of the nine far Western States for which the two samples are available, they checked within a bushel.

In Table 11 are presented for comparisons, (1) the size of corn yield-per-acre sample, (2) the average yield, (3) dispersion, (4) variation, and (5) probable error of the average yield obtained for several States. The standard deviation of corn yields as reported in samples from individual States varies from as low as 5 or 6 bushels in Mississippi to as high as nearly 12 bushels in certain years in Kentucky and Nebraska In the important Corn Belt States it usually varies between 7 and 11 bushels. In Iowa, where conditions are probably more uniform than in any other State of equal size, the coefficient of variation was as low as 19 or 20 per cent in three out of four years and in the fourth year it was slightly less than 25 per cent. In Illinois and Missouri the coefficient of variation was slightly higher, or about 26 or 27 per cent in the years included in Table 11. In Nebraska it was as low as 24 per cent in 1923 and 27 per cent in 1927, years of high average yields for that State, while in 1926, a year of low yields, the standard deviation was high, and consequently the coefficient of variation reached 67 per cent. The highest coefficient of variation, 73 per cent, was found in the 1926 sample for Montana, when the average yield for the State was only 12 bushels; but in 1927, with an average yield of 22 bushels, it was only 34 per cent. In Texas, the coefficient of variation was as low as 37 per cent in 1926 and as high as 71 per cent in 1925, a year of low yields.

TABLE 11.—*Corn: Yields per acre. Selected illustrations of size of sample, measures of dispersion, and probable error*

State, year, and district	Reports	Average yield (arithmetic mean)	Standard deviation of reported yields	Coefficient of variation	Probable error of the average yield, or mean	Relative probable error
	Number	*Bushels*	*Bushels*	*Per cent*	*Bushels*	*Per cent*
Iowa:						
1928	492	43.15	8.09	18.7	0.25	0.6
1	53	40.85	6.25	15.3	.58	1.4
2	49	41.42	4.27	10.3	.41	1.0
3	61	43.77	8.66	19.8	.75	1.7
4	62	41.05	5.67	13.8	.49	1.2
5	70	45.64	5.96	13.1	.48	1.1
6	50	48.90	7.71	15.8	.74	1.5
7	46	40.65	8.79	21.6	.87	2.1
8	45	42.44	8.28	19.5	.83	2.0
9	56	43.75	7.88	18.0	.71	1.6
1927	901	35.42	8.63	24.4	.19	.5
1	107	36.60	7.10	19.4	.46	1.3
2	97	32.00	6.04	18.9	.41	1.3
3	98	32.50	8.82	27.1	.60	1.8
4	116	39.00	6.94	17.8	.43	1.1
5	115	39.20	6.94	17.7	.44	1.1
6	88	38.50	8.40	21.8	.60	1.6
7	91	38.60	7.78	20.2	.55	1.4
8	104	29.70	8.04	27.1	.53	1.8
9	85	31.40	9.54	30.4	.70	2.2
1926	784	37.40	7.33	19.6	.18	.5
1	93	35.70	7.88	22.1	.55	1.5
2	83	35.96	5.52	15.4	.41	1.1
3	74	37.84	8.06	21.3	.63	1.7
4	95	37.21	7.64	20.5	.53	1.4
5	99	40.86	5.12	12.5	.35	.9
6	92	41.68	7.49	18.0	.53	1.3
7	78	34.10	5.48	16.1	.42	1.2
8	89	33.71	6.56	19.5	.47	1.4
9	81	38.83	7.19	18.5	.54	1.4
1925	885	45.70	9.26	20.3	.21	.5
1	107	36.50	8.74	23.9	.57	1.6
2	100	47.10	7.32	15.5	.49	1.0
3	93	51.80	10.28	19.8	.72	1.4
4	110	44.20	8.74	19.4	.56	1.3
5	112	47.70	6.12	12.8	.39	.8
6	96	52.90	9.04	17.1	.62	1.2
7	85	44.20	5.08	11.5	.37	.8
8	95	42.80	6.52	15.2	.45	1.1
9	87	45.20	8.87	19.6	.64	1.4
Illinois:						
1927	463	31.56	8.14	25.8	.26	.8
1	67	33.81	8.25	24.4	.68	2.0
3	54	30.65	8.11	26.5	.74	2.4
4	52	29.33	8.14	27.8	.76	2.6
4a	68	34.48	11.50	33.4	.94	2.7
5	43	33.50	6.69	20.0	.69	2.1
6	54	32.04	6.61	20.6	.61	1.9
6a	50	27.20	8.38	30.8	.80	2.9
7	45	31.66	7.32	23.1	.74	2.3
9	30	28.50	6.79	23.8	.84	2.9
1926	433	35.27	9.49	26.9	.31	.9
1	46	38.81	8.02	20.7	.80	2.1
3	44	38.75	8.06	20.8	.82	2.1
4	50	38.10	5.91	15.5	.56	1.5
4a	64	33.05	9.50	28.7	.80	2.4
5	43	39.30	7.75	19.7	.80	2.0
6	50	40.20	6.10	15.2	.58	1.4
6a	55	32.55	9.70	29.8	.88	2.7
7	44	27.16	12.40	45.7	1.26	4.6
9	37	30.68	7.07	23.0	.78	2.5

TABLE 11.—*Corn: Yields per acre. Selected illustrations of size of sample, measures of dispersion, and probable error*—Continued

State, year, and district	Reports	Average yield (arithmetic mean)	Standard deviation of reported yields	Coefficient of variation	Probable error of the average yield, or mean	Relative probable error
	Number	*Bushels*	*Bushels*	*Per cent*	*Bushels*	*Per cent*
Michigan:						
1927	492	27.30	11.02	40.4	0.34	1.2
1	6	10.80	12.25	113.4	3.37	31.2
2	46	25.90	11.00	42.5	1.09	4.2
3	9	25.30	12.12	47.9	2.72	10.8
4	27	25.30	10.44	41.3	1.35	5.3
5	43	24.80	11.71	47.2	1.20	4.8
6	51	29.70	10.49	35.3	.99	3.3
7	99	24.10	8.06	33.4	.55	2.3
8	103	28.60	10.06	35.2	.67	2.3
9	108	30.60	12.10	39.5	.79	2.6
Missouri:						
1927	987	29.61	8.12	27.4	.17	.6
1	145	34.62	7.57	21.9	.42	1.2
2	118	30.34	6.88	22.7	.43	1.4
3	77	20.46	8.44	41.3	.65	3.2
4	127	30.67	5.50	17.9	.32	1.1
5	181	29.81	7.95	26.7	.40	1.3
6	116	30.17	8.89	29.5	.56	1.9
7	64	30.15	7.93	26.3	.67	2.2
8	120	29.67	6.96	23.5	.43	1.4
9	39	25.28	7.76	30.7	.84	3.3
Nebraska:						
1928	345	22.01	9.30	42.3	.34	1.5
1927	337	32.05	8.60	26.8	.32	1.0
1926	294	16.95	11.35	67.0	.45	2.7
1925	348	26.35	10.85	41.2	.39	1.5
1924	342	24.25	7.40	30.5	.27	1.1
1923	402	32.16	7.60	23.6	.26	.8
Minnesota:						
1927	508	30.19	11.65	38.6	.35	1.2
1926	481	34.31	10.21	29.8	.31	.9
1924	330	30.56	9.17	30.0	.34	1.1
Virginia:						
1927	327	28.50	9.40	33.0	.35	1.2
2	52	32.60	12.80	39.3	1.20	3.7
4	25	32.20	10.40	32.3	1.40	4.3
5	80	27.60	8.10	29.3	.61	2.2
6	29	28.50	6.20	21.8	.78	2.7
7	64	31.50	9.20	29.2	.78	2.5
8	45	24.30	6.00	24.7	.60	2.5
9	32	26.70	8.60	32.2	1.02	3.8
1926	271	28.50	10.40	36.5	.43	1.5
Kentucky:						
1928	429	24.25	11.46	47.3	.37	1.5
1	56	19.02	8.69	45.7	.78	4.1
2	51	34.90	9.63	27.6	.91	2.6
3	43	24.89	8.79	35.3	.90	3.6
4	60	33.17	6.65	20.0	.58	1.7
5	40	23.50	10.91	46.4	1.16	4.9
6	38	14.08	6.87	48.8	.75	5.3
7	39	17.44	6.88	39.4	.74	4.2
8	64	20.63	8.55	41.4	.72	3.5
9	38	21.19	10.97	51.8	1.20	5.7
1927	428	26.55	9.78	36.8	.32	1.2

TABLE 11.—*Corn: Yields per acre. Selected illustrations of size of sample, measures of dispersion, and probable error*—Continued

State, year, and district	Reports	Average yield (arithmetic mean)	Standard deviation of reported yields	Coefficient of variation	Probable error of the average yield, or mean	Relative probable error
	Number	*Bushels*	*Bushels*	*Per cent*	*Bushels*	*Per cent*
Mississippi:						
1927	430	17.60	5.51	31.3	0.18	1.0
1	17	22.90	6.75	29.5	1.11	4.8
2	52	16.80	5.30	31.5	.50	3.0
3	59	18.00	5.60	31.1	.49	2.7
4	27	17.80	8.85	49.7	1.15	6.5
5	68	17.10	4.48	26.2	.37	2.2
6	58	16.20	3.81	23.5	.34	2.1
7	38	16.60	4.46	26.9	.49	3.0
8	47	17.60	5.35	30.4	.53	3.0
9	64	18.90	5.10	27.0	.43	2.3
Oklahoma:						
1927	449	24.90	8.20	32.9	.26	1.0
1	14	21.80	4.85	22.2	.87	4.0
2	79	25.60	8.30	32.4	.63	2.5
3	55	25.20	9.10	36.1	.83	3.3
4	56	23.80	11.55	48.5	1.04	4.4
5	80	26.60	7.75	29.1	.58	2.2
6	39	24.50	7.68	31.3	.83	3.4
7	46	24.40	7.60	31.1	.75	3.1
8	52	25.00	7.80	31.2	.73	2.9
9	28	23.80	6.35	26.7	.81	3.4
New Jersey:						
1928	222	40.61	10.85	26.7	.49	1.2
2	61	42.46	11.10	26.1	.96	2.3
5	89	40.50	10.15	25.1	.73	1.8
8	72	39.16	9.55	24.4	.76	1.9
1926	212	45.82	10.75	23.5	.50	1.1
Texas:						
1928	348	20.00	9.17	45.8	.33	1.6
1927	328	22.00	8.73	39.7	.33	1.5
1926	276	26.00	9.50	36.5	.39	1.5
1925	247	11.00	7.80	70.9	.33	3.0
Montana:						
1927	52	22.04	7.48	33.9	.70	3.2
1926	90	12.06	8.78	72.8	.62	5.1

The probable error of the corn-yield averages seldom exceeds 0.5 bushel in a State in which corn is at all important and frequently the probable error is as low as 0.2 or 0.3 bushel in States like Iowa, Illinois, Missouri, and Mississippi. The relative probable error for corn yields is lower than the error for any other crop analyzed; it does not exceed 0.5 or 0.6 per cent in Iowa, and seldom exceeds 1 per cent in Illinois, Missouri, Mississippi, and some of the other States. Only in some of the far Western States such as Montana, or in Texas in years of low yields, does the relative probable error exceed 1.5 per cent. In Iowa the relative probable errors of the crop-reporting district averages fall almost entirely within a range of 1 or 2 per cent; in Illinois, with a much smaller sample, they usually fall between 2 and 3 per cent.

When allowance is made for the effect of stratification and for the fact that at least one additional sample of a size similar to the one analyzed was also included as a basis for the estimate of corn yields, it is evident that in most States the size of sample is sufficient to give an average with a high degree of precision. Geographic representativeness is well taken care of by the distribution of the sample. Cash-crop bias is not likely to be a serious factor except in a few States in which corn is sold, and then only in years of low prices for corn.

Repeating the November 1 yield inquiry in December, making supplementary estimates of "corn for grain only" and allowing for the two crops grown each year in the South are helping to improve the accuracy of the corn estimates. The fact that corn is harvested for other purposes than grain and that different units of measurement are used in different regions, makes estimating the yield difficult. Experimentation in the making of the estimates is undoubtedly improving their basis, and those of the last few years are undoubtedly more reliable than those of previous years.

OATS

Oats, like corn, are widely grown over the entire country. Only four of the smaller States have less than 10,000 acres. Table 12 shows that the straight and weighted averages check closely and that the greatest differences tend to occur in the far Western States with their varied conditions. As with other crops, there is the tendency to report yields in figures divisible by 5, but since oat yields are generally much higher than wheat yields, this tendency is not likely to be a source of error as large as with wheat samples. Since oats are primarily a feed crop, little if any cash-crop bias need be expected. For the same reason a utilization check, based upon car-lot shipments and mill-door receipts, is not conclusive.

TABLE 12.—*Oats: Averages of yields per acre computed from reports of crop correspondents, and the official estimate, by States, 1927 and 1928*

State	1927						1928					
		Reported by the township list		Reported by the field-aid list				Reported by the township list		Reported by the field-aid list		
	Acreage	Average (arithmetic mean)	Weighted average[1]	Average (arithmetic mean)	Weighted average[1]	Official estimate	Acreage	Average (arithmetic mean)	Weighted average[1]	Average (arithmetic mean)	Weighted average[1]	Official estimate
	1,000 acres	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*1,000 acres*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*
Maine	124	-----	-----	35.0	36.5	37.0	120	-----	-----	34.0	35.6	35.0
New Hampshire	11	-----	-----	38.0	39.1	39.0	10	-----	-----	41.0	41.0	39.0
Vermont	83	-----	-----	39.0	38.5	39.0	79	-----	-----	34.0	33.7	34.0
Connecticut	15	-----	-----	34.0	32.6	32.0	15	-----	-----	28.0	25.6	27.0
New York	1,000	35.9	35.9	36.1	35.7	35.0	1,020	27.3	27.6	27.7	28.2	33.0
New Jersey	49	36.0	36.2	39.0	37.0	36.0	50	-----	-----	31.0	30.0	30.0
Pennsylvania	1,100	34.1	34.0	35.7	35.7	36.0	1,067	32.5	32.5	31.8	31.9	32.5
Ohio	1,900	31.3	32.8	31.2	31.6	32.0	2,413	36.0	37.6	35.3	36.6	37.0
Indiana	1,948	23.4	24.2	24.7	24.7	25.0	2,430	36.1	36.7	36.6	37.0	37.0
Illinois	4,008	23.7	24.3	23.7	25.8	25.5	4,649	36.7	37.1	37.6	37.4	37.5
Michigan	1,617	32.0	32.8	33.5	34.4	33.5	1,633	35.3	35.6	35.8	36.1	35.8
Wisconsin	2,422	38.0	38.2	37.9	38.5	38.5	2,495	42.5	42.8	43.7	44.1	43.5
Minnesota	4,350	27.6	28.2	27.5	26.8	26.8	4,089	36.7	36.9	37.5	37.6	36.5
Iowa	6,001	31.3	32.2	31.4	32.5	32.0	6,004	38.8	39.6	40.6	41.0	40.0
Missouri	1,565	18.3	16.4	18.0	18.0	17.0	1,706	27.5	27.2	28.8	28.5	28.0
North Dakota	2,125	23.0	21.6	23.9	21.4	21.5	1,934	31.9	31.3	31.3	30.5	31.0
South Dakota	2,550	28.9	29.0	29.6	29.8	29.3	2,193	27.0	26.2	27.6	27.5	27.0
Nebraska	2,441	27.6	27.4	30.1	28.7	28.6	2,392	31.6	31.2	32.6	32.6	33.0
Kansas	1,301	24.6	23.8	23.4	22.7	23.5	1,301	28.1	27.8	30.0	29.9	29.0
Maryland	51	-----	-----	32.9	33.5	33.5	54	-----	-----	31.4	31.5	31.5
Virginia	186	23.7	22.9	24.1	22.7	21.5	182	25.2	25.0	25.4	25.7	25.5
West Virginia	217	25.8	26.0	24.7	24.1	24.2	204	28.5	28.2	29.0	27.8	28.0
North Carolina	273	18.0	17.1	19.7	19.6	21.0	191	20.3	20.4	22.6	22.4	22.0
South Carolina	449	17.9	17.8	16.8	16.4	23.0	337	21.2	21.1	19.7	20.3	23.0
Georgia	442	15.6	16.4	14.6	14.7	21.0	205	17.4	17.9	18.7	-----	20.0
Florida	11	-----	-----	9.9	10.2	11.0	11	-----	-----	14.6	14.1	17.4
Kentucky	215	19.3	19.7	19.9	19.3	19.0	305	24.3	24.6	28.5	27.6	26.0
Tennessee	179	19.1	18.0	18.5	18.8	17.0	188	22.4	21.7	21.3	21.3	21.5
Alabama	101	16.1	15.9	13.0	14.0	17.5	70	17.7	18.3	17.0	16.0	17.5
Mississippi	48	17.8	16.6	15.7	16.1	19.0	41	19.2	18.6	18.2	18.0	20.0
Arkansas	207	19.6	21.7	18.2	18.6	20.0	155	22.9	24.4	23.4	21.0	22.0
Louisiana	35	17.5	15.0	13.6	12.4	17.5	44	19.1	19.5	23.2	24.3	24.5
Oklahoma	1,112	19.3	19.2	19.4	19.1	19.0	890	26.9	26.9	25.5	25.6	26.0
Texas	2,003	18.6	18.5	21.0	21.5	21.0	1,402	26.9	-----	24.8	25.3	25.5
Montana	596	38.2	37.3	39.9	40.0	40.0	554	35.5	35.3	36.4	35.7	36.5
Idaho	143	44.1	43.1	51.9	48.9	47.0	137	45.2	42.3	53.0	50.0	47.0
Wyoming	120	38.7	36.7	39.3	39.9	36.0	132	35.7	33.0	42.2	35.3	31.0
Colorado	189	36.6	34.3	38.9	30.2	29.0	193	40.5	37.5	37.3	36.2	31.0
New Mexico	30	28.8	26.9	35.1	28.8	22.0	36	22.3	21.6	31.2	32.3	20.0
Arizona	17	40.8	39.5	43.3	41.1	36.0	14	50.0	50.0	42.0	44.0	38.0
Utah	51	49.0	50.8	53.4	54.7	42.0	55	51.7	53.1	50.0	47.0	45.0
Washington	183	52.3	49.0	53.9	49.8	50.0	201	46.9	44.5	51.3	50.6	47.0
Oregon	310	38.9	35.6	-----	-----	34.0	304	38.3	36.3	40.8	36.9	36.0
California	147	-----	-----	-----	-----	28.5	154	-----	-----	36.4	34.4	34.5

[1] Crop reporting district or county averages weighted by acreage weights.

PRECISION OF THE SAMPLE AVERAGES

The samples of oats yields are nearly as stable as the samples of corn yields, with only a few States showing a difference of more than 2 bushels between the weighted averages of the township and field-aid samples. The greatest differences exist in the samples from the South Central and far Western States.

Table 13 presents for comparison: (1) the size of oats yield-per-acre sample, (2) the average yield, (3) standard deviation, (4) variation, and (5) probable error of the average yield obtained for several States. In about one-half the State samples shown in Table 13 the coefficient of variation is less than 30 per cent, but it reached 45 per cent in Missouri in 1927, when the yield was only about 18 bushels, and it reached 44 per cent in Texas in 1928. In Idaho, the standard deviation was almost double that of the other States, but the high yield of over 50 bushels per acre resulted in a coefficient of variation of less than 28 per cent. The probable error is less than a half bushel in practically all but the far Western States, where the dispersion is always large and the samples are small in size. The probable error was largest in California, in 1927, when there were only 66 reports, and in Idaho, in 1927, when there were only 91 reports. The relative probable error was less than 1 per cent in many of the States but exceeded 2 per cent in South Carolina, Texas, Idaho, and California.

TABLE 13.—*Oats: Yields per acre. Selected illustrations of size of sample measures of dispersion, and probable error*

State, year, and districts	Reports	Average yield (arithmetic mean)	Standard deviation of reported yields	Coefficient of variation	Probable error of the average yield or mean	Relative probable error
	Number	*Bushels*	*Bushels*	*Per cent*	*Bushels*	*Per cent*
Iowa: 1927	995	31.30	9.07	29.0	0.19	0.6
1	119	34.10	6.85	20.1	.42	1.2
2	111	35.00	6.55	18.7	.42	1.2
3	120	29.50	8.30	28.1	.51	1.7
4	108	32.60	6.10	18.7	.40	1.2
5	148	38.40	6.95	18.1	.39	1.0
6	88	32.70	6.90	21.1	.50	1.5
7	89	29.00	6.00	20.7	.43	1.5
8	114	24.00	9.35	39.0	.59	2.5
9	98	22.90	10.35	45.2	.71	3.1
Illinois: 1928	403	37.80	8.31	22.0	.28	.7
1	54	42.60	8.71	20.4	.80	1.9
3	46	42.30	6.82	16.1	.68	1.6
4	45	40.45	7.88	19.5	.79	2.0
4a	52	39.40	7.33	18.6	.69	1.8
5	59	37.90	7.13	18.8	.63	1.7
6	49	33.15	5.68	17.1	.55	1.7
6a	40	33.00	8.65	26.2	.92	2.8
7	29	34.15	6.58	19.3	.82	2.4
9	29	32.95	7.13	21.6	.89	2.7
North Dakota 1927	393	24.30	9.85	40.5	.34	1.4
1	67	27.60	8.28	30.0	.68	2.5
2	43	25.30	6.42	25.4	.66	2.6
3	75	17.70	6.80	38.4	.53	3.0
4	36	31.70	7.09	22.4	.80	2.5
5	30	19.60	10.08	51.4	1.24	6.3
6	25	16.20	5.49	33.9	.74	4.6
7	34	30.60	8.99	29.4	1.04	3.4
8	40	33.10	7.21	21.8	.77	2.3
9	43	17.60	8.17	46.4	.84	4.8
Ohio: 1928 [1]	440	36.01	9.04	25.1	.29	.8
Michigan: 1927	679	33.70	10.63	31.5	.28	.8
Minnestota: 1927	516	27.74	9.08	32.7	.27	1.0
Missouri: 1927	504	17.69	8.01	45.3	.24	1.4
Nebraska: 1928	295	32.65	8.45	25.9	.33	1.0
New York: 1927	146	35.30	8.60	24.4	.17	.5
Pennsylvania: 1927 [2]	829	36.91	8.36	22.6	.20	.5
South Carolina: 1927	183	21.60	9.20	42.6	.46	2.1
Texas: 1928	174	23.00	10.16	44.2	.52	2.[illegible]
Montana: 1927	168	39.80	12.24	30.8	.64	1.6
Washington: 1927	218	52.80	18.51	35.1	.85	1.6
California: 1927	66	31.37	12.20	38.9	1.01	[illegible]
Idaho: 1927	91	52.00	14.50	27.9	1.03	2.0
1925	122	50.40	14.00	27.8	.85	1.7
6	38	53.40	13.98	26.2	1.53	[illegible]
8	30	53.30	12.99	24.4	1.60	[illegible]

District stratification resulted in districts with smaller standard deviations than the deviations for the State in the three important oat States Iowa, Illinois, and North Dakota. This is to be expected, as oat yields are generally lower the farther south they are grown. The crop-reporting districts would tend to show the higher yields in the more northern districts, and this was the case in Iowa and Illinois.

The averages of the samples of oat yield are so stable that no increase in the size of sample or improvement in method of stratification and weighting would materially change the results in the larger States east of the Rocky Mountains. Even in the far Western States the sample seems to be somewhat more stable than is the case with some of the other crops.

BARLEY

Although barley is now primarily a feed crop it is not as well distributed over the country as corn or oats. Little barley is grown in the southern States. The important spring-wheat States are also the important barley States. The acreage of barley has been increasing rapidly over the Corn Belt during the last four or five years, and it has been difficult to maintain adequate acreage weights for use with yield-per-acre samples. The barley samples for 1927 and 1928, in Table 14, showed a surprisingly close agreement between the straight and weighted averages of the samples. It is not until the far Western States are reached or Texas and Oklahoma are considered, that the straight and weighted averages differ by more than 2 bushels, and even in these States the difference exceeds 2 bushels in only about one-half of the samples. The weighted averages from the township and field-aid samples checked within 1 or 2 bushels in most of the States west of the Rocky Mountains. In these Western States, where great differences exist and where the acreage of the crop and consequently of the samples obtained are very small, the two averages frequently differ by several bushels.

Table 15 presents for comparison (1) the size of barley yield-per-acre sample, (2) the average yield, (3) dispersion, (4) variation, and (5) probable error of the average yield obtained for several States. The coefficient of variation ranged from a low of 22 per cent in Minnesota in 1924 to 51 per cent in Nebraska in 1926, exceeding 40 per cent in only a few cases, usually in years of low average yields. The standard deviation for barley yields seldom exceeds 8 or 10 bushels. The probable error was less than 0.3 bushel in Iowa, North Dakota, and Minnesota, and exceeded 1 bushel only in States like Pennsylvania that have a small acreage. The relative probable error was as low as 1 per cent in Iowa and Minnesota. For 1925 and 1926 it exceeded 2 per cent in Nebraska, in Pennsylvania, where the sample was very small, and in California, where the dispersion was large.

TABLE 14.—*Barley: Averages of yields per acre computed from reports of crop correspondents, and the official estimate, by States, 1927 and 1928*

State	1927 Acreage	1927 Reported by the township list: Average (arithmetic mean)	1927 Reported by the township list: Weighted average[1]	1927 Reported by the field-aid list: Average (arithmetic mean)	1927 Reported by the field-aid list: Weighted average[1]	1927 Official estimate	1928 Acreage	1928 Reported by the township list: Average (arithmetic mean)	1928 Reported by the township list: Weighted average[1]	1928 Reported by the field-aid list: Average (arithmetic mean)	1928 Reported by the field-aid list: Weighted average[1]	1928 Official estimate
	1,000 acres	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*1,000 acres*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*
New York	188	29.5	30.0	30.6	30.7	29.0	169	27.3	27.6	27.7	28.2	27.5
Pennsylvania	21	27.0	27.2	27.0	27.7	28.0	29	29.4	30.8	27.1	27.4	27.0
Ohio	155	26.9	26.7	27.6	27.4	27.0	333	27.7	27.6	26.7	27.6	27.6
Indiana	35	25.4	24.1	23.5	23.5	23.8	94	25.6	25.6	23.9	23.0	24.0
Illinois	453	27.5	30.0	28.3	29.8	29.5	680	27.5	29.3	28.6	29.7	29.5
Michigan	186	27.3	27.2	29.4	29.0	28.5	270	29.5	29.6	30.7	30.7	30.0
Wisconsin	620	34.1	34.3	34.2	34.5	34.5	725	36.2	36.4	37.1	37.5	37.1
Minnesota	1,460	29.1	28.5	30.7	29.5	30.0	2,000	30.2	28.5	31.0	29.7	30.0
Iowa	454	31.6	31.6	31.8	31.9	31.4	802	32.7	33.2	33.2	34.1	33.5
Missouri	7	25.0	26.0	23.0	23.0	23.0	17	19.7	19.1	24.0	22.0	22.0
North Dakota	1,663	26.8	26.0	25.5	24.7	25.5	2,179	26.4	25.8	26.0	25.3	25.5
South Dakota	1,200	30.1	30.0	30.6	30.1	30.1	1,644	24.2	21.5	23.5	21.9	21.7
Nebraska	246	28.7	29.8	30.0	31.2	30.8	430	30.7	30.6	31.3	33.7	32.6
Kansas	452	18.8	17.1	17.6	14.6	12.6	633	25.9	25.7	28.3	28.5	27.9
Maryland	9			30.7	30.5	30.5	13			31.4	31.6	31.0
Virginia	13	26.0	26.3	26.0	25.6	26.0	14	30.0	30.2	30.5	30.5	29.0
North Carolina	20	22.0		25.1		24.0	32	21.8		25.4	28.2	23.0
Tennessee	42	18.3	17.6	21.0		19.0	21	24.3	23.6	22.0		20.0
Oklahoma	36	16.6	13.1	18.9	17.9	16.5	23	23.0	24.9	20.7	22.8	22.0
Texas	195	18.2	14.6	18.0	16.0	16.0	156	21.6	18.4	20.2	20.6	21.0
Montana	195	33.1	32.6	32.7	32.6	33.0	209	29.1	29.2	30.7	30.7	30.5
Idaho	129	40.3	40.7	49.5	45.6	44.0	144	36.4	35.4	49.0	47.0	43.0
Wyoming	59	33.6	34.8	36.9	37.9	34.0	77	33.1	30.4	33.5	34.3	30.0
Colorado	410	30.5	23.8	32.6	26.9	22.0	547	33.1	26.7	30.9	28.7	24.0
New Mexico	8	23.3	22.0	28.5	22.6	18.0	12	26.2	24.9	28.1	32.3	19.0
Arizona	20	33.8	34.0	35.9	36.4	35.0	17	40.0	40.0	38.0	39.0	38.0
Utah	30	46.3	47.5	48.9	52.7	47.0	34	52.4	50.1	52.0	52.9	49.0
Nevada	9	45.5	38.5	53.9	55.2	45.0	11	43.0	46.7	37.0	36.1	40.0
Washington	58	40.1	38.6	43.0	41.8	42.0	55	37.2	35.6	37.3	35.3	35.5
Oregon	91	38.9	38.9	35.5	35.4	35.0	105	34.4	34.5	36.0		35.0
California	994					27.5	1,044			31.4	30.4	30.5

[1] Crop reporting district or county averages weighted by acreage weights.

Stratification of the State into crop-reporting districts resulted in district samples with standard deviations materially smaller than those for the State as a whole, in both Iowa and North Dakota.

The samples of barley yields show less stability and the averages have less precision than do those of either oats or corn. This is to be expected as barley is a major crop in only a few States, such as Minnesota, North Dakota, and South Dakota. In some of the States with small acreage and small samples some increase in size of sample would undoubtedly improve the precision of the sample averages, but barley is of such minor importance as a crop in most of these States that it would hardly be worth while, considering the facilities available at present, to enlarge the sample.

TABLE 15.—*Barley: Yields per acre. Selected illustrations of size of sample, measures of dispersion, and probable error*

State, year, and district	Reports	Average yield (arithmetic mean)	Standard deviation of reported yields	Coefficient of variation	Probable error of the average yield, or mean	Relative probable error
	Number	*Bushels*	*Bushels*	*Per cent*	*Bushels*	*Per cent*
Iowa:						
1927	634	31.50	7.67	24.3	0.21	0.7
1	103	34.00	6.70	19.7	.45	1.3
2	94	34.60	6.61	19.1	.46	1.3
3	90	31.20	7.36	23.6	.52	1.7
4	78	31.70	6.90	21.8	.53	1.7
5	97	33.40	7.54	22.6	.52	1.6
6	58	29.00	7.30	25.2	.65	2.2
7	58	25.80	6.00	23.3	.53	2.1
8	41	28.50	8.94	31.4	.94	3.3
9	15	24.70	7.84	31.7	1.37	5.5
1926	478	31.00	8.75	28.2	.27	.9
1925	490	32.80	8.20	25.0	.25	.8
North Dakota:						
1927	401	26.80	8.05	30.0	.27	1.0
1	71	28.60	7.47	26.1	.60	2.1
2	37	27.80	7.59	27.3	.84	3.0
3	84	20.80	5.24	25.2	.39	1.9
4	33	32.20	9.62	29.9	1.13	3.5
5	32	25.50	7.22	28.3	.86	3.4
6	31	25.90	6.47	25.0	.78	3.0
7	31	30.30	8.28	27.3	1.00	3.3
8	35	31.10	6.67	21.4	.76	2.4
9	47	26.40	6.52	24.7	.64	2.4
Pennsylvania:						
1927 [1]	139	28.00	8.36	29.9	.48	1.7
1927	53	27.00	7.54	27.9	.70	2.6
1926	24	28.30	7.92	28.0	1.09	3.9
1925	29	26.10	8.55	32.8	1.07	4.1
Michigan:						
1927	333	29.40	8.77	29.8	.32	1.1
1925	226	24.80	8.11	32.7	.36	1.5
1921	309	18.00	7.75	43.1	.30	1.7
Minnesota:						
1927	489	30.70	8.31	27.1	.25	.8
1926	508	26.13	8.23	31.5	.25	1.0
1924	475	32.77	7.35	22.4	.23	.7
Nebraska:						
1928	174	31.26	8.40	26.9	.43	1.4
1927	172	30.06	7.05	23.5	.36	1.2
1926	123	21.00	10.70	51.0	.65	3.1
1925	130	23.05	8.60	37.3	.51	2.2
1924	154	25.61	7.60	29.7	.41	1.6
1923	234	29.04	8.50	29.3	.37	1.3
California:						
1927	167	27.55	7.68	27.9	.40	1.5
1926	174	28.02	11.33	40.4	.58	2.1
1925	139	29.68	11.02	37.1	.63	2.1
4	32	32.66	13.97	42.8	1.66	5.1
5	43	33.02	9.83	29.8	1.01	3.1
5a	39	26.93	8.73	32.4	.94	3.5

[1] Return from a special list of crop correspondents.

COTTON

REPRESENTATIVENESS

The township and field-aid samples for 1927 and 1928 are shown in Table 16. The straight and weighted averages checked within a few pounds in most of the important cotton States. The greatest differences occurred in the Mississippi samples for 1928. In Mississippi there is a great difference between the yield per acre of cotton in the so-called Delta section of the State (districts 1 and 4) and in the highland sections. Difficulty in obtaining a sufficient number of reporters in this Delta section means that in years when the Delta has a good crop of cotton, the weighted average is higher than the straight average. Difficulty in obtaining fully representative samples in New Mexico and Arizona means that the weighted average frequently differs considerably from the straight average. In these States, as with other crops, sample-data on cotton yields must be supplemented by other check information.

TABLE 16.—*Cotton: Averages of yields per acre computed from reports of crop correspondents, and the official estimate, by States, 1927 and 1928*

State	1927						1928					
		Reported by the township list		Reported by the field-aid list				Reported by the township list		Reported by the field-aid list		
	Acreage	Average (arithmetic mean)	Weighted average[1]	Average (arithmetic mean)	Weighted average[1]	Official estimate	Acreage	Average (arithmetic mean)	Weighted average[1]	Average (arithmetic mean)	Weighted average[1]	Official estimate
	1,000 acres	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*1,000 acres*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Missouri	291	188	189	168	164	188	334	157	157	189	194	210
Virginia	64	210	210	218	217	230	79	264	264	263	281	265
North Carolina	1,728	227	226	227	228	238	1,860	192	192	211	211	215
South Carolina	2,356	139	134	148	142	148	2,361	134	133	145	143	147
Georgia	3,413	153	144	162	156	154	3,728	136	128	140	133	132
Florida	64	114	113	130	129	126	95	107	107	94	98	97
Tennessee	965	172	162	167	168	178	1,107	174	178	178	175	185
Alabama	3,166	171	167	176	177	180	3,534	147	140	145	142	150
Mississippi	3,340	189	196	193	190	194	4,029	163	172	163	170	175
Arkansas	3,048	150	152	135	145	157	3,681	147	151	144	152	162
Louisiana	1,542	165	163	177	178	170	1,990	150	160	160	171	166
Oklahoma	3,601	108	124	131	131	138	4,243	120	121	127	127	136
Texas	16,176	117	119	125	127	129	17,743	137	133	131	131	138
New Mexico	95	316	323	331	361	352	117	292	335	343	362	360
Arizona	139	310	315	373	372	315	200	388	349	436	421	357
California	138	478	478	349	352	340	218	418	418	414	420	378

[1] Crop-reporting district or county averages weighted by acreage.

BIAS

The greatest difficulty encountered in obtaining the average yield per acre of cotton is the presence of a large degree of cash-crop bias in the individual reports. With both the acreage and yield of cotton there is always a marked tendency for crop reporters and others to underestimate acreage, yield, or production, until after the crop leaves the farmers' hands. Table 17 shows the comparison of the reported yields per acre of cotton lint from both the township and field-aid lists for three successive months during the season of harvest—October, November, and December—and the returns from an inquiry sent out in March after a large proportion of the cotton has left farmers' hands.

TABLE 17.—*Cotton lint: Weighted averages of yields per acre reported by crop correspondents and the official estimate, by States and by months, crops of 1927 and 1928*

State and list	Crop of 1927 as reported in—					Crop of 1928 as reported in—				
	October,[1] 1927	November, 1927	December, 1927	March 1928	Final	October,[1] 1928	November, 1928	December, 1928	March 1929	Final
	Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Missouri:										
Township	174	151	189	204	------	176	162	157	186	------
Field aid	148	168	164	219	------	185	189	194	230	------
Estimate	------	------	------	------	188	------	------	------	------	210
Virginia:										
Township	199	230	210	257	------	237	248	264	302	------
Field aid	231	247	217	237	------	227	211	281	279	------
Estimate	------	------	------	------	230	------	------	------	------	265
North Carolina:										
Township	189	200	226	251	------	187	195	192	216	------
Field aid	196	206	228	258	------	195	194	211	240	------
Estimate	------	------	------	------	238	------	------	------	------	215
South Carolina:										
Township	113	116	134	165	------	132	126	133	147	------
Field aid	124	129	142	157	------	135	127	143	162	------
Estimate	------	------	------	------	148	------	------	------	------	147
Georgia:										
Township	127	137	144	168	------	117	117	128	141	------
Field aid	135	146	156	178	------	115	117	133	146	------
Estimate	------	------	------	------	154	------	------	------	------	132
Florida:										
Township	141	113	113	148	------	80	109	107	103	------
Field aid	123	145	129	187	------	91	95	98	98	------
Estimate	------	------	------	------	126	------	------	------	------	97
Tennessee:										
Township	131	151	162	184	------	138	146	178	195	------
Field aid	135	158	168	194	------	136	142	175	188	------
Estimate	------	------	------	------	178	------	------	------	------	185
Alabama:										
Township	147	154	167	191	------	114	126	140	157	------
Field aid	142	158	179	203	------	125	127	142	166	------
Estimate	------	------	------	------	180	------	------	------	------	150
Mississippi:										
Township	153	170	196	222	------	144	158	172	191	------
Field aid	165	174	190	224	------	139	149	170	192	------
Estimate	------	------	------	------	194	------	------	------	------	175
Arkansas:										
Township	135	146	152	179	------	130	138	151	169	------
Field aid	130	131	145	169	------	131	141	152	165	------
Estimate	------	------	------	------	157	------	------	------	------	162
Louisiana:										
Township	132	149	163	183	------	130	143	160	178	------
Field aid	148	158	178	205	------	133	154	171	187	------
Estimate	------	------	------	------	170	------	------	------	------	166
Oklahoma:										
Township	97	113	124	139	------	99	108	121	138	------
Field aid	101	114	131	148	------	99	109	127	144	------
Estimate	------	------	------	------	138	------	------	------	------	136
Texas:										
Township	109	112	119	132	------	117	128	133	142	------
Field aid	110	114	127	139	------	117	128	131	145	------
Estimate	------	------	------	------	129	------	------	------	------	138
New Mexico:										
Township	329	268	323	479	------	240	385	335	------	------
Field aid	352	382	361	387	------	350	364	362	378	------
Estimate	------	------	------	------	352	------	------	------	------	360
Arizona:										
Township	405	343	315	379	------	291	329	349	------	------
Field aid	------	318	372	------	------	397	402	421	421	------
Estimate	------	------	------	------	315	------	------	------	------	357
California:										
Township	366	358	478	380	------	309	326	418	346	------
Field aid	371	378	352	440	------	352	402	420	520	------
Estimate	------	------	------	------	340	------	------	------	------	378
United States:										
Estimate	------	------	------	------	154.5	------	------	------	------	152.9

[1] Probable yield as reported on Oct. 1.

One might expect a low probable yield to be reported on the first of October, when the crop has not been harvested to any appreciable extent, as in most of the States there is always a possibility that bad weather will prevent or retard the picking and maturing of cotton after that date. In practically all States in which cotton is an important crop the reported yields were higher for each successive inquiry, the highest being reported in March of the following year. It is possible that the crop reporter overestimates the yield in March, for that is the time of the year when farmers, obtaining credit for the next year's crop, are inclined to be optimistic concerning their ability to grow cotton. This optimism may result in reporting yields somewhat above the facts.

Fortunately there is a better check on the production of cotton than of any other crop; the cotton ginnings are ascertained through periodic personal visits to gins by special agents of the Bureau of the Census. Although it is known that there is a large degree of bias in sample data on both cotton acreage and cotton yield, it is extremely difficult to determine just how much of this bias occurs in the yield reports and how much in the acreage reports. Development of more refined methods of determining acreage changes will make it possible to solve this problem.

PRECISION OF THE SAMPLE AVERAGES

The weighted averages from the township and the field-aid samples checked fully as well as in the case of other major crops in 1927 and 1928. The greatest differences between these two samples occur in the less important cotton States, Missouri, Virginia, and Florida, and in the far Western States, where conditions are extremely variable or the sample is very small. No increase in the number of reports is likely to change materially the averages obtained from the present lists of crop reporters. The matter of bias can not be corrected by increasing the size of sample.

Table 18 presents for comparison (1) the size of cotton yield-per-acre samples, (2) the average yield, (3) dispersion, (4) variation, and (5) probable error of the average yield obtained for several States. Samples of cotton yield show greater dispersion than do most other samples of yield per acre. The coefficient of variation is seldom less than 35 per cent, and in a State like Oklahoma, in 1927, the coefficient of variation was 80 per cent. The probable error of cotton-yield samples was usually below 2 pounds in Mississippi, Georgia, and Texas for the years studied. The probable error exceeded 3 pounds in South Carolina, where the sample is smaller than in most States. The relative probable error was about 1 per cent in Georgia, but was more than 2 per cent in some of the other States, depending largely on the size of the sample.

The crop reporting district method of stratifying cotton yields materially reduced the probable error of the resulting weighted averages. The district samples showed, on an average, smaller standard deviations than did the sample for the State as a whole. In Oklahoma, for example, the standard deviation for the State in 1927 was 93 pounds, whereas four of the district samples showed a standard deviation of less than 50 pounds.

TABLE 18.—*Cotton: Yields per acre. Selected illustrations of size of sample, measures of dispersion, and probable error*

State, year, and district	Reports	Average yield (arithmetic mean)	Standard deviation of reported yields	Coefficient of variation	Probable error of the average yield or mean	Relative probable error
	Number	*Pounds*	*Pounds*	*Per cent*	*Pounds*	*Per cent*
Georgia:						
1927 [1]	664	166	65.00	39.2	1.70	1.0
1927 [2]	759	154	60.20	39.1	1.47	1.0
1	103	181	53.40	29.5	3.55	2.0
2	119	193	66.70	34.6	4.12	2.1
3	68	159	52.90	33.3	4.32	2.7
4	153	143	51.20	35.8	2.79	2.0
5	119	133	53.80	40.5	3.33	2.5
6	54	120	38.80	32.3	3.56	3.0
7	57	148	51.30	34.7	4.65	3.1
8	58	150	57.80	38.5	5.12	3.4
9	28	129	66.40	51.5	8.47	6.6
1927 [3]	568	139	53.10	38.2	1.50	1.1
1926 [3]	474	164	56.50	34.5	1.75	1.1
1	51	171	52.70	30.8	4.98	2.9
2	79	148	49.70	33.6	3.77	2.5
3	52	143	44.70	31.3	4.18	2.9
4	89	176	57.10	32.4	4.08	2.3
5	66	165	59.70	36.2	4.96	3.0
6	35	183	69.40	37.9	7.91	4.3
7	39	166	42.50	25.6	4.59	2.8
8	44	158	46.70	29.6	4.75	3.0
1926 [2]	532	150	54.20	36.1	1.58	1.1
Mississippi:						
1927 [4]	625	223	79.49	35.6	2.14	1.0
1927 [1]	637	196	69.55	35.5	1.86	1.0
1923 [1]	285	73	42.50	58.2	1.70	2.3
Oklahoma:						
1927 [1]	376	116	93.00	80.2	3.24	2.8
3	30	81	38.10	47.0	4.69	5.8
4	39	186	99.60	53.5	10.77	5.8
5	83	87	49.40	56.8	3.66	4.2
6	43	48	42.00	87.5	4.32	9.0
7	94	214	76.50	35.7	5.32	2.5
8	55	49	54.30	110.8	4.94	10.1
9	26	57	47.10	82.6	6.23	10.9
1926 [1]	292	172	85.50	49.7	3.37	2.0
2	18	180	77.50	43.1	12.33	6.8
3	14	137	54.00	39.4	9.74	7.1
4	35	247	90.00	36.4	10.25	4.1
5	59	179	68.10	38.0	5.98	3.3
6	28	107	54.60	51.0	6.96	6.5
7	71	123	75.80	61.6	6.06	4.9
8	51	126	65.40	51.9	6.18	4.9
9	16	86	47.00	54.7	7.93	9.2
1924 [1]	219	177	60.30	34.1	2.75	1.6
1924 [2]	234	170	57.70	33.9	2.54	1.5
South Carolina:						
1927 [1]	257	152	73.60	48.4	3.10	2.0
1926 [1]	117	166	78.20	47.1	4.87	2.9
1925 [1]	99	146	48.00	32.9	3.25	2.2
1924 [1]	132	161	61.10	38.0	3.59	2.2
Alabama:						
1928 [1]	281	149	76.00	51.0	3.06	2.1
1927 [1]	404	175	67.00	38.3	2.25	1.3
Texas:						
1928 [1]	1,245	144	64.94	45.1	1.24	.9
1927 [1]	1,336	127	58.36	46.0	1.08	.9
1926 [1]	567	143	60.12	42.0	1.70	1.2
1925 [1]	540	106	60.78	57.3	1.76	1.7

[1] As reported in December.
[2] As reported in November.
[3] As reported in October.
[4] As reported in March, 1928.

There is probably no crop on which more inquiries are sent out regarding the yield per acre than on cotton. Not only are yields obtained from the regular township and field-aid reporters, but lists of ginners and bankers, and other special lists, are circularized with cotton-yield questionnaires. The final estimate of the yield of cotton per acre is determined in part on the basis of the yield per acre as derived by dividing the production of cotton shown by the ginning reports, by the estimate of acreage harvested in each State. A large degree of cash crop bias makes it almost impossible until after the crop has left the farmer's hands, to secure a sample on yield per acre that can be used as an estimate of the actual yield. Not until a more satisfactory method of estimating acreage changes has been developed will it be possible definitely to measure the bias of the cotton-yield samples.

TOBACCO

Tobacco is grown in rather limited areas. In any one year dispersion in yield per acre of tobacco in a State is due not only to geographic distribution of weather factors, but also to differences in soils on which the tobacco is grown and to the various types of tobacco produced. In Kentucky, for example, six types of tobacco are grown in more or less sharply defined districts, usually referred to as type districts. As a result of this diversity in the factors that determine yield per acre, farmers report tobacco yields that range from 300 to 1,700 pounds or more per acre.

REPRESENTATIVENESS

Table 19 shows the State average yields per acre of tobacco as obtained from the township and the field-aid samples. The straight and weighted averages differed considerably in some of the States in which the production of tobacco is highly localized; in fact, county weights are frequently used in place of district weights with such a highly localized crop as tobacco. Although the difference between the straight and weighted averages in the same sample may amount to anywhere from 1 pound to several hundred pounds, it is necessary to keep in mind that the true average yield of tobacco on a State basis may be anywhere from 500 to 1,400 pounds, depending on the State and on the type of tobacco grown. On the whole, the tobacco samples show no larger differences between straight and weighted averages than do the samples of most other crops of similar acreage. In Table 19 States with acreages less than 10,000 have been included.

TABLE 19.—*Tobacco: Averages of yields per acre computed from reports of crop correspondents, and the official estimate, by States, 1927 and 1928*

State	1927						1928					
		Reported by the township list		Reported by the field-aid list				Reported by the township list		Reported by the field-aid list		
	Acreage	Average (arithmetic mean)	Weighted average[1]	Average (arithmetic mean)	Weighted average[1]	Official estimate	Acreage	Average (arithmetic mean)	Weighted average[1]	Average (arithmetic mean)	Weighted average[1]	Official estimate
	1,000 acres	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*1,000 acres*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Massachusetts	7	------	------	1,383	1,399	1,223	8	------	------	1,411	1,376	1,245
Connecticut	24	------	------	1,255	1,193	1,223	25	------	------	1,311	1,205	1,190
New York	1	1,239	1,272	1,250	------	1,200	1	1,080	------	1,200	------	1,275
Pennsylvania	34	1,329	1,336	1,330	1,329	1,360	37	1,327	1,335	1,395	1,380	1,340
Ohio	30	851	832	826	828	819	42	733	744	869	859	800
Indiana	8	768	781	758	740	760	14	627	826	820	812	820
Wisconsin	31	1,023	1,025	990	1,010	1,070	37	1,281	1,324	1,215	1,255	1,325
Missouri	4	957	1,435	818	1,010	1,100	4	880	1,157	825	940	1,100
Maryland	32	------	------	818	818	818	31	------	------	752	739	700
Virginia	177	792	731	732	703	723	181	------	------	716	640	600
West Virginia	4	794	794	822	820	775	7	------	------	756	752	750
North Carolina	659	692	693	720	708	737	728	627	628	636	632	651
South Carolina	104	677	678	765	756	737	148	542	545	553	549	556
Georgia	82	722	759	734	723	725	122	643	662	673	712	690
Kentucky	290	726	718	705	707	697	388	737	742	756	754	775
Tennessee	88	825	787	776	752	780	109	858	782	736	742	787
Louisiana	1	------	------	400	------	400	1	------	------	405	------	405

[1] Crop-reporting district or county averages weighted by acreage weights.

BIAS

With tobacco, a reliable check on production is obtained through the records of sales and is of material assistance in rectifying not only the estimates of production, but also those of acreage and yield per acre. There is some tendency toward cash-crop bias in some States. Tobacco is such a highly localized crop that in all except the States of largest production the official estimates are more likely to be based on special information obtained by the State statistician from personal contacts with the trade, than on sample data reported by the regular correspondents.

PRECISION OF THE SAMPLE AVERAGES

The methods of handling the yield samples for tobacco vary considerably from one State to another, depending on local conditions. Consequently the averages from the field lists of crop correspondents are not always comparable with the averages from the township lists, and such a comparison is not particularly significant as an indication of the stability of two samples drawn from the same universe, except in the States with the greatest acreage. In 1927 the two weighted averages from the separate samples were 693 and 708 pounds in North Carolina, 718 and 707 pounds in Kentucky, and 731 and 703 pounds in Virginia. In 1928 these averages were 628 and 632 pounds in North Carolina and 742 and 754 pounds in Kentucky. The two lists were merged in Virginia in 1928. These three States have about 70 per cent of the tobacco acreage of this country, whereas the remaining 30 per cent is distributed among 14 other States.

TABLE 20.—*Tobacco: Yields per acre. Selected illustrations of size of sample, measures of dispersion, and probable error*

State, year, district, and type	Reports	Average yield (arithmetic mean)	Standard deviation of reported yields	Coefficient of variation	Probable error of the average yield or mean	Relative probable error
	Number	*Pounds*	*Pounds*	*Per cent*	*Pounds*	*Per cent*
Kentucky:						
1928	246	763	163.6	21.4	7.0	0.9
1927	411	708	184.4	26.0	6.1	.9
1927	452	710	177.3	25.0	5.6	.8
1	79	708	166.0	23.4	12.6	1.8
2	76	717	204.8	28.6	15.8	2.2
3	30	740	160.0	21.6	19.7	2.7
5	88	717	197.0	27.5	14.2	2.0
7	50	738	163.6	22.2	15.6	2.1
7a	64	703	123.8	17.6	10.4	1.5
8	60	677	180.0	26.6	15.7	2.3
Clarksville and Hopkinsville	32	678	131.5	19.4	15.7	2.3
Paducah	44	736	164.0	22.3	16.7	2.3
Henderson	29	734	153.7	20.9	19.2	2.6
Green River	23	691	141.0	20.4	19.8	2.9
One sucker	35	731	116.5	15.9	13.3	1.8
Burley	289	704	164.3	23.3	6.5	.9
1926	461	875	206.2	23.6	6.5	.7
1926	518	870	194.0	22.3	5.7	.7
1	87	936	228.4	24.4	16.5	1.8
2	91	837	191.4	22.9	13.5	1.6
3	32	856	174.8	20.4	20.8	2.4
5	100	903	171.2	19.0	11.5	1.3
7	68	812	154.0	19.0	12.6	1.6
7a	75	868	164.0	18.9	12.8	1.5
8	58	878	174.3	19.9	15.4	1.8
Clarksville and Hopkinsville	34	829	127.5	15.4	14.8	1.8
Paducah	52	788	142.4	18.1	13.2	1.7
Henderson	27	881	172.2	19.5	22.3	2.5
Green River	28	907	146.1	16.1	18.6	2.1
One sucker	39	895	188.0	21.0	20.3	2.3
Burley	338	864	207.8	24.1	7.6	.9
1925	250	753	173.0	23.0	7.4	1.0
Pennsylvania:						
1928	70	1,394	213.1	15.3	17.2	1.2
1927	21	1,330	204.6	15.4	30.1	2.3
1926	16	1,331	299.4	22.5	50.5	3.8
1925	22	1,428	302.1	21.2	43.4	3.0
Virginia:						
1927	113	771	195.0	25.3	12.4	1.6
1926	94	813	296.0	36.4	20.6	2.5
1924	96	794	336.0	42.3	23.1	2.9
1921	83	609	216.0	35.5	16.0	2.6
South Carolina:						
1927	27	759	128.5	16.9	16.7	2.2
1926	27	678	147.5	21.8	19.1	2.8
Georgia:						
1927	136	740	221.0	29.9	12.8	1.7
1927	25	714	156.0	21.8	21.0	2.9
1926	62	771	167.0	21.7	14.3	1.9
1926	25	741	152.0	20.5	20.5	2.8
1925	183	697	204.0	29.3	10.2	1.5
1924	75	748	190.0	25.4	14.8	2.0

Table 20 presents for comparison (1) the size of tobacco yield-per-acre sample, (2) the average yield, (3) dispersion, (4) variation, and (5) probable error of the average yield obtained for several States. The coefficient of variation in samples of tobacco yield seldom exceeds 30 per cent and in some cases is below 20 per cent. The probable error in a State that has a large sample, like Kentucky, seldom exceeds 6 or 7 pounds for the State as a whole, but in most States the sample of tobacco yields is small, frequently no more than 25 observations; consequently the probable error may range from 10 pounds to as much as 50 pounds. In dealing with a crop like tobacco the relative probable error is undoubtedly the more significant basis for comparison. In Kentucky the relative probable error was usually less than 1 per cent, and even in some of the States with a small sample the relative probable error seldom exceeded 3 per cent.

STRATIFICATION

A comparison of the standard deviation obtained from the crop-reporting districts and the standard deviation obtained from the type-districts shows that there is somewhat less dispersion when the sample is stratified by type districts than by the regular crop-reporting districts. With a highly localized crop, such as tobacco, made up of from one to several types in a given State, there is no question but that a special system of stratification should be used, which would take into consideration types as well as geographic location. Such a method of stratification would tend to improve the precision of the average yield and result in estimates not only more reliable, but far more useful to persons interested in tobacco.

POTATOES

REPRESENTATIVENESS

Potatoes are grown in practically every State, but in many States the acreage is small. The straight and weighted averages of potato samples, as shown in Table 21, checked within 10 bushels in a surprisingly large number of States. Only in an occasional sample of potato yields per acre did these two averages differ by more than 20 bushels; most of these occurred in the far Western States.

TABLE 21.—*Potatoes: Averages of yields per acre computed from reports of crop correspondents, and the official estimate, by States, 1927 and 1928*

State	1927						1928					
	Acreage	Reported by the township list: Average (arithmetic mean)	Reported by the township list: Weighted average[1]	Reported by the field-aid list: Average (arithmetic mean)	Reported by the field-aid list: Weighted average[1]	Official estimate	Acreage	Reported by the township list: Average (arithmetic mean)	Reported by the township list: Weighted average[1]	Reported by the field-aid list: Average (arithmetic mean)	Reported by the field-aid list: Weighted average[1]	Official estimate
	1,000 acres	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*1,000 acres*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*
Maine	161	------	------	173	194	232	179	------	------	163	194	220
New Hampshire	12	------	------	146	154	150	12	------	------	131	138	138
Vermont	21	------	------	161	157	155	21	------	------	149	151	142
Massachusetts	14	------	------	102	100	100	15	------	------	112	103	108
Connecticut	15	------	------	100	98	109	17	------	------	122	129	130
New York	270	96	108	92	106	106	284	110	117	104	113	114
New Jersey	57	144	154	140	167	161	57	------	------	163	162	160
Pennsylvania	220	117	113	117	117	120	246	125	126	134	138	130
Ohio	116	105	102	105	105	105	123	104	100	99	97	98
Indiana	53	107	105	96	98	95	61	109	109	104	109	109
Illinois	64	81	82	87	86	84	70	116	114	109	107	110
Michigan	289	84	83	83	81	80	306	115	115	119	119	117
Wisconsin	260	91	91	91	91	92	278	121	117	116	113	115
Minnesota	328	106	102	104	100	101	354	119	117	118	110	110
Iowa	75	84	83	84	84	82	81	134	132	138	138	135
Missouri	68	84	85	81	83	83	85	121	120	115	112	121
North Dakota	113	114	105	112	101	102	141	107	109	103	104	105
South Dakota	60	110	112	116	119	115	67	85	93	84	88	90
Nebraska	84	96	100	102	107	106	105	94	90	97	95	96
Kansas	49	95	97	90	96	110	54	116	125	125	130	140
Maryland	43	------	------	117	122	122	47	------	------	107	115	115
Virginia	130	105	123	106	115	152	151	------	------	100	92	143
West Virginia	52	116	117	110	112	113	60	------	------	130	125	125
North Carolina	72	99	87	88	86	102	95	94	87	84	84	111
South Carolina	29	68	91	74	------	105	36	65	83	71	------	113
Georgia	17	80	78	69	70	77	22	68	69	82	------	76
Kentucky	52	89	90	89	92	91	57	101	99	104	108	105
Tennessee	39	92	92	87	88	88	43	98	100	92	91	95
Alabama	33	81	72	62	65	75	38	82	83	78	78	74
Mississippi	12	78	72	80	77	78	15	87	95	80	85	89
Arkansas	29	76	77	65	61	68	36	77	76	64	61	75
Louisiana	41	65	45	68	61	65	41	88	61	67	63	70
Oklahoma	45	60	65	62	59	65	63	74	72	72	66	80
Texas	35	63	69	56	69	66	39	75	71	53	60	69
Montana	36	148	151	135	136	135	37	112	112	106	112	115
Idaho	115	186	214	218	211	212	116	147	174	167	168	170
Wyoming	17	151	144	142	142	137	21	107	110	113	117	112
Colorado	96	128	145	136	167	150	110	102	134	104	120	122
Utah	22	168	171	157	154	135	23	162	155	185	197	144
Washington	79	152	166	165	198	170	67	126	149	112	113	135
Oregon	52	135	125	116	116	120	52	122	110	132	142	120
California	52	------	------	124	153	153	56	------	------	131	138	138

[1] Crop reporting district or county averages weighted by acreage.

BIAS

In some of the strictly commercial areas there is definite evidence of cash-crop bias. The final estimates of yields per acre of potatoes in Maine are generally many bushels higher than the averages of the combined field-aid and township samples. In Maine, the car-lot shipments of potatoes furnish a valuable basis for determining the total production of potatoes in that State. In Virginia, the official estimates of yield per acre run much higher than do the sample averages. A large part of the potatoes of Virginia are grown in concentrated commercial districts on each side of Chesapeake Bay, and ... a check on production estimates. There

seems to be less evidence of cash-crop bias in reports from the far Western States or from the Central States of Michigan, Wisconsin, and Minnesota.

PRECISION OF SAMPLE AVERAGES

The weighted averages from the two samples, township and field-aid, checked within 10 bushels in practically all States east of the Rocky Mountains. As might be expected, some rather wide differences were shown in the far Western States. Table 22 presents a comparison of (1) the size of yield-per-acre sample, (2) the average yield, (3) dispersion, (4) variation, and (5) probable error of the average yield obtained for several States. The coefficient of variation for potato yields was higher than for the yield samples of most other crops. In very few cases did the sample have a dispersion of less than 40 per cent, and frequently the dispersion reached 50 and 60 per cent, and in the State of Washington in 1924 the coefficient of variation was 81 per cent. The probable error in the important potato States was not far from 1 bushel, while in the far Western States Idaho and Washington, it was from 6 to 8 bushels. The relative probable error is a more satisfactory basis for comparison because of the wide difference in yields as between States. The relative probable error of samples of potato yield was not far from 1 per cent in New York, Michigan, and Minnesota, whereas in North Dakota the relative probable error was slightly more than 2 per cent and reached as much as 6 per cent in Washington in 1924.

TABLE 22.—*Potatoes: Yields per acre. Selected illustrations of size of sample, measures of dispersion, and probable error*

State, year, and district	Reports	Average yield (arithmetic mean)	Standard deviation of reported yields	Coefficient of variation	Probable error of the average yield, or mean	Relative probable error
	Number	*Bushels*	*Bushels*	*Per cent*	*Bushels*	*Per cent*
New York:						
1927	1,824	101.50	54.40	53.6	.86	0.8
1925[1]	1,086	79.00	41.60	52.7	.85	1.1
2	70	70.70	38.00	53.7	3.06	4.3
3	30	71.00	38.20	53.8	4.70	6.6
4	265	73.50	34.60	47.1	1.43	1.9
5	231	74.00	45.10	60.9	2.00	2.7
6	113	59.10	29.10	49.2	1.85	3.1
7	147	87.80	37.40	42.6	2.08	2.4
8	120	80.80	30.60	37.9	1.88	2.3
9	81	92.80	47.30	51.0	3.54	3.8
9a	29	184.10	46.70	25.4	5.84	3.2
1924	745	138.10	55.50	40.2	1.37	1.0
New Jersey:						
1928	211	155.59	59.30	38.1	2.75	1.8
2	47	107.45	52.70	49.0	5.18	4.8
5	81	175.43	57.10	32.5	4.28	2.4
8	83	163.49	49.30	30.2	3.65	2.2
1926	179	144.59	61.40	42.5	3.10	2.1
2	52	135.00	59.60	44.1	5.58	4.1
5	64	154.37	60.70	39.3	5.12	3.3
8	63	142.54	62.20	43.6	5.28	3.7
Pennsylvania:						
1927[1]	826	125.00	57.08	45.7	1.34	1.1
1927	404	117.00	50.83	43.4	1.71	1.5
1926	342	108.00	42.85	39.7	1.56	1.4
1925	361	121.00	44.20	36.5	1.57	1.3
Montana:						
1927	111	128.28	67.60	52.7	4.33	3.4
1926	144	90.84	29.90	23.0	1.17	1.3

[1] Return from a special list of crop correspondents.

Table 22.—*Potatoes: Yields per acre. Selected illustrations of size of sample, measures of dispersion, and probable error*—Continued

State, year, and district	Reports	Average yield (arithmetic mean)	Standard deviation of reported yields	Coefficient of variation	Probable error of the average yield, or mean	Relative probable error
	Number	*Bushels*	*Bushels*	*Per cent*	*Bushels*	*Per cent*
Idaho:						
1927	94	222.90	82.10	36.8	5.71	2.6
6	27	209.10	55.90	26.7	7.25	3.5
8	40	299.10	74.90	25.0	7.99	2.7
1926	72	205.50	78.85	38.4	6.26	3.0
1925	89	201.70	85.60	42.4	6.12	3.0
6	28	221.40	70.65	31.9	9.01	4.1
8	22	268.20	94.80	35.3	13.63	5.1
Washington:						
1927	135	178.00	111.65	62.7	6.48	3.6
1926	103	145.00	93.35	64.4	6.20	4.3
1925	78	136.00	96.15	70.7	7.34	5.4
1924	83	132.00	106.60	80.8	7.89	6.0
Iowa:						
1927 [2]	714	81.15	39.93	49.2	1.01	1.2
1	103	99.80	39.17	39.2	2.60	2.6
2	85	91.30	35.97	39.4	2.63	2.9
3	63	68.60	36.29	52.9	3.08	4.5
4	83	79.50	36.34	45.7	2.69	3.4
5	137	85.11	44.89	52.7	2.59	3.0
6	60	75.66	35.04	46.3	3.05	4.0
7	79	66.58	35.25	52.9	2.67	4.0
8	48	72.50	36.88	50.9	3.59	5.0
9	56	72.14	38.11	52.8	3.44	4.8
1926	630	76.10	35.80	47.0	.96	1.3
1925	664	56.08	31.01	55.3	.81	1.4
North Dakota:						
1927	483	111.00	45.75	41.2	1.40	1.3
1	86	123.00	49.25	40.0	3.58	2.9
2	48	125.00	45.00	36.0	4.38	3.5
3	94	92.00	32.50	35.3	2.26	2.5
4	47	119.00	50.75	42.6	4.99	4.2
5	23	98.00	40.25	41.1	5.66	5.8
6	37	98.00	26.00	26.5	2.88	2.9
7	46	120.00	55.75	46.5	5.55	4.6
8	49	114.00	51.25	45.0	4.94	4.3
9	53	116.00	38.75	33.4	3.59	3.1
1926	261	75.00	42.25	56.3	1.76	2.3
1923	186	82.50	38.50	46.7	1.90	2.3
1920	184	76.80	38.50	50.1	1.92	2.5
Virginia:						
1927	209	107.00	48.20	45.0	2.25	2.1
1926	153	77.00	39.90	51.8	2.18	2.8
1924	199	89.00	46.40	52.1	2.22	2.5
1921	220	67.00	35.90	53.6	1.63	2.4
Minnesota:						
1927	558	104.17	40.49	38.9	1.16	1.1
1926	546	96.61	42.90	44.4	1.24	1.3
1924	436	136.87	52.03	38.0	1.68	1.2
Illinois:						
1927	188	87.00	41.10	47.2	2.02	2.3
1926	207	85.00	43.00	50.6	2.02	2.4
Michigan:						
1927	562	82.70	35.36	42.8	1.01	1.2
1926	634	122.30	47.54	38.9	1.27	1.0
1925	554	107.00	41.57	38.9	1.19	1.1

[2] As reported in November.

STRATIFICATION

Only about one-half of the districts in the three States for which district data are available—New York, North Dakota, and Iowa—showed smaller standard deviations than the State as a whole. A separation of commercial districts from noncommercial districts would be the most important step toward the stratification of a State into more homogeneous districts, as commercial districts usually have higher yields per acre than do noncommercial districts. To arrange special districts for potatoes would undoubtedly materially improve the homogeneity of the districts, render the sample more representative, and increase the precision of the weighted average for the States.

SWEETPOTATOES

Sweetpotatoes are primarily a southern crop, for in only three northern States—New Jersey, Illinois, and Missouri—are 10,000 acres or more grown. In only a few scattered cases (Table 23) did the straight average of the samples differ from the weighted average by more than 10 bushels, and seldom did the weighted average from the separate samples show a difference of more than 10 or 15 bushels. Throughout the South sweetpotatoes are grown primarily for home use, although there are important commercial districts in such States as New Jersey, Virginia, and Maryland. Generally speaking, however, sweetpotato acreage is fully as well distributed in the Southern States as is the potato acreage in the Northern States.

Table 23.—*Sweetpotatoes: Averages of yields per acre computed from reports of crop correspondents, and the official estimate, by States, 1927 and 1928*

State	1927						1928					
		Reported by the township list		Reported by the field-aid list				Reported by the township list		Reported by the field-aid list		
	Acreage	Average (arithmetic mean)	Weighted average [1]	Average (arithmetic mean)	Weighted average [1]	Official estimate	Acreage	Average (arithmetic mean)	Weighted average [1]	Average (arithmetic mean)	Weighted average [1]	Official estimate
	1,000 acres	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*1,000 acres*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*
New Jersey	15	126	128	128	126	126	15	-----	-----	130	138	145
Illinois	10	112	97	110	107	103	10	101	101	111	97	98
Missouri	12	110	109	114	-----	112	11	112	110	100	-----	105
Maryland	11	-----	-----	132	144	144	10	-----	-----	144	152	150
Virginia	43	115	134	116	138	135	44	-----	-----	99	112	144
North Carolina	89	123	114	116	118	114	80	104	101	96	93	98
South Carolina	53	96	98	100	102	100	49	89	92	83	83	86
Georgia	132	81	86	75	76	80	119	85	86	89	86	86
Florida	29	-----	-----	95	92	92	28	-----	-----	94	88	88
Kentucky	16	99	99	87	85	93	14	87	88	89	89	89
Tennessee	48	103	104	97	97	98	41	105	103	92	88	95
Alabama	78	93	94	94	100	98	70	109	111	100	100	93
Mississippi	69	111	115	110	112	112	55	110	118	103	107	110
Arkansas	38	116	117	114	115	116	28	104	100	84	83	90
Louisiana	99	101	98	90	102	98	74	104	91	93	90	90
Oklahoma	23	116	109	108	106	106	20	89	90	90	89	89
Texas	133	94	102	88	96	90	109	84	89	71	73	76
California	12	-----	-----	121	99	90	12	-----	-----	129	96	96

[1] Crop-reporting district or county averages weighted by acreage.

Table 24 presents for comparison (1) the size of sweetpotato yield-per-acre sample, (2) the average yield, (3) dispersion, (4) variation, and (5) probable error of the average yield obtained for the sweetpotato sample for Georgia for four years. The coefficient of variation was high, ranging from 49 to 89 per cent. The relative probable error varied from 1.4 to 2.3 per cent. Georgia is probably a typical Southern State so far as sweetpotato production is concerned.

TABLE 24.—*Sweetpotatoes: Yields per acre. Selected illustrations of size of sample, measures of dispersion, and probable error*

State, and year	Reports	Average yield (arithmetic mean)	Standard deviation of reported yields	Coefficient of variation	Probable error of the average yield, or mean	Relative probable error
	Number	*Bushels*	*Bushels*	*Per cent*	*Bushels*	*Per cent*
Georgia:						
1927[1]	538	74.4	36.1	48.5	1.05	1.4
1926	378	85.2	44.4	51.8	1.53	1.8
1925	652	41.1	36.4	88.6	.96	2.3
1924	569	68.6	34.1	49.7	.96	1.4

[1] As reported in November.

TAME HAY

REPRESENTATIVENESS

Tame hay of some kind is grown in every State; even Rhode Island has over 40,000 acres in tame hay and Delaware about 80,000 acres. Table 25 shows a comparison of the averages from the two sources of sample data—yields of tame hay, and illustrates the small differences that exist between straight and weighted averages for a crop grown so uniformly over a State.

TABLE 25.—*All tame hay: Averages of yields per acre computed from reports of crop correspondents, and the official estimates, by States, 1927 and 1928*

State	1927 Acreage	1927 Reported by the township list: Average (arithmetic mean)	1927 Reported by the township list: Weighted average[1]	1927 Reported by the field-aid list: Average (arithmetic mean)	1927 Reported by the field-aid list: Weighted average[1]	1927 Official estimate	1928 Acreage	1928 Reported by the township list: Average (arithmetic mean)	1928 Reported by the township list: Weighted average[1]	1928 Reported by the field-aid list: Average (arithmetic mean)	1928 Reported by the field-aid list: Weighted average[1]	1928 Official estimate
	1,000 acres	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*1,000 acres*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
Maine	1,247	------	------	1.18	1.17	1.22	1,235	------	------	1.31	1.34	1.28
New Hampshire	463	------	------	1.39	1.38	1.27	459	------	------	1.48	1.48	1.41
Vermont	922	------	------	1.55	1.56	1.53	914	------	------	1.67	1.69	1.63
Massachusetts	466	------	------	1.58	1.59	1.45	460	------	------	1.61	1.62	1.56
Rhode Island	44	------	------	1.50	1.47	1.34	43	------	------	1.81	1.78	1.56
Connecticut	359	------	------	1.49	1.53	1.46	354	------	------	1.86	1.90	1.61
New York	4,850	1.55	1.55	1.51	1.51	1.51	4,597	1.46	1.45	1.45	1.46	1.40
New Jersey	257	1.73	1.72	1.61	1.66	1.79	247	------	------	1.57	1.60	1.83
Pennsylvania	3,075	1.58	1.54	1.66	1.67	1.65	2,924	1.58	1.54	1.59	1.59	1.69
Ohio	3,139	1.57	1.59	1.56	1.58	1.64	2,780	1.27	1.27	1.25	1.26	1.33
Indiana	2,027	1.43	1.44	1.50	1.50	1.47	1,844	1.28	1.28	1.29	1.28	1.37
Illinois	3,556	1.50	1.46	1.50	1.46	1.49	3,064	1.23	1.20	1.21	1.20	1.33
Michigan	3,036	1.44	1.44	1.46	1.47	1.56	2,832	1.33	1.34	1.35	1.37	1.51
Wisconsin	3,444	1.87	1.87	1.90	1.91	2.03	3,270	1.48	1.46	1.66	1.67	1.53
Minnesota	2,454	1.86	1.83	1.77	1.76	2.07	2,355	1.56	1.52	1.57	1.53	1.79

[1] Crop-reporting district or county averages weighted by acreage.

TABLE 25.—*All tame hay: Averages of yields per acre computed from reports of crop correspondents, and the official estimate, by States, 1927 and 1928*—Con.

State	1927 Acreage	1927 Reported by the township list: Average (arithmetic mean)	1927 Reported by the township list: Weighted average	1927 Reported by the field-aid list: Average (arithmetic mean)	1927 Reported by the field-aid list: Weighted average	1927 Official estimate	1928 Acreage	1928 Reported by the township list: Average (arithmetic mean)	1928 Reported by the township list: Weighted average	1928 Reported by the field-aid list: Average (arithmetic mean)	1928 Reported by the field-aid list: Weighted average	1928 Official estimate
	1,000 acres	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*1,000 acres*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
Iowa	3,135	1.43	1.42	1.44	1.43	1.66	2,835	1.32	1.31	1.38	1.35	1.51
Missouri	3,553	1.33	1.31	1.31	1.30	1.46	3,299	1.17	1.09	1.12	1.07	1.27
North Dakota	1,040	1.66	1.64	1.60	1.61	1.87	1,063	1.51	1.45	1.49	1.47	1.87
South Dakota	1,105	1.66	1.65	1.65	1.68	2.06	1,086	1.22	1.16	1.10	1.08	1.52
Nebraska	1,727	1.68	1.68	1.79	1.80	2.40	1,550	1.43	1.40	1.41	1.36	2.16
Kansas	1,678	1.87	1.87	1.99	1.99	2.53	1,496	1.75	1.77	1.90	1.90	2.37
Delaware	80	1.90	1.67	1.75	1.73	1.78	81	------	------	1.51	------	1.70
Maryland	443	------	------	1.60	1.58	1.65	430	------	------	1.58	1.57	1.75
Virginia	1,077	1.62	1.59	1.44	1.43	1.37	1,063	1.44	1.44	1.35	1.36	1.37
West Virginia	831	1.51	1.52	1.51	1.49	1.52	814	1.57	1.56	1.49	1.47	1.45
North Carolina	806	.93	------	.94	------	.94	752	[2]1,958	------	[2]1,896	------	.98
South Carolina	441	.72	------	.70	------	.80	434	[2]1,363	------	[2]1,430	[2]1,245	.87
Georgia	808	.78	------	.82	.83	.70	792	[2]1,674	------	.62	.62	.64
Florida	95	------	------	.71	.72	.67	88	------	------	[2]1,425	[2]1,424	.73
Kentucky	1,318	1.41	1.39	1.37	1.37	1.42	1,253	1.35	1.30	1.21	1.21	1.31
Tennessee	1,352	1.34	1.33	1.27	1.22	1.30	1,310	1.37	1.37	1.34	1.40	1.36
Alabama	615	1.35	.82	[2]1,490	[2]1,500	.84	615	[2]1,609	------	[2]1,558	[2]1,600	.77
Mississippi	491	1.06	------	1.10	1.20	1.21	451	[2]2,135	------	1.05	1.10	1.25
Arkansas	643	[2]2,067	1.03	1.04	1.06	1.14	625	[2]2,106	------	[2]2,331	[2]2,467	1.09
Louisiana	278	1.27	------	.94	1.49	1.28	297	[2]2,062	------	[2]2,554	[2]3,180	1.43
Oklahoma	566	1.35	------	1.26	1.21	1.59	576	[2]2,612	------	[2]2,193	[2]2,285	1.46
Texas	629	1.22	------	1.15	1.20	1.19	637	[2]2,356	------	[2]2,390	[2]2,400	1.15
Montana	1,274	1.77	1.83	1.84	1.83	2.12	1,294	1.55	1.62	1.64	1.65	1.98
Idaho	1,014	2.61	2.81	2.89	3.24	3.11	1,047	2.40	2.65	2.65	2.68	2.53
Wyoming	685	1.65	1.62	1.75	2.00	1.78	681	1.44	1.45	1.56	1.59	1.80
Colorado	1,225	1.81	1.83	1.83	1.89	2.17	1,207	1.75	1.74	1.90	1.96	2.07
New Mexico	196	1.48	1.47	1.92	2.09	2.21	186	1.82	1.76	1.83	1.94	2.19
Arizona	192	3.25	3.32	3.00	4.10	3.50	185	3.03	3.69	3.30	3.50	3.77
Utah	567	2.73	2.77	2.85	2.80	2.60	570	2.49	2.49	2.00	2.40	2.46
Nevada	208	2.19	2.38	2.24	2.29	2.38	208	2.31	2.44	3.00	3.00	2.60
Washington	932	2.36	2.55	2.36	2.33	2.49	906	2.07	2.09	2.16	2.17	2.36
Oregon	898	2.35	2.47	2.04	2.11	2.28	905	2.15	2.13	2.02	1.96	2.26
California	1,649	------	------	------	------	3.13	1,654	------	------	------	------	3.09

[2] Pounds per acre.

BIAS

There is no particular reason to expect a cash-crop bias in the case of a crop like tame hay that is largely fed. But there is considerable shrinkage in hay; as a result, the quantity used or sold is never equal in tons to the quantity harvested. Shrinkage and wastage due to field stacking are undoubtedly more serious with hay than with grain crops.

PREVENTABLE ERRORS

The final estimate of the yield per acre of all tame hay was in many cases somewhat different from the indication shown by the sample. This difference is due to the fact that the department's definition of what constitutes tame hay differs in many cases from the definition that the farmer has in mind. Consequently the estimates of the yield of tame hay are derived figures obtained by first building up the estimates of the yield of hay by varieties and then dividing the total production by the total acreage. When an Iowa farmer is asked to report on the average yield of all tame hay in his locality he seldom includes the high-yielding alfalfa or sweetclover hay, Sudan grass, millet, or other special hay crops in his estimate of the average yield for all tame hay.

PRECISION OF THE SAMPLE AVERAGES

The difference between the weighted averages from the two samples seldom exceeded one-tenth of a ton except in some of the far Western States. The yield samples for several varieties of tame hay, such as timothy and alfalfa, show practically the same degree of stability as was shown for all tame hay in Table 25.

Table 26 presents for comparison (1) the size of tame-hay yield-per-acre sample, (2) the average yield, (3) dispersion, (4) variation, and (5) probable error of the average yield obtained for several States. Few yield-per-acre samples of tame hay had a coefficient of variation much below 30 per cent or above 40 or 50 per cent. The relative probable errors for most of the State samples analyzed fall between 1 and 2 per cent, with a few less than 1 per cent.

TABLE 26.—*Tame hay and alfalfa: Yields per acre. Selected illustrations of size of sample, measures of dispersion, and probable error*

TAME HAY

State, year, and district	Reports	Average yield (arithmetic mean)	Standard deviation of reported yields	Coefficient of variation	Probable error of the average yield, or mean	Relative probable error
	Number	*Tons*	*Tons*	*Per cent*	*Tons*	*Per cent*
New York:						
1927[1]	441	1.51	0.45	29.8	0.01	0.7
2	57	1.53	.47	30.7	.04	2.6
3	25	1.57	.54	34.4	.07	4.5
4	370	1.55	.41	26.5	.01	.6
5	187	1.63	.55	33.7	.03	1.8
6	45	1.31	.38	29.0	.04	3.1
7	152	1.48	.48	32.4	.03	2.0
8	79	1.33	.37	27.8	.03	2.8
9	81	1.48	.50	33.8	.04	2.7
1925	308	1.36	.40	29.4	.02	1.5
Illinois:						
1928	364	1.27	.44	34.6	.02	1.6
1	50	1.27	.43	33.9	.04	3.1
3	41	1.37	.46	33.6	.05	3.6
4	42	1.21	.39	32.2	.04	3.3
4a	47	1.32	.41	31.1	.04	3.0
5	52	1.33	.45	33.8	.04	3.0
6	37	1.25	.59	47.2	.07	5.6
6a	41	1.10	.34	30.9	.04	3.6
7	27	1.34	.34	25.4	.04	3.0
9	27	1.19	.33	27.7	.04	3.4
North Dakota:						
1927	282	1.60	.57	35.6	.02	1.2
1	53	1.60	.65	40.6	.06	3.8
2	28	1.48	.48	32.4	.06	4.1
3	63	1.53	.50	32.6	.04	2.6
4	19	1.39	.48	34.5	.07	5.0
5	22	1.55	.62	40.0	.09	5.8
6	21	1.76	.57	32.4	.08	4.5
7	26	1.63	.50	30.7	.07	4.8
8	21	1.81	.55	30.4	.08	4.4
9	29	1.86	.74	39.8	.09	4.6
1926	212	.93	.48	51.6	.02	2.2
Virginia:						
1927	270	1.47	.48	32.7	.02	1.4
1926	257	1.12	.47	42.0	.02	1.8
1924	253	1.51	.48	31.8	.02	1.3
1921	266	1.06	.47	44.3	.02	1.9

TABLE 26.—*Tame hay and alfalfa: Yields per acre. Selected illustrations of size of sample, measures of dispersion, and probable error*—Continued

TAME HAY—Continued

State, year, and district	Reports	Average yield (arithmetic mean)	Standard deviation of reported yields	Coefficient of variation	Probable error of the average yield, or mean	Relative probable error
	Number	*Tons*	*Tons*	*Per cent*	*Tons*	*Per cent*
Missouri:						
1927	541	1.32	0.45	34.1	0.01	0.8
1926	391	1.05	.40	38.1	.01	1.0
Pennsylvania:						
1927	362	1.62	.44	27.2	.02	1.2
1926	338	1.27	.42	33.1	.02	1.6
1925	384	1.31	.41	31.3	.01	.8
Ohio: 1928	436	1.27	.42	33.1	.01	.8
Michigan:						
1927	607	1.47	.43	29.3	.01	.7
1925	477	.91	.46	50.5	.01	1.1
1923	479	1.19	.38	31.9	.01	.8
Minnesota:						
1927	459	1.80	.52	28.9	.02	1.1
1926	460	1.15	.57	49.6	.02	1.7
1924	507	1.65	.68	41.2	.02	1.2
ALFALFA						
California:						
1927[1]	277	4.77	1.67	35.0	0.07	1.5
4	34	4.44	1.52	34.2	.18	4.1
5	56	5.29	1.62	30.6	.15	2.8
5a	101	5.08	1.58	31.1	.11	2.2
8	47	5.28	1.82	34.5	.18	3.4
1926	283	4.68	2.00	42.7	.08	1.7
1925	190	4.48	2.03	45.3	.10	2.2
Nebraska:						
1928[1]	267	2.10	.77	36.7	.03	1.4
1927	320	2.48	.78	31.5	.03	1.2
1926	340	1.84	.85	46.2	.03	1.6
1925	257	2.11	.81	38.3	.03	1.4
1924	274	2.22	.93	41.9	.04	1.8
1923	380	2.59	.71	27.4	.02	0.8

[1] As reported in October.

STRATIFICATION

In none of the three States shown by districts in Table 26 were the standard deviations of districts materially smaller than that of the entire sample. It is doubtful if a more refined method of geographic stratification would materially help the precision of tame-hay averages except perhaps in some of the far Western States. Stratification by varities, however, has greatly improved the representativeness and, consequently, the accuracy of the yield samples.

FLAXSEED

Flaxseed is an important crop in North Dakota, South Dakota, and Minnesota, but it is of very minor importance in the few other States in which it is grown. Table 27 shows that in no case did the straight and weighted averages of yield-per-acre reports of flaxseed differ by more than 1 bushel, and the weighted averages of the township and field-aid samples were within 1 bushel or less of each other in all cases. Records of car-lot shipments of flaxseed are available in North Dakota, South Dakota, Minnesota, and Montana as a check on the production of flaxseed. There is apparently little evidence of cash-crop bias in flaxseed yield samples.

TABLE 27.—*Flaxseed: Averages of yields per acre computed from reports of crop correspondents, and the official estimate, by States, 1927 and 1928*

State	1927						1928					
		Reported by the township list		Reported by the field-aid list				Reported by the township list		Reported by the field-aid list		
	Acreage	Average (arithmetic mean)	Weighted average [1]	Average (arithmetic mean)	Weighted average [1]	Official estimate	Acreage	Average (arithmetic mean)	Weighted average [1]	Average (arithmetic mean)	Weighted average [1]	Official estimate
	1,000 acres	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*1,000 acres*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*
Minnesota	757	9.7	9.5	10.0	9.5	9.7	643	8.2	7.7	7.8	7.4	7.6
Iowa	19	11.6	11.8	11.6	12.0	12.0	19	10.4	10.6	10.2	10.2	10.4
North Dakota	1,242	8.8	8.4	8.5	8.0	8.2	1,143	7.3	7.2	7.1	7.1	7.1
South Dakota	594	9.7	9.7	9.9	10.1	10.0	588	5.8	5.4	6.2	6.0	5.8
Kansas	31	5.7	5.5	6.2	6.5	5.5	25	6.6	6.7	7.2	7.2	6.9
Montana	170	10.0	10.1	10.1	9.8	10.2	196	8.7	8.7	8.6	8.1	8.5

[1] Crop-reporting district or county averages weighted by acreage.

Table 28 presents for comparison (1) the size of flaxseed yield-per-acre sample, (2) the average yield, (3) dispersion, (4) variation, and (5) probable error of the average yield, obtained for several States. The coefficient of variation showed a range from as low as 28 per cent in Minnesota in 1924, when the yield was about 11 bushels per acre, to 63 per cent in Montana in 1926, when the average yield per acre was only 5 bushels. Relative probable error varied from 1.1 per cent to as high as 5.5 per cent. On the whole, stratification of the sample by crop-reporting districts seemed materially to improve the precision of the average for the State, as the district standard deviations in North Dakota were generally smaller than for the State as a whole.

TABLE 28.—*Flaxseed: Yield per acre. Selected illustrations of size of sample, measures of dispersion, and probable error*

State, year, and district	Reports	Average yield (arithmetic mean)	Standard deviation of reported yields	Coefficient of variation	Probable error of the average yield, or mean	Relative probable error
	Number	*Bushels*	*Bushels*	*Per cent*	*Bushels*	*Per cent*
Minnesota:						
1927	406	9.97	3.70	37.1	0.12	1.2
1926	423	9.32	3.07	32.9	.10	1.1
1924	299	11.38	3.17	27.9	.12	1.1
Montana:						
1927	63	10.06	2.53	25.1	.21	2.1
3	19	9.74	1.14	11.7	.18	1.8
6	21	9.00	3.11	34.6	.46	5.1
1926	61	5.13	3.23	63.0	.28	5.5
3	31	6.10	3.56	58.4	.43	7.0
6	17	3.24	1.36	42.0	.22	6.8
North Dakota:						
1927	493	9.09	3.21	35.3	.10	1.1
1	83	9.5	2.71	28.5	.20	2.1
2	44	9.3	2.86	30.7	.29	3.1
3	94	5.9	2.69	45.6	.19	3.2
4	52	10.0	2.50	25.0	.23	2.0
5	26	7.5	2.24	29.9	.30	4.0
6	42	6.9	2.28	33.0	.24	3.5
7	46	10.4	2.69	25.8	.27	2.6
8	48	11.1	3.06	27.6	.30	2.7
9	58	8.1	2.79	34.4	.25	3.0
1926	277	5.68	3.30	58.1	.13	2.3
1	45	5.2	2.40	46.2	.24	4.6
2	24	5.3	2.76	52.1	.38	7.2
3	49	7.6	2.82	37.1	.27	3.6
4	28	2.9	1.56	53.8	.20	6.9
5	26	5.4	1.86	34.4	.25	4.6
6	33	6.5	2.74	42.2	.32	4.9
7	24	3.7	1.50	40.5	.21	5.7
8	20	2.1	1.02	48.6	.15	7.1
9	28	4.3	2.00	46.5	.26	6.0
1923	196	8.28	2.84	34.3	.14	1.7
1920	181	5.88	2.96	50.3	.15	2.6

BUCKWHEAT

Buckwheat is a crop of minor importance in all of the States in which it is grown. Only in New York and Pennsylvania were as much as 200,000 acres grown in 1927. Remarkably little difference exists between the straight and weighted averages computed from reports of crop correspondents (Table 29) for a crop no more important than buckwheat. The weighted averages from the two samples checked closely considering the scattered acreage of the crop.

TABLE 29.—*Buckwheat: Averages of yields per acre computed from reports of crop correspondents, and the official estimate, by States, 1927 and 1928*

State	1927						1928					
		Reported by the township list		Reported by the field-aid list				Reported by the township list		Reported by the field-aid list		
	Acreage	Average (arithmetic mean)	Weighted average [1]	Average (arithmetic mean)	Weighted average [1]	Official estimate	Acreage	Average (arithmetic mean)	Weighted average [1]	Average (arithmetic mean)	Weighted average [1]	Official estimate
	1,000 acres	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*1,000 acres*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*
Maine	14	------	------	24.0	27.9	23.0	13	------	------	25.5	26.0	23.0
New York	201	21.3	21.3	20.6	21.0	21.0	192	18.0	17.8	17.9	17.8	18.1
Pennsylvania	210	23.5	23.3	22.5	22.7	23.5	195	19.2	19.0	20.0	19.9	19.5
Ohio	28	20.6	21.1	21.8	21.0	21.0	35	18.3	18.5	22.2	22.0	20.0
Indiana	15	17.4	17.6	16.0	------	17.0	15	17.1	17.1	13.8	14.3	15.0
Michigan	53	13.6	13.6	13.9	12.9	13.0	48	15.5	15.6	15.1	14.4	15.0
Wisconsin	23	16.6	16.2	16.8	16.4	16.6	25	15.1	14.5	17.4	16.3	16.5
Minnesota	126	14.0	11.8	14.9	14.3	14.0	88	13.2	12.5	12.1	------	12.2
Iowa	15	14.3	14.0	16.0	15.6	13.0	6	15.7	16.0	15.4	14.0	14.5
North Dakota	11	14.8	13.9	15.5	------	14.5	10	15.5	14.9	14.3	------	14.5
South Dakota	18	16.1	18.6	15.6	14.8	15.5	19	14.7	14.3	13.9	14.6	14.5
Virginia	14	19.4	19.7	22.9	22.5	21.0	17	------	------	19.5	19.2	19.2
West Virginia	39	22.0	22.5	21.9	22.1	22.0	40	------	------	19.5	20.0	20.0
North Carolina	10	------	------	------	------	20.0	10	------	------	------	------	19.0
Kentucky	9	16.4	15.3	17.0	16.8	16.0	14	18.2	18.6	17.3	16.2	17.0

[1] Crop-reporting district or county averages weighted by acreage.

Table 30 presents for comparisons (1) the size of buckwheat yield-per-acre sample, (2) the average yield, (3) dispersion, (4) variation, and (5) probable error of the average yield obtained for several States. The coefficient of variation for New York and Pennsylvania ranged from 24 to 34 per cent, whereas in Michigan it was 40 to 56 per cent. The relative probable error in New York State was 1 per cent or less, in Pennsylvania less than 2 per cent, and in Michigan between 2 and 3 per cent.

TABLE 30.—*Buckwheat, field beans, and peanuts: Yields per acre. Selected illustrations of size of sample, measures of dispersion, and probable error*

BUCKWHEAT

State and year	Reports	Average yield (arithmetic mean)	Standard deviation of reported yields	Coefficient of variation	Probable error of the average yield, or mean	Relative probable error
	Number	*Bushels*	*Bushels*	*Per cent*	*Bushels*	*Per cent*
New York:						
1927 [1]	237	20.6	4.90	23.8	0.21	1.0
1927 [1 2]	771	20.8	5.90	28.4	.14	.7
Pennsylvania:						
1927 [3]	460	24.2	6.40	26.4	.20	.8
1927	215	22.5	5.78	25.7	.27	1.2
1926	193	20.4	6.11	30.0	.30	1.5
1925	219	23.5	7.99	34.0	.36	1.5
Michigan:						
1927	166	13.8	7.69	55.7	.40	2.9
1926	177	15.2	6.10	40.1	.31	2.0
1925	176	14.3	6.15	43.0	.31	2.2
FIELD BEANS						
New York:						
1927 [1 2]	61	13.1	3.20	24.4	0.28	2.1
1927 [1]	375	13.1	3.90	29.8	.14	1.1
1927 [4]	115	13.9	4.40	31.7	.28	2.0
1926 [2 5]	161	14.0	5.00	35.7	.27	1.9
1925 [1]	376	11.3	4.80	42.5	.17	1.5
Michigan: [1 2]						
1927	386	8.6	2.87	33.4	.10	1.2
1925	381	13.6	4.22	31.0	.15	1.1
1924	196	11.1	3.85	34.7	.19	1.7
PEANUTS						
Virginia:						
1927	35	8.9	1.98	22.2	0.23	2.6
1926	38	12.1	2.56	21.2	.28	2.3
Georgia: [1]		*Pounds*	*Pounds*		*Pounds*	
1927	237	725.0	328.0	45.2	14.38	2.0
1926	146	592.0	260.0	43.9	14.52	2.5
1925	274	478.0	288.0	60.3	11.74	2.5
1924	239	634.0	251.0	39.6	10.95	1.7

[1] As reported in November.
[2] Return from a special list of crop correspondents.
[3] Return from a special list of commercial correspondents.
[4] As reported in October.
[5] As reported in January.

FIELD BEANS

The estimates of bean production, acreage, and yield per acre, are based primarily on sample data from the field aids and from observations made by the field statisticians; consequently there is no opportunity to compare the samples from the two sources as was done with other crops. Table 31 shows both straight and weighted averages from the field-aid sample. The straight and weighted averages checked as closely as in the case of most other seed or grain crops. In most States car-lot shipments of beans are available as a check on the production. There is a possibility of cash-crop bias in the estimates of farmers concerning the yield of beans per acre, but in the two years under consideration there is little evidence that cash-crop bias was allowed for in the making of the estimates of yield per acre.

TABLE 31.—*Field beans: Averages of yields per acre computed from reports of crop correspondents, and the official estimate, by States, 1927 and 1928*

State	1927				1928			
	Acreage	Reported by the field-aid list [1]		Official estimate	Acreage	Reported by the field-aid list [1]		Official estimate
		Average (arithmetic mean)	Weighted average [2]			Average (arithmetic mean)	Weighted average [2]	
	1,000 acres	*Bushels*	*Bushels*	*Bushels*	*1,000 acres*	*Bushels*	*Bushels*	*Bushels*
New York	75	13.6	13.2	13.0	80	14.7	14.5	14.5
Michigan	566	8.5	8.8	8.5	538	12.5	10.8	11.0
Montana	32	18.2	17.5	20.0	43	------	------	14.5
Idaho	72	23.7	21.7	23.7	82	20.7	18.4	19.0
Wyoming	17	20.1	20.3	18.0	24	15.9	------	15.0
Colorado	281	6.8	6.0	5.5	309	4.1	4.7	4.5
New Mexico	195	7.0	6.6	5.0	214	5.7	6.6	4.0
California	296	17.0	17.5	16.3	250	20.3	19.7	17.3

[1] Reports received only from field aids.
[2] Crop-reporting district or county averages weighted by acreage.

Table 30 presents for comparison (1) the size of field beans yield-per-acre sample, (2) the average yield, (3) dispersion, (4) variation, and (5) probable error of the average yield obtained for New York and Michigan. The coefficient of variation fell within a range of 24 to 42 per cent, and the relative probable error was between 1 and 2 per cent in practically all cases.

PEANUTS

Concentration of the peanut acreage in limited areas of commercial production necessitates careful weighting of district or county averages if a representative average for the State is to be obtained. There is considerable difference between the straight and weighted averages from the same sample as well as between the weighted averages of the two samples, largely because of the localization of the crop. (Table 32.) Since peanuts are a cash crop in the commercial districts, a cash-crop bias must be guarded against by the statistician. A later inquiry than that on November 1 is frequently necessary if the yield per acre of peanuts is to be accurately determined. Peanuts are such a specialized and highly localized crop that special inquiries and field travel by the State statistician are necessary to supplement the regular field-aid and township returns.

Table 30 presents for comparison (1) the size of peanut yield-per-acre sample, (2) the average yield, (3) dispersion, (4) variation, and (5) probable error of the average yield obtained for samples from two important States—Virginia and Georgia. The coefficient of variation in Virginia was only about 22 per cent, whereas in Georgia it varied from 40 to 60 per cent. The relative probable error was between 2 and 3 per cent in both States for most years. The large dispersion in Georgia was practically offset by samples several times larger than those obtained in Virginia.

TABLE 32.—*Peanuts: Averages of yields per acre computed from reports of crop correspondents, and the official estimate, by States, 1927 and 1928*

State	1927						1928					
	Acreage	Reported by the township list		Reported by the field-aid list		Official estimate	Acreage	Reported by the township list		Reported by the field-aid list		Official estimate
		Average (arithmetic mean)	Weighted average [1]	Average (arithmetic mean)	Weighted average [1]			Average (arithmetic mean)	Weighted average [1]	Average (arithmetic mean)	Weighted average [1]	
	1,000 acres	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*1,000 acres*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Virginia	152	------	------	840	881	810	152	------	------	840	------	910
North Carolina	211	994	1,011	1,058	1,050	954	195	1,023	993	1,014	1,097	950
South Carolina	11	808	757	996	954	775	10	680	748	731	656	690
Georgia	304	765	733	732	758	725	350	597	602	538	542	540
Florida	44	------	------	654	641	640	44	------	------	608	599	575
Tennessee	20	------	------	990	------	850	18	------	------	756	------	800
Alabama	230	675	738	655	650	680	210	598	624	612	675	560
Mississippi	9	714	692	756	747	725	10	589	597	602	604	500
Arkansas	11	758	782	901	838	800	12	675	720	736	740	720
Louisiana	13	543	623	684	636	625	12	532	527	374	338	450
Oklahoma	20	734	------	783	856	800	47	695	------	768	783	750
Texas	117	661	642	706	719	600	120	767	780	647	623	650

[1] Crop-reporting district or county averages weighted by acreage.

RICE

Rice is a highly specialized and localized crop; it is grown in quantity only in Arkansas, Louisiana, Texas, and California. Special inquiries addressed to rice mills, and field travel by the State statistician, are necessary to obtain an adequate estimate of the yield per acre of such a specialized crop as rice. (Table 33.) The differences between straight and weighted averages in the same sample are likely to be somewhat large because of the extreme localization of the crop, and small samples must necessarily be supplemented by the first-hand information of the State statistician. Fairly adequate checks on production are obtained from the mills and cooperative associations that handle the bulk of the rice crop.

TABLE 33.—*Rice: Averages of yields per acre computed from reports of crop correspondents, and the official estimate, by States, 1927 and 1928*

State	1927						1928					
	Acreage	Reported by the township list		Reported by the field-aid list		Official estimate	Acreage	Reported by the township list		Reported by the field-aid list		Official estimate
		Average (arithmetic mean)	Weighted average [1]	Average (arithmetic mean)	Weighted average [1]			Average (arithmetic mean)	Weighted average [1]	Average (arithmetic mean)	Weighted average [1]	
	1,000 acres	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*1,000 acres*	*Bushels*	*Bushels*	*Bushels*	*Bushels*	*Bushels*
Arkansas	175	48.5	47.0	51.5	43.5	44.0	164	50.8	49.1	49.7	48.0	47.0
Louisiana	500	35.0	35.4	37.5	34.7	40.0	484	33.4	34.6	36.0	34.2	38.0
Texas	174	49.2	46.0	41.0	39.0	46.2	174	27.7	27.0	43.0	43.4	42.0
California	160	------	------	59.0	54.3	56.0	133	------	------	62.1	63.3	60.7

[1] Crop reporting district or county averages weighted by acreage.

OTHER MINOR CROPS

Table 34 presents for comparison with respect to Danish cabbage in New York, cowpeas in South Carolina, sugar beets in Michigan, and sorghum sirup in three States (1) the size of sample (2) the average yield (3) dispersion, (4) variation and (5) probable error of the average for yield samples. The samples of cabbage yield in New York showed a coefficient of variation between 33 and 46 per cent and a relative probable error of 1 to 2 per cent. The cowpea samples in South Carolina had rather wide dispersion, with coefficients of variation varying from 47 to 95 per cent. With the small size of sample that occurs in a small State like South Carolina, the relative probable error was necessarily large in the case of crops that show such wide dispersion in yields as do cowpeas.

TABLE 34.—*Danish cabbage, sugar beets, cowpeas, and sorghum sirup: Yield per acre. Selected illustrations of size of sample, measures of dispersion, and probable error*

State, year, and district	Reports	Average yield (arithmetic mean)	Standard deviation of reported yields	Coefficient of variation	Probable error of the average yield, or mean	Relative probable error
DANISH CABBAGE						
	Number	*Tons*	*Tons*	*Per cent*	*Tons*	*Per cent*
New York:						
1927 [1]	363	10.8	3.6	33.3	0.13	1.2
1927 [2]	140	10.5	4.0	38.1	.23	2.2
1925	367	9.4	4.3	45.7	.15	1.6
COWPEAS						
		Bushels	*Bushels*		*Bushels*	
South Carolina:						
1927	102	10.0	5.08	50.8	0.34	3.4
1926	64	9.2	4.33	47.1	.37	4.0
1925	20	5.8	5.52	95.2	.83	14.3
1924	40	6.9	4.16	60.3	.44	6.4
SUGAR BEETS						
		Tons	*Tons*		*Tons*	
Michigan:						
1927	60	7.9	2.47	31.3	0.21	2.7
1926	60	9.0	2.37	26.3	.21	2.3
SORGHUM SIRUP [1]						
		Gallons	*Gallons*		*Gallons*	
Mississippi:						
1927	254	86.2	42.4	49.2	1.79	2.1
1926	390	110.3	55.3	50.1	1.89	1.7
Georgia:						
1927	285	83.0	38.6	46.5	1.54	1.9
1926	292	74.9	48.0	64.1	1.89	2.5
1925	362	46.4	37.5	80.8	1.33	2.9
1924	339	68.7	35.7	52.0	1.31	1.9
Florida:						
1928 [2]	74	89.2	56.71	63.6	4.45	5.0
1927 [2]	94	90.7	50.78	56.0	3.53	3.9
1926	73	96.6	42.96	44.5	3.39	3.5

[1] As reported in November. [2] As reported in October.

Sugar-beet yields in Michigan had a small degree of dispersion as the coefficients of variation were 26 per cent one year and 31 per cent the other, and the relative probable error was between 2 and 3 per cent. The yield per acre of sugar beets is ascertained from reports from the sugar-beet factories as well as from crop correspondents.

Yields of sorghum sirup show rather wide variability, but are subject to only moderate errors whenever large samples can be obtained.

DISPERSION OF YIELD SAMPLES

The approximate ranges in dispersion of the observations in the yield samples for the more important crops in States east of the Rocky Mountains are presented in summary form in Table 35. The minimum limit of dispersion for these yield samples, as measured by the coefficient of variation, was usually between 20 and 30 per cent. In tobacco samples, however, it was as low as 15 per cent and in potato and cotton samples it exceeded 30 per cent. In samples of two crops —flaxseed and tame hay—it was 30 per cent. The modal minimum variation for these crops was 25 per cent. Winter wheat, spring wheat, rye, buckwheat, and field beans were included in the group with a minimum coefficient of variation of about 25 per cent. Corn, oats, and barley had less dispersion than the modal group.

The maximum limit of dispersion was usually between 45 and 55 per cent. The lowest was 40 per cent, for tobacco, and the highest was 80 per cent, for cotton. In the modal group which included spring wheat, rye, flaxseed, potatoes, and buckwheat, it was 55 per cent; in corn, oats, and field bean samples, which were below the modal group, it was about 45 per cent. The maximum variation for winter wheat, barley, and tame hay was 50 per cent.

TABLE 35.—*Comparison[1] of the dispersion and probable errors for the yield estimates of several crops*

Crop	Dispersion				Probable error of the average yields			
	Standard deviation		Coefficient of variation		Probable error		Relative Probable error	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
	Bushels	*Bushels*	*Per cent*	*Per cent*	*Bushels*	*Bushels*	*Per cent*	*Per cent*
Winter wheat	3.5	6.0	25	50	0.15	0.20	0.8	1.5
Spring wheat	2.5	5.5	25	55	.15	.20	.8	2.0
Rye	4.0	6.0	25	55	.20	.40	1.0	4.0
Corn	6.0	11.0	20	45	.18	.45	.5	1.5
Oats	8.0	10.0	22	45	.20	.35	.5	1.5
Barley	7.5	9.0	22	50	.20	.60	.7	2.5
Flaxseed	3.0	4.0	30	55	.10	.20	1.1	2.5
Buckwheat	5.0	8.0	25	55	.15	.40	.7	3.0
Field beans	3.0	5.0	25	45	.10	.30	1.1	2.0
Potatoes	40.0	60.0	38	55	1.00	2.00	.8	2.5
	Pounds	*Pounds*			*Pounds*	*Pounds*		
Cotton	50	80	35	80	1.5	5.0	1.0	2.0
Tobacco	150	300	15	40	5.0	20.0	.7	3.0
	Tons	*Tons*			*Tons*	*Tons*		
Tame hay	.40	.60	30	50	.01	.02	.7	2.0

[1] These values are only approximations of the minimum and maximum limits which include from 80 to 90 of the samples for a given crop; samples from the far Western States are not included.

From this study it might be possible to array or rank these crops in order on the basis of the variation shown by the yield samples. Tobacco samples could be given first place as having the least dispersion and cotton last as having the greatest. Corn would be second, oats, third, barley and field beans would rank in fourth place, winter wheat fifth, spring wheat, rye, tame hay, and buckwheat would tie for sixth, flaxseed seventh, potatoes eighth, and cotton ninth or last. Of the crops not included in Table 35, for which only a very few samples were studied, sweetpotatoes in Georgia showed greater dispersion than did cotton, and cowpeas in South Carolina showed greater dispersion than either cotton or sweetpotatoes. Yield samples of cabbage, sugar beets, and peanuts had no more than the average degree of dispersion indicated for the more important crops.

COMPARISON WITH OTHER SAMPLE DATA

The dispersion of crop-yield samples is from two to three times as large as is the dispersion of farm-price samples, which vary from as low as 5 to 10 per cent with the farm prices for surplus farm products of corn, hogs, wheat, and cotton, to as much as 30 to 40 per cent with apples (*14*).

Samples of farm-wage data have a dispersion about equal to those of some of the grain crops or from 25 to 40 per cent. Samples of land values vary from as low as 25 per cent dispersion in a homogeneous State with few large cities, like Iowa, to 90 per cent or more in States that include large cities like New York or States in which there are great differences in value between improved and unimproved land as in some of the far Western States. On the other hand, yield samples usually have much less dispersion than have individual farm samples of either acreages or numbers of livestock, which seldom have a coefficient of variation of less than 60 or 70 per cent and frequently exceed 200 per cent.[11]

PROBABLE ERRORS OF THE AVERAGES OF YIELD SAMPLES

Table 35 also presents the approximate range in the probable errors of the averages of yield samples for some of the more important crops in States east of the Rocky Mountains. The samples of crop yields are so large for important and universally grown crops in the more important producing States that the minimum relative probable error seldom exceeded 1 per cent. For corn and oats it was 0.5 per cent, for tame hay, barley, buckwheat, and tobacco it was 0.7 per cent, and the highest minimum was 1.1 per cent, for flaxseed and field beans. The maximum relative probable error was about 1.5 per cent for corn, oats, and winter wheat, 2 per cent for spring wheat, cotton, and field beans, 2.5 per cent for barley, flaxseed, and potatoes, about 3 per cent for tobacco and buckwheat, and 4 per cent for rye.

A comparison of the relative probable errors between different crops is much less satisfactory than a comparison of the coefficients of variation. The relative probable error is necessarily large when only a small acreage of a crop is grown in a State and the reports from crop reporters are few in number. The relative probable error varies directly as the size of the coefficients of variation and inversely as the square root of the number of reports. Rye yields have about the same dispersion as other grain crops in most States, but the sample is usually so small that the relative probable error is likely to be very large. If a rye yield sample for a given State has the minimum variation of about 25 per cent, then about 284 reports are sufficient to result in a relative probable error of about 1 per cent. On the other hand, if the maximum variation of 55 per cent occurs, a sample made up of 1,376 reports would be required if the relative probable error is not to exceed 1 per cent.

[11] These figures of coefficient of variation are from unpublished studies made by the author and other workers in the Division of Crop and Livestock Estimates. See article by A. J. Beyleveld (*1*).

The relative probable errors of the official estimates are much smaller than those for the individual samples that have been analyzed, as two or more samples of about the same size as the one studied usually form the basis of the official estimates. Stratification of the sample also tends to reduce the size of the relative probable error below that computed from these samples on the basis of a sample selected at random. There is always the possibility of bias in the individual observations of highly commercialized cash crops, such as cotton. Check data usually obtainable for these cash crops make it possible to bridge the gap from the biased sample to a fairly close approximation of the true average of the universe from which the sample was drawn.

COMPARISON OF YIELD ESTIMATES OF THE DEPARTMENT OF AGRICULTURE AND YIELDS DERIVED FROM CENSUS DATA

Thus far in this study the adequacy and reliability of the official estimates of the yields per acre of crops have been considered primarily with regard to the application of the principles of sampling. Yields of important crops in the surplus-producing States, as reported by one list of crop correspondents have been compared with those reported by another list of correspondents of similar size, composition, and geographic distribution. Differences between these indications of yield are about what would be expected when the probable errors of the samples are taken into account and when allowance is made for differences in editing the two samples.

Allowance must be made for such consistent and continued downward bias in the sample as is found with cash crops like cotton. Such allowance is made on the basis of past experience in which the sample is compared with check data on yields derived from ginnings, car-lot shipments, and other commercial movements. This method of measuring bias is not entirely satisfactory because the bias of the acreage sample that is also present when production is used as a basis for checking, can not always be allowed for separately. The use of the crop meter in the Southern States has been of great assistance in obtaining an indication, free from bias, of acreage change. After all, the essential thing is, of course, the reliability of the estimates of production, and accurate estimates of yield per acre are only a means to that end. The estimates of yields per acre of cotton, for example, may be carried along from year to year on too low a level and the estimates of acreage on too high a level, while at the same time the estimates of production of cotton may check closely with cotton ginnings.

It is possible, however, to derive a yield-per-acre figure for a State from census data, which could be used as a basis for checking estimates of yields, or the yields obtained by sampling. On first thought it would seem that a yield-per-acre figure obtained by dividing the production of a crop by acreage, as reported by the census, would from sample data. But experience has shown several rather serious limitations to the use of census data as an indication of the yield per acre of a given crop, or as an absolute check on the official estimates of yield.

There is the matter of the weight per bushel of small grains and corn. A bushel of specified weight over the entire country is designated on the questionnaires that are sent to crop correspondents, whereas the legal weight of a bushel for a given crop varies as between States. On the other hand the census enumerator obtains his data in terms of bushels, without specification as to weight. A census is usually taken several months to a year after the crop is harvested, and consequently memory bias is a much more serious source of error with census data than with the samples taken soon after harvest.

Memory bias is especially serious in areas of small farms with small acreages where surplus crops are not grown for market. With the lapse of any considerable period of time the farmer tends to report an acreage greater than the acreage from which his production, as he estimates it, was obtained.

Where the reported production of a crop is actually from the acreage of the crop as reported to the census enumerator, the yield per acre derived by dividing the production of a crop by the acreage would be a satisfactory indication of yield per acre for that crop, assuming, of course, equal completeness of enumeration over the entire State. There is always the possibility that the production as reported to the census enumerator includes only that part of the grain crop that was harvested and threshed.

The reported acreage, however, may include either the entire acreage planted to that crop (of which a part might have been abandoned prior to harvest), or some part of the total acreage reported that was not harvested for grain. The longer the period from time of harvest to the time when the enumerator calls on the farmer, the more likely is the farmer to report as the acreage harvested of a given crop the acreage of the field in which it was grown, without deductions for the parts of the field from which no crop was actually harvested. His total production is more than likely to be reported as the quantity actually threshed as shown by the number of bushels on his bill for threshing. The part of the crop used for some other purpose is likely to be omitted because it has been forgotten. The smaller the acreage per farm, the more serious is this source of error.

In spite of the obvious limitations of census data, it is desirable to make a systematic comparison between yields as derived from the census, on the one hand, and, on the other, official estimates made prior to the completion of the enumeration, or the averages of the returns from sample inquiries to crop correspondents. Where the several indications check closely, greater confidence will be warranted in both the census yields and the yields obtained from sample data.

Such a comparison as this supplements the analysis of estimates of crop yields made with regard to the general principles of sampling. It is an attack on the problem of the adequacy and reliability of the official estimates of crop yields per acre from an entirely different angle, one which should not be omitted in a study of this kind. It would be desirable to have a much more detailed explanation of some of the discrepancies which appear when these sample indications and [illegible] yields derived from the census, but

TABLE 36.—*Wheat: Yield per acre computed from census data of acreage and production, official estimates of the United States Department of Agriculture, and averages of yield per acre reported by crop correspondents on the county and township lists, by States, for stated years*

Commodity, group of States, and State	1879		1889		1899				1909				1919				1924			
	Official estimates	Census yields	Official estimates	Census yields	County reports	Township reports	Official estimates	Census yields	County reports	Township reports	Official estimates	Census yields	County reports	Township reports	Official estimates	Census yields	County reports	Township reports	Official estimates	Census yields
Winter wheat:																				
Northern—	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*
New York	15.0	15.7	13.8	18.0	17.8	18.5	18.5	18.7	22.5	21.3	21.0	23.0	21.5	22.0	22.0	19.7	16.5	17.7	18.0	18.6
New Jersey	12.3	12.7	12.2	15.0	14.5	14.9	14.5	14.4	19.8	18.0	17.9	17.8	18.8	18.7	18.0	16.2	17.0	19.4	18.5	18.8
Pennsylvania	15.3	13.5	12.3	16.4	13.3	13.6	13.6	13.6	17.4	16.7	17.0	17.6	15.6	17.3	17.5	16.5	14.1	15.8	16.5	16.3
Ohio	19.5	18.0	14.6	15.7	14.4	14.9	14.2	15.7	14.3	16.1	15.9	16.8	18.1	18.8	19.1	19.9	16.8	16.8	16.8	18.3
Indiana	20.3	18.0	14.7	14.5	10.2	9.8	9.8	12.1	15.3	15.1	15.3	16.3	14.3	14.9	16.0	16.2	15.6	15.1	17.0	16.5
Illinois	18.7	15.9	16.0	16.7	8.8	8.9	10.0	10.8	17.1	18.4	17.4	17.3	16.7	17.1	17.0	17.3	13.2	14.3	14.7	16.0
Michigan	19.2	19.5	14.7	16.5	7.9	8.1	8.4	10.7	18.3	18.8	18.8	20.0	19.4	19.8	20.3	19.3	19.3	19.0	22.0	23.8
Missouri	14.0	12.0	13.0	15.5	10.1	10.7	9.9	11.2	14.1	14.7	14.7	14.8	15.1	13.5	13.5	14.3	12.1	12.0	12.8	13.3
Nebraska	11.3	9.4	12.0	13.2	8.1	8.7	10.3	9.8	18.9	19.6	19.4	17.9	12.3	13.7	14.8	13.5	17.9	17.5	19.5	19.5
Kansas	11.0	9.3	18.4	19.2	9.8	9.5	9.8	10.2	14.5	15.1	14.5	13.0	12.8	14.0	13.0	13.2	15.5	15.5	16.3	15.6
Oklahoma	----	----	----	----	----	----	----	----	13.1	13.7	12.8	12.0	13.2	13.7	14.0	14.0	15.9	14.5	16.4	15.5
Texas	7.6	6.9	10.3	12.2	10.2	10.9	11.1	11.9	8.5	11.8	9.1	7.9	14.9	16.6	16.5	15.1	17.7	17.0	18.5	16.1
Southern—																				
Delaware	13.0	13.4	11.6	15.9	11.0	15.6	12.8	15.8	13.2	14.1	14.0	14.8	12.0	12.5	12.0	12.5	16.0	16.9	16.0	17.6
Maryland	14.4	14.1	11.3	16.3	13.6	14.1	14.1	15.2	14.5	13.7	14.5	16.0	13.5	13.9	13.5	14.5	16.5	15.1	15.8	15.8
Virginia	9.2	8.7	8.4	10.7	8.1	8.4	8.4	9.6	11.1	10.5	11.2	11.7	11.5	11.2	11.8	11.6	13.3	13.1	13.1	13.4
West Virginia	13.0	10.2	10.2	10.4	9.0	9.6	9.3	9.7	13.1	13.5	13.0	12.3	14.5	13.8	13.5	12.6	14.0	12.1	13.2	12.3
North Carolina	7.0	5.3	6.2	6.4	6.8	6.8	6.7	5.8	9.5	9.7	9.5	7.6	9.0	9.3	8.5	7.6	10.1	11.4	12.0	11.0
South Carolina	8.4	5.6	6.0	5.7	5.8	6.5	6.5	5.8	9.1	13.5	10.0	7.2	9.5	10.3	9.0	7.5	10.4	13.1	12.0	10.1
Georgia	9.0	6.6	6.3	5.6	6.4	7.1	6.8	5.5	10.2	10.9	10.0	8.1	10.5	10.3	10.5	7.7	10.2	11.0	10.5	8.1
Kentucky	14.0	9.8	11.0	11.9	8.8	9.1	9.1	10.0	11.6	12.4	11.8	12.8	11.3	11.3	11.5	12.4	10.9	10.3	10.0	10.2
Tennessee	8.0	6.1	7.5	9.5	7.2	8.0	8.7	8.4	10.2	10.4	10.4	10.5	10.0	9.3	9.0	9.3	----	11.2	10.5	10.1
Spring wheat:																				
Minnesota	12.3	11.4	14.6	15.5	13.0	13.4	13.4	14.5	16.5	17.0	16.8	17.4	8.6	9.4	9.3	9.9	18.9	21.8	21.8	22.2
North Dakota	----	----	9.4	9.7	12.1	12.1	12.8	13.5	12.6	14.3	13.7	14.3	6.5	6.1	6.9	6.8	15.3	15.2	15.5	14.8
South Dakota	----	----	----	----	9.9	10.0	10.7	10.5	13.4	14.1	14.1	14.6	9.4	7.6	8.0	8.0	14.7	14.8	14.9	14.2
All wheat: United States	13.8	13.0	12.9	13.9	----	----	11.5	12.5	----	----	15.8	15.4	----	----	14.7	12.9	----	----	16.2	15.7

TABLE 37.—*Corn: Yield per acre computed from census data of acreage and production, official estimates of the United States Department of Agriculture, and averages of yield per acre reported by crop correspondents on the county and township lists, by States, for stated years*

State	1879		1889		1899				1909				1919				1924			
	Official estimates	Census yields	Official estimates	Census yields	County reports	Township reports	Official estimates	Census yields	County reports	Township reports	Official estimates	Census yields	County reports	Township reports	Official estimates	Census yields	County reports	Township reports	Official estimates	Census yields
	Bush.	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*
Maine	30.0	31.0	36.0	35.0	35.1	34.2	36.0	38.3	36.5	-------	38.0	42.7	50.0	38.4	55.0	41.4	45.0	41.5	42.0	39.7
New Hampshire	32.5	36.9	36.5	41.6	34.1	38.6	39.0	42.1	34.7	-------	35.1	46.2	35.1	32.0	50.0	46.3	28.0	42.4	44.0	48.0
Vermont	36.0	36.5	35.0	40.7	42.5	36.0	36.0	38.3	43.1	-------	37.0	40.0	46.3	50.3	53.0	44.2	36.7	43.3	47.0	45.2
Massachusetts	36.0	34.2	34.3	39.1	43.8	37.5	36.0	39.4	35.6	-------	38.0	48.6	61.1	54.2	60.0	52.4	46.8	43.8	45.0	45.0
Rhode Island	32.0	31.4	31.3	32.5	31.5	43.6	31.0	35.4	30.0	-------	33.2	41.1	35.0	43.2	45.0	42.4	36.3	40.5	42.0	40.1
Connecticut	29.0	33.7	31.0	36.4	40.0	39.4	39.0	40.3	45.7	-------	41.0	48.0	49.0	45.5	60.0	48.5	38.9	33.9	43.0	39.9
New York	33.0	33.0	29.3	30.6	28.5	29.1	31.0	30.4	30.5	36.1	36.0	35.4	39.6	38.9	43.0	44.0	32.4	37.0	33.0	36.5
New Jersey	34.0	32.4	30.2	32.3	39.2	39.0	39.0	37.2	31.5	36.7	32.7	37.7	37.8	40.8	40.0	37.6	30.0	39.7	34.0	33.2
Pennsylvania	35.0	33.4	29.8	33.8	36.0	36.3	32.0	35.0	32.4	30.4	32.0	30.1	49.0	46.1	47.0	45.6	38.3	36.9	36.0	36.4
Ohio	35.0	34.1	29.6	35.7	36.5	36.2	36.8	39.7	39.6	38.7	39.5	40.2	40.8	43.6	44.0	42.1	27.0	28.8	26.0	27.5
Indiana	33.0	31.4	29.0	30.4	37.1	36.6	38.0	39.8	38.2	38.0	40.0	39.9	35.8	36.2	37.0	35.6	28.2	28.8	25.4	27.8
Illinois	35.0	36.1	32.3	36.8	34.9	34.8	36.0	38.8	34.6	35.8	35.9	38.8	32.7	33.0	35.0	36.1	31.7	34.1	32.0	33.4
Michigan	37.0	35.3	23.5	28.9	31.7	31.7	25.0	29.7	35.4	36.9	35.4	33.3	38.4	39.2	39.0	35.5	29.8	27.1	26.0	28.2
Wisconsin	39.0	33.7	26.3	30.4	33.3	33.5	35.0	35.6	34.2	35.0	33.0	33.7	51.9	42.7	47.0	38.7	28.7	27.2	26.0	25.1
Minnesota	35.0	33.8	28.5	27.4	32.7	34.3	33.0	32.8	34.5	34.9	34.8	33.9	37.7	40.0	40.0	35.6	28.1	30.9	28.0	26.5
Iowa	38.0	41.6	39.5	41.3	34.0	35.6	31.0	39.1	32.3	33.9	31.5	37.1	39.5	39.9	41.6	41.2	30.1	31.6	28.0	28.4
Missouri	37.0	31.2	32.2	32.4	25.8	27.5	26.0	28.1	34.5	26.4	26.4	26.9	26.6	26.0	27.0	26.3	25.0	26.5	26.0	23.5
North Dakota	-------	-------	-------	-------	30.4	23.6	23.0	20.6	34.6	34.0	31.0	26.7	30.4	29.1	33.0	20.3	22.6	21.5	20.0	19.2
South Dakota	-------	-------	-------	-------	27.2	24.8	26.0	27.1	29.9	30.8	31.7	27.3	30.0	26.2	28.5	25.1	21.6	23.2	22.0	20.6
Nebraska	41.0	40.1	36.5	39.4	27.4	26.8	28.0	28.8	25.8	23.8	24.8	24.8	23.4	24.4	26.2	23.9	24.9	25.4	24.2	21.2
Kansas	33.0	30.9	35.3	35.5	27.3	27.4	27.0	27.8	18.2	19.8	19.9	19.1	14.4	16.3	15.5	16.2	25.1	23.9	25.2	21.0
Delaware	27.0	19.3	17.5	17.7	20.5	27.1	22.0	24.7	16.9	34.0	31.0	25.6	20.0	39.5	30.0	21.6	25.0	31.2	27.0	23.9
Maryland	30.6	24.0	20.6	25.4	27.8	32.0	32.0	30.0	28.5	31.6	31.4	27.7	34.0	41.8	41.0	34.0	36.2	32.9	31.0	27.8
Virginia	19.0	16.5	15.9	17.0	20.5	20.9	20.0	19.2	21.8	23.3	23.2	20.6	25.1	28.6	28.0	23.4	20.6	22.6	21.0	20.8
West Virginia	31.0	24.9	22.4	23.2	26.0	26.0	26.0	22.9	27.4	31.0	31.4	25.3	32.0	37.3	34.0	29.9	25.6	30.3	28.0	23.3
North Carolina	15.0	12.2	12.0	10.9	13.3	13.1	13.0	12.8	15.3	16.7	16.8	13.8	18.5	20.7	19.0	17.7	17.6	18.3	18.0	15.8
South Carolina	7.5	9.0	11.5	10.2	7.8	9.0	9.0	9.8	14.4	16.1	16.7	13.3	15.9	19.3	16.0	15.7	17.2	11.7	11.5	12.1
Georgia	9.3	9.1	11.2	11.3	10.1	10.0	10.0	9.8	13.9	14.7	13.9	11.6	14.8	16.0	14.5	12.1	10.6	12.6	12.2	10.5
Florida	8.5	8.8	10.7	9.8	9.8	10.4	10.0	9.3	12.6	16.1	12.6	11.6	14.1	15.4	15.0	11.2	10.8	13.5	14.5	11.9
Kentucky	32.0	24.1	26.5	26.5	21.6	23.5	21.0	22.3	26.8	27.6	29.0	24.3	22.0	25.6	25.0	22.0	24.0	26.6	25.0	22.8
Tennessee	25.0	21.6	22.0	22.8	18.6	19.5	20.0	19.9	20.4	21.9	22.0	21.5	23.0	25.3	23.0	21.4	21.4	21.9	22.0	21.0
Alabama	13.0	12.4	13.5	14.1	15.5	12.4	12.0	12.8	12.4	14.6	13.5	11.9	15.6	16.2	14.5	13.1	12.8	13.0	13.0	12.0
Mississippi	16.0	13.6	14.8	15.3	15.9	16.1	16.0	17.0	14.4	15.4	14.5	13.1	15.1	17.0	15.0	14.3	10.3	12.0	12.0	12.1
Arkansas	24.0	18.6	20.0	20.6	20.2	19.7	20.0	19.0	15.3	19.2	18.0	16.5	19.6	18.1	18.0	14.9	17.2	17.0	16.5	15.3
Louisiana	15.0	13.3	17.5	15.6	14.9	17.0	18.0	16.4	18.5	23.0	23.0	16.4	17.9	16.7	17.5	14.4	11.5	11.3	11.5	11.1
Oklahoma	-------	-------	-------	-------	30.4	26.4	19.0	27.6	16.1	16.1	17.0	15.9	22.7	24.2	24.0	21.8	21.4	20.7	20.5	17.8
Texas	13.0	11.8	18.3	22.4	21.3	22.4	18.0	21.9	14.3	15.9	15.0	14.7	28.8	29.5	30.0	22.8	17.8	17.2	17.0	15.0
Montana	-------	-------	-------	-------	22.8	33.7	23.0	23.0	-------	43.7	35.0	28.8	-------	16.6	13.5	8.5	17.1	18.6	18.0	14.0
Idaho	-------	-------	-------	-------	-------	-------	-------	-------	37.6	34.5	30.6	34.6	26.6	33.2	35.0	27.5	22.8	35.4	35.0	30.7
Wyoming	-------	-------	-------	-------	26.2	22.0	22.0	19.2	25.0	-------	28.0	19.0	12.0	14.6	16.0	10.1	11.2	19.5	14.0	10.5
Colorado	-------	-------	25.4	12.7	15.8	15.6	17.0	15.0	22.6	24.2	24.2	15.0	14.6	22.9	16.7	13.4	13.6	14.3	10.0	9.4
New Mexico	-------	-------	20.0	20.4	25.4	15.3	20.0	16.4	32.4	20.0	31.3	13.5	25.1	24.2	30.0	20.9	23.4	15.3	20.0	13.2
Arizona	-------	-------	-------	-------	-------	-------	-------	-------	32.1	32.1	32.1	19.1	20.0	29.4	33.0	20.1	22.9	20.9	30.0	13.3
Utah	-------	-------	18.3	14.7	22.3	24.3	20.0	21.7	33.3	28.0	31.4	23.4	33.1	27.5	18.0	19.2	30.0	29.4	26.0	22.9
Nevada	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	24.0	50.0	30.0	26.9	50.0	35.5	27.0	25.0
Washington	-------	-------	-------	-------	15.0	22.5	23.0	20.9	29.5	27.8	27.8	21.6	58.0	29.7	36.0	25.9	31.6	39.5	33.5	29.8
Oregon	32.0	22.5	20.0	19.7	20.0	26.8	22.0	21.2	19.6	31.5	30.7	26.1	30.4	28.3	26.2	26.5	31.7	31.2	30.5	30.2
California	28.0	27.8	28.2	33.9	27.3	31.5	27.0	27.4	34.3	31.8	34.8	24.5	-------	-------	-------	-------	36.4	22.9	35.0	30.7
United States	29.2	28.1	27.0	29.4	-------	-------	25.3	28.1	-------	-------	25.5	25.9	-------	-------	28.6	26.7	-------	-------	23.2	22.2

The indications of yield per acre from the census are available for six years—1879, 1889, 1899, 1909, 1919, and 1924. The yields as reported by the county list of crop reporters and also by the township list are obtainable for only the four years—1899, 1909, 1919, and 1924. The four indications concerning yield per acre (1) those derived from the census, (2) those from the county reporters, (3) those from the township reporters, and (4) the official estimates, for wheat, corn, oats, flaxseed, cotton, and tobacco are shown in Tables 36 to 41, respectively.

This analysis is designed primarily to answer two questions:

(1) How closely do the yields obtained by the methods of sampling used by the department check in an absolute sense with the yields derived from census data? That is, how closely do the yields per acre obtained by the two methods compare when checked directly, one with the other, for a given crop, in a certain State, for a given year?

(2) What degree of correlation is there between the yields per acre derived from census data and the official estimates of yield, as well as between census yields and the two indications from sample data? Although the yield reports by States obtained by one method, might be generally higher than the reports obtained by the other, because of bias in the individual observations of the sample, or to inherent limitations in the census material, either one indication or the other might reflect relative differences as between different States, or as between different years in the same State. The correlation coefficient is used here in its generic sense of measuring the covariation between two variables, both of which are measurements of the same physical phenomena, agricultural yields per acre in given States. No causal relationship between the variables is involved.

This analysis will serve to show also how closely the small sample of county reports, weighted by county weights, compares with the larger sample of township reports, unweighted in 1899 and 1909 and weighted by districts in most cases in 1919 and 1924. The correlation of these two separate indications from sample returns will be of assistance in evaluating the dependability of the county samples of crop yields per acre. This correlation bears directly on the reliability of these estimates of yield made prior to 1896, when returns were first obtained from the township list of crop correspondents, and while the county sample was the chief source and basis of the official estimates of all kinds. Prior to 1882 the samples of reports from county correspondents were the basis of these estimates.

In making the comparisons of yields per acre on an absolute basis, the States are divided into three mutually exclusive categories: the States where the yield data from any two sources check within (1) States where the yield data from any two sources check within 1 bushel for grain crops, 0.5 bushel for flaxseed, 10 pounds or less for cotton and 50 pounds or less for tobacco, (2) States where the estimates or sample averages of yields are higher by more than these amounts than those derived from census data, and (3) States where estimates or sample averages and of yields are lower by more than these amounts than the census yields. The number of States falling within each of these three categories is then expressed as a percentage of the total number of States involved in the comparison. The sum of these three percentage figures would therefore be 100. A fourth category, not mutually exclusive so far as the other three are con-

cerned, includes the States for which the yield data from any two sources check within 2 bushels or less for grain crops, 1 bushel for flaxseed, 20 pounds or less for cotton, and 100 pounds or less for tobacco. The number of cases falling in this fourth category is expressed as a percentage of the total number of cases included in the comparison.

This analysis shows the percentage of cases in which official estimates of yields per acre and census yields check within 1 bushel for wheat, corn and oats, the percentage of cases in which they check within 2 bushels, and whether there is a tendency for estimates to be higher or lower than the census yields. A similar comparison is made between census yields and yields as reported by the county reporters, and also between census yields and yields reported by reporters on the township lists.

In Table 42 these comparisons are made for all years by geographic groups of States. This makes it possible to differentiate between various sections of the country in drawing conclusions. In Table 43 all States are combined for each given year, thereby making it possible to study each census year separately and to note any changes taking place with the passage of time.

TABLE 38.—*Oats: Yield per acre computed from census data of acreage and production, official estimates of the United States Department of Agriculture, and averages of yield per acre reported by crop correspondents on the county and township lists, by States, for census years, 1879–1924*

State	1879		1889		1899				1909				1919				1924			
	Official estimates	Census yields	Official estimates	Census yields	County reports	Township reports	Official estimates	Census yields	County reports	Township reports	Official estimates	Census yields	County reports	Township reports	Official estimates	Census yields	County reports	Township reports	Official estimates	Census yields
	Bush.	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*
Maine	30.0	28.8	29.4	30.2	37.0	34.7	35.0	35.0	32.3	-------	37.0	35.0	38.8	33.1	34.0	30.9	38.7	37.5	37.0	37.9
New Hampshire	35.0	34.5	30.5	33.5	32.9	35.1	35.0	39.5	37.5	-------	31.5	35.6	35.0	36.5	37.0	33.0	40.0	36.1	39.0	39.4
Vermont	33.0	37.6	31.5	32.6	41.3	36.6	37.0	37.4	36.7	-------	32.2	29.9	34.9	35.0	36.0	28.8	39.9	41.2	38.0	34.1
Massachusetts	31.0	31.2	27.2	27.1	34.9	36.6	33.0	36.0	20.0	-------	31.0	33.9	40.0	36.0	38.0	30.2	20.0	34.9	34.0	36.7
Rhode Island	24.0	28.6	26.5	27.6	24.5	25.2	26.0	30.8	25.0	-------	25.0	27.9	-------	31.0	34.0	28.4	22.0	30.0	30.0	36.4
Connecticut	23.0	27.5	25.6	24.3	28.3	-------	28.0	32.0	23.1	-------	27.5	26.8	29.7	32.0	31.0	27.1	28.5	31.4	29.0	29.1
New York	31.0	29.8	26.0	27.4	29.1	31.0	31.0	30.7	28.0	28.4	28.2	26.7	24.5	25.5	25.5	23.0	35.8	36.8	36.0	33.2
New Jersey	32.0	27.0	23.6	23.4	26.4	23.9	24.0	21.1	24.7	27.6	25.5	19.1	27.8	29.9	30.0	20.8	30.0	34.9	32.0	27.2
Pennsylvania	31.0	27.3	26.2	27.6	33.3	32.5	33.0	31.7	28.7	25.9	26.0	24.6	30.9	28.9	31.0	24.8	33.5	36.6	36.0	33.7
Ohio	29.9	31.5	31.3	33.0	35.3	35.5	36.0	37.7	32.7	31.7	32.5	32.2	33.3	31.8	33.5	32.2	37.2	43.5	41.0	41.0
Indiana	28.3	25.0	28.2	28.6	33.0	32.8	32.0	34.0	28.2	29.3	30.5	30.3	32.0	31.0	33.0	30.6	37.0	36.6	38.0	26.3
Illinois	32.0	32.2	37.5	35.6	37.5	36.9	38.0	39.5	34.1	33.0	36.6	36.0	30.1	28.1	30.0	30.1	40.0	38.4	40.0	39.2
Michigan	32.2	33.9	32.7	34.0	32.6	34.1	34.0	35.6	29.1	30.2	30.5	30.7	23.7	24.6	25.0	24.4	40.0	42.3	42.0	39.8
Wisconsin	39.0	34.4	34.5	37.3	36.4	34.4	36.0	35.5	36.3	35.1	35.0	33.0	32.9	32.1	33.4	30.3	38.3	40.0	40.0	35.5
Minnesota	35.0	37.9	34.0	31.6	34.3	33.6	32.0	33.6	31.8	32.9	33.0	31.5	25.9	27.9	28.0	26.0	41.4	42.7	43.0	41.6
Iowa	36.0	33.6	36.3	39.1	35.6	35.1	33.0	35.9	26.9	27.8	27.0	27.5	33.8	32.9	34.6	34.1	38.3	41.7	43.0	39.4
Missouri	24.6	21.3	25.5	23.7	24.6	26.5	25.0	22.4	25.6	26.5	27.0	23.1	27.0	27.1	27.0	23.7	23.4	25.2	27.5	20.9
North Dakota	-------	-------	18.7	14.3	30.6	29.5	30.0	28.3	28.6	32.6	32.0	30.7	14.9	14.9	16.0	14.6	31.3	32.7	34.0	30.1
South Dakota	-------	-------	-------	-------	26.3	28.3	26.0	28.1	27.8	30.0	30.0	28.0	29.4	27.1	29.0	27.8	36.6	36.6	37.0	35.2
Nebraska	32.0	26.2	27.6	29.2	27.3	28.0	30.0	30.1	24.7	24.9	25.0	22.6	32.6	31.4	32.8	29.5	29.1	31.2	31.0	26.7
Kansas	25.0	18.8	26.5	30.5	27.2	30.2	29.0	27.2	27.4	26.8	28.2	24.6	28.3	28.4	28.1	25.6	26.6	27.2	26.0	23.0
Delaware	22.0	22.1	18.3	19.8	15.0	27.8	20.0	25.1	20.0	20.7	25.5	23.2	20.0	15.0	23.0	14.9	-------	31.4	30.0	29.4
Maryland	23.0	17.7	18.7	20.4	22.1	25.9	23.0	24.9	25.4	26.6	25.4	23.6	33.8	26.4	28.0	22.2	26.3	35.6	34.0	29.2
Virginia	12.0	9.5	13.5	11.5	14.6	14.8	14.0	11.9	18.7	18.9	19.0	14.1	19.5	22.2	22.0	14.4	22.2	25.0	23.5	19.2
West Virginia	22.3	15.0	17.2	16.3	23.8	21.9	23.0	18.4	22.0	21.5	22.0	16.7	21.2	25.0	25.0	18.0	24.3	27.2	26.0	23.1
North Carolina	16.0	7.7	10.2	8.3	11.4	12.2	12.0	9.1	16.7	15.6	16.5	12.2	19.2	18.5	11.7	13.3	23.4	19.9	18.0	15.5
South Carolina	15.0	10.4	10.5	9.8	10.0	12.9	12.0	12.0	17.9	22.7	21.0	17.7	20.8	25.5	23.0	18.4	22.1	21.3	21.4	20.2
Georgia	15.0	9.1	11.0	9.2	10.1	11.4	9.0	9.8	20.3	19.5	19.0	15.1	16.8	19.6	20.0	14.7	19.6	18.1	17.0	14.7
Florida	16.0	9.8	10.5	9.3	9.8	10.6	9.0	9.5	16.5	18.6	17.0	14.0	15.7	16.2	19.0	12.9	12.0	14.8	15.0	13.2
Kentucky	16.8	11.4	18.5	13.6	16.9	18.7	18.0	12.7	18.7	21.6	22.3	13.8	21.7	22.7	22.5	12.2	20.7	23.8	23.2	19.3
Tennessee	18.0	10.1	11.5	12.5	14.0	15.4	14.0	11.6	19.7	19.8	20.0	13.8	22.3	22.6	23.0	14.9	20.8	23.4	22.0	18.3
Alabama	17.0	9.4	9.5	9.4	10.9	11.7	10.0	8.7	16.4	17.2	16.5	12.6	15.3	19.1	18.0	13.1	19.8	19.4	15.0	14.5
Mississippi	11.6	9.9	10.2	10.2	12.2	11.5	10.0	9.9	13.7	16.4	16.0	13.1	16.2	17.6	19.0	14.3	19.7	18.7	18.0	15.8
Arkansas	23.2	13.3	16.5	14.5	22.4	18.9	19.0	14.0	20.8	23.0	22.8	16.3	24.1	21.1	22.0	15.6	23.2	21.6	20.0	18.5
Louisiana	14.0	8.6	9.4	11.0	18.2	24.1	18.0	11.3	18.6	18.4	20.0	14.1	16.7	19.2	22.0	14.6	22.5	22.3	20.0	20.6
Oklahoma	-------	-------	-------	-------	-------	-------	-------	-------	26.3	28.8	29.0	27.3	32.1	32.0	33.0	28.9	26.0	26.2	27.0	22.5
Texas	25.0	20.6	22.7	23.8	25.8	27.8	25.0	28.6	16.2	13.5	18.7	16.0	42.6	40.5	42.0	34.3	33.4	37.6	34.0	29.7
Montana	-------	-------	30.0	29.1	38.0	39.3	38.0	35.4	51.8	-------	51.3	41.4	15.4	12.7	10.0	13.5	39.6	30.8	29.5	25.9
Idaho	-------	-------	28.0	26.7	30.3	34.0	34.0	30.2	43.6	45.2	44.5	37.4	27.2	31.9	35.0	21.7	34.3	35.0	36.0	26.3
Wyoming	-------	-------	-------	26.6	30.4	34.1	30.0	28.4	33.5	-------	35.0	27.1	13.6	15.4	18.0	17.2	29.9	33.4	31.0	23.5
Colorado	-------	-------	32.0	28.6	33.8	32.1	27.0	25.5	42.3	33.6	38.0	27.7	28.5	32.3	26.2	26.0	37.8	34.4	25.0	25.3
New Mexico	-------	-------	21.0	20.8	24.2	21.9	24.0	21.6	43.7	33.1	40.0	21.4	22.8	32.1	36.0	27.1	19.3	24.5	24.0	15.6
Arizona	-------	-------	-------	-------	-------	-------	-------	-------	33.0	33.9	37.0	32.3	35.0	41.2	41.0	31.8	-------	41.5	35.0	22.3
Utah	-------	-------	25.0	26.3	33.6	36.2	34.0	33.1	43.6	-------	46.1	39.9	45.2	37.2	34.0	27.9	54.1	45.7	40.0	32.8
Nevada	-------	-------	-------	-------	-------	-------	-------	-------	36.5	-------	40.0	42.7	13.2	30.0	32.0	25.2	30.0	32.8	34.0	30.5
Washington	-------	-------	31.0	34.9	36.6	42.4	37.0	42.1	42.7	47.4	49.0	49.0	22.9	39.1	40.0	42.1	25.5	39.5	39.5	38.6
Oregon	36.0	28.9	25.7	27.2	26.6	30.3	30.0	25.7	32.1	34.4	37.8	32.1	26.7	37.5	32.0	29.4	22.7	35.7	31.0	27.8
California	33.0	26.9	25.0	25.4	33.5	30.7	31.0	32.3	29.4	27.5	31.4	21.6	-------	-------	-------	-------	32.2	22.9	23.5	18.2
United States	28.7	25.3	27.4	28.6	-------	-------	30.2	31.9	-------	-------	30.3	28.6	-------	-------	29.4	27.8	-------	-------	36.3	34.7

TABLE 39.—*Flaxseed: Yield per acre computed from census data of acreage and production, official estimates of the United States Department of Agriculture, and averages of yield per acre reported by crop correspondents on the county and township lists, by States, for stated years*

State	1909				1919				1924			
	County reports	Township reports	Official estimates	Census yields	County reports	Township reports	Official estimates	Census yields	County reports	Township reports	Official estimates	Census yields
	Bush.	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*
Minnesota	9.4	10.1	10.0	9.1	8.9	8.3	9.0	7.0	11.4	12.3	11.4	10.9
Iowa	9.6	11.0	9.8	9.1	10.9	9.9	9.5	6.3	10.2	12.5	11.7	9.9
North Dakota	9.2	9.7	9.3	9.6	4.7	5.0	5.0	4.6	7.8	8.4	8.5	7.4
South Dakota	8.5	9.5	9.4	9.2	7.9	8.0	8.0	7.0	8.8	8.8	8.9	8.3
Kansas	6.8	7.6	7.0	6.7	8.0	5.6	6.3	5.9	-------	6.2	7.0	5.9
Montana	-------	10.0	12.0	11.9	1.8	1.9	1.7	2.5	7.0	8.8	8.9	7.1
United States	-------	-------	9.4	9.4	-------	-------	5.3	5.3	-------	-------	9.2	8.2

TABLE 40.—*Cotton: Yield of lint per acre, computed from census data of acreage and production, official estimates of the United States Department of Agriculture, and averages of yield per acre reported by crop correspondents on the county and township lists, by States, for stated years*

Group of States and State	1879		1889		1899				1909				1919				1924			
	Official estimates	Census yields	Official estimates	Census yields	County reports	Township reports	Official estimates	Census yields	County reports	Township reports	Official estimates	Census yields	County reports	Township reports	Official estimates	Census yields	County reports	Township reports	Official estimates	Census yields
	Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
South Atlantic:																				
Virginia	------	------	83	62	180	199	120	187	104	180	190	193	200	263	255	248	154	162	180	193
North Carolina	156	183	98	127	181	168	193	204	193	211	210	235	241	243	266	287	188	168	196	224
South Carolina	143	161	141	170	148	156	165	191	146	199	210	231	210	220	240	261	153	150	160	193
Georgia	156	131	155	161	152	151	159	168	177	182	184	191	140	151	152	170	152	153	157	177
Florida	105	85	139	102	142	128	94	115	99	119	110	104	29	54	74	78	59	129	130	115
South Central:																				
Missouri	------	------	------	------	259	230	195	281	300	258	271	279	265	295	257	293	120	205	185	192
Tennessee	268	201	89	115	137	151	166	178	184	148	158	167	147	184	195	187	149	165	170	182
Alabama	170	130	163	150	131	150	176	163	136	133	142	141	120	139	122	128	155	154	154	158
Mississippi	186	201	165	184	178	193	209	210	151	147	157	159	163	166	160	155	179	180	176	174
Arkansas	275	253	217	189	159	152	193	201	141	161	153	176	157	166	155	166	115	166	169	188
Louisiana	202	257	180	240	252	176	238	246	133	148	130	131	84	88	93	108	142	136	145	165
Oklahoma	------	------	------	------	------	------	------	------	120	138	147	132	177	191	195	179	163	181	187	192
Texas	175	174	169	171	137	151	185	169	120	120	125	122	125	124	140	130	127	131	138	142
United States	188.0	172.8	158.8	168.7	------	------	183.8	180.3	------	------	154.8	156.6	------	------	161.5	163.9	------	------	157.4	166.6

TABLE 41.—*Tobacco: Yield per acre computed from census data of acreage and production, official estimates of the United States Department of Agriculture, and averages of yield per acre reported by crop correspondents on the county and township lists, by States for stated years*

Group of States and State	1879		1889		1899				1909				1919				1924			
	Official estimates	Census yields	Official estimates	Census yields	County reports	Township reports	Official estimates	Census yields	County reports	Township reports	Official estimates	Census yields	County reports	Township reports	Official estimates	Census yields	County reports	Township reports	Official estimates	Census yields
	Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Northern:																				
Massachusetts	1,500	1,599	1,580	1,389	1,755	1,621	1,850	1,674	1,500	------	1,600	1,730	1,770	1,400	1,540	1,568	1,629	1,283	1,310	1,389
Connecticut	1,400	1,621	1,600	1,402	1,549	1,392	1,600	1,673	1,702	------	1,650	1,752	1,427	1,689	1,560	1,567	1,550	1,315	1,315	1,335
New York	1,315	1,313	1,150	1,060	840	1,104	1,050	1,234	------	1,048	1,175	1,301	1,350	1,303	1,290	1,284	1,800	1,178	1,175	1,136
Pennsylvania	1,459	1,340	1,280	1,074	1,089	1,169	1,100	1,495	941	881	985	1,106	1,300	1,325	1,320	1,308	1,100	1,316	1,300	1,258
Ohio	671	1,002	806	854	929	713	775	923	895	908	925	832	809	901	860	850	668	777	650	702
Indiana	840	742	608	823	846	772	700	837	1,145	955	950	903	751	944	850	835	814	881	877	890
Wisconsin	1,033	1,204	1,020	1,125	1,334	1,262	1,300	1,345	1,008	1,065	1,180	1,160	1,213	1,254	1,270	1,265	978	892	940	928
Southern:																				
Missouri	663	774	735	830	500	820	720	698	943	724	885	989	600	866	1,000	908	586	1,084	1,000	895
Maryland	633	683	400	609	647	689	810	573	677	693	710	685	719	685	675	607	847	733	765	709
Virginia	763	568	475	439	752	719	690	667	794	746	775	717	512	569	570	454	550	621	650	598
West Virginia	658	564	700	560	437	512	500	602	652	894	875	801	800	832	700	675	------	618	800	731
North Carolina	556	472	443	375	594	577	560	628	596	611	600	626	496	613	560	610	525	544	560	583
South Carolina	------	------	------	------	750	------	750	765	800	770	800	850	702	808	600	688	297	456	440	491
Georgia	------	------	------	------	565	------	400	480	973	600	700	734	770	672	530	422	779	890	761	782
Florida	------	------	------	------	486	------	490	547	779	500	710	879	------	925	950	1,043	1,000	462	800	842
Kentucky	793	757	700	808	737	775	730	817	853	838	835	848	765	781	830	798	690	749	834	779
Tennessee	800	707	530	707	701	661	600	684	747	709	730	760	757	813	800	811	680	720	750	795
United States	795	740	645	702	------	------	739.2	788.0	------	------	804.3	815.0	------	------	730.8	737.0	------	------	733.6	719.4

TABLE 42.—*Percentage of cases in which official estimates of yield per acre, averages of yield reported by county correspondents, and averages of yields reported by township correspondents compared with yields derived from census data, by commodities, geographic groups of States,[1] and stated years*

Crops and group of States	Official estimates, 1879–1924				Official estimates, 1899–1924				County reports, 1899–1924				Township reports, 1899–1924			
	Within 1 bushel	Lower by 1 bushel or more	Higher by 1 bushel or more	Within 2 bushels	Within 1 bushel or more	Lower by 1 bushel or more	Higher by 1 bushel or more	Within 2 bushels	Within 1 bushel	Lower by 1 bushel or more	Higher by 1 bushel or more	Within 2 bushels	Within 1 bushel	Lower by 1 bushel or more	Higher by 1 bushel or more	Within 2 bushels
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Winter wheat:																
Northern	52	25	23	85	64	19	17	91	45	40	15	92	53	28	19	83
Southern	54	18	28	76	61	14	25	83	44	28	28	89	50	17	33	78
Northern and Southern	53	22	25	81	63	17	20	88	45	35	20	90	52	23	25	81
Spring wheat:																
Three States	93	7	0	100	92	8	0	100	42	50	8	92	83	17	0	100
Corn:																
North Atlantic	20	48	32	39	17	44	39	33	14	53	33	25	25	50	25	47
North Central	32	24	34	59	36	29	35	58	27	33	40	54	25	29	46	48
South Atlantic	31	8	61	46	28	3	69	38	31	19	50	59	12	0	88	28
South Central	37	9	54	67	34	10	56	66	34	19	47	66	38	3	59	53
Far Western	20	6	74	26	15	5	80	26	18	13	69	31	8	5	87	15
United States	28	23	49	48	26	19	55	44	25	28	47	46	21	19	60	39
Oats:																
North Atlantic	22	32	46	43	19	25	56	31	11	31	58	28	17	28	55	28
North Central	19	25	56	56	25	15	60	62	37	23	40	58	29	19	52	58
South Atlantic	15	10	75	38	13	9	78	28	9	19	72	31	9	3	88	25
South Central	15	7	78	29	13	3	84	23	10	3	87	16	3	3	94	13
Far Western	18	16	66	29	15	12	73	22	15	24	61	22	10	12	78	19
United States	18	19	63	41	18	13	69	35	18	21	61	33	15	14	71	31
	Within 0.5 bushel	Lower by 0.5 bushel or more	Higher by 0.5 bushel or more	Within 1 bushel	Within 0.5 bushel	Lower by 0.5 bushel or more	Higher by 0.5 bushel or more	Within 1 bushel	Within 0.5 bushel	Lower by 0.5 bushel or more	Higher by 0.5 bushel or more	Within 1 bushel	Within 0.5 bushel	Lower by 0.5 bushel or more	Higher by 0.5 bushel or more	Within 1 bushel
Flaxseed:[2] 3 States					39	6	55	67	63	12	25	81	33	11	56	67
	Within 10 pounds	Lower by 10 pounds or more	Higher by 10 pounds or more	Within 20 pounds	Within 10 pounds	Lower by 10 pounds or more	Higher by 10 pounds or more	Within 20 pounds	Within 10 pounds	Lower by 10 pounds or more	Higher by 10 pounds or more	Within 20 pounds	Within 10 pounds	Lower by 10 pounds or more	Higher by 10 pounds or more	Within 20 pounds
Cotton:																
South Atlantic	34	59	17	48	30	65	5	55	10	85	5	20	5	70	25	35
South Central	42	32	26	77	52	29	19	93	39	55	6	45	29	55	16	77
United States	36	43	21	65	45	43	12	78	27	67	6	33	20	61	19	61
	Within 50 pounds	Lower by 50 pounds or more	Higher by 50 pounds or more	Within 100 pounds	Within 50 pounds	Lower by 50 pounds or more	Higher by 50 pounds or more	Within 100 pounds	Within 50 pounds	Lower by 50 pounds or more	Higher by 50 pounds or more	Within 100 pounds	Within 50 pounds	Lower by 50 pounds or more	Higher by 50 pounds or more	Within 100 pounds
Tobacco:																
Northern	40	41	19	57	54	39	7	68	30	40	30	52	27	46	27	62
Southern	39	30	31	74	45	27	28	82	34	37	29	60	40	30	30	62
Northern and Southern	40	34	26	67	49	32	19	76	32	39	29	57	35	36	29	62

[1] The number of cases (States by years) in each category is expressed as a percentage of all cases included in the comparison.
[2] States in the groups designated are shown in Tables 36–41.
[3] 1909–1924.

TABLE 43.—*Percentage of cases in which official estimates of yield per acre, averages of yields, reported by county correspondents, and averages of yields reported by township correspondents compared with yields derived from census data, by commodities and stated years* [1]

Crop and year	Official estimates				County reports				Township reports			
	Within 1 bushel	Lower by 1 bushel or more	Higher by 1 bushel or more	Within 2 bushels	Within 1 bushel	Lower by 1 bushel or more	Higher by 1 bushel or more	Within 2 bushels	Within 1 bushel	Lower by 1 bushel or more	Higher by 1 bushel or more	Within 2 bushels
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Winter wheat:												
1879	30	0	70	65								
1889	35	65	0	70								
1899	60	35	5	85	40	60	0	90	65	30	5	90
1909	57	14	29	95	43	24	33	66	33	19	48	66
1919	71	0	29	90	52	19	29	90	53	14	33	81
1924	62	19	19	81	43	38	19	76	57	29	14	86
Corn:												
1879	30	14	56	53								
1889	36	49	15	59								
1899	38	42	20	58	31	42	27	55	29	31	40	60
1909	24	21	55	34	21	32	47	36	21	19	60	30
1919	13	2	85	34	26	19	55	47	13	13	74	23
1924	31	13	56	52	21	19	60	48	23	12	65	42
Oats:												
1879	11	17	72	25								
1889	26	44	30	79								
1899	22	36	42	51	22	33	45	42	29	22	49	47
1909	15	8	77	33	21	23	56	29	8	19	73	27
1919	11	6	83	21	11	11	78	26	15	8	77	28
1924	23	4	73	35	19	17	64	35	8	6	86	23
	Within 0.5 bushel	Lower by 0.5 bushel	Higher by 0.5 bushel	Within 1 bushel	Within 0.5 bushel	Lower by 0.5 bushel	Higher by 0.5 bushel	Within 1 bushel	Within 0.5 bushel	Lower by 0.5 bushel	Higher by 0.5 bushel	Within 1 bushel
Flaxseed:												
1909	67	0	33	100	80	20	0	100	33	17	50	67
1919	33	17	50	67	17	17	66	50	33	17	50	83
1924	17	0	83	33	100	0	0	100	33	0	67	50
	Within 50 pounds	Lower by 50 pounds	Higher by 50 pounds	Within 100 pounds	Within 50 pounds	Lower by 50 pounds	Higher by 50 pounds	Within 100 pounds	Within 50 pounds	Lower by 50 pounds	Higher by 50 pounds	Within 100 pounds
Tobacco:												
1879	21	36	43	57								
1889	14	43	43	29								
1899	23	65	12	59	35	41	24	71	14	64	22	57
1909	47	35	18	65	44	31	25	56	27	53	20	67
1919	65	12	23	88	25	37	38	56	41	12	47	53
1924	59	18	23	94	25	44	31	44	53	24	23	71
	Within 10 pounds	Lower by 10 pounds or more	Higher by 10 pounds or more	Within 20 pounds	Within 10 pounds	Lower by 10 pounds or more	Higher by 10 pounds or more	Within 20 pounds	Within 10 pounds	Lower by 10 pounds or more	Higher by 10 pounds or more	Within 20 pounds
Cotton (lint):												
1879	10	40	50	30								
1889	18	46	36	36								
1899	33	42	25	67	17	75	8	25	0	83	17	50
1909	69	23	8	77	39	46	15	46	31	54	15	69
1919	46	46	8	77	39	61	0	39	31	38	31	69
1924	31	61	8	85	15	85	0	23	15	70	15	54

[1] The number of cases (States by years) in each category is expressed as a percentage of all cases included in the comparison. Figures are for States in groups shown in Tables 36-41.

TABLE 44.—*Coefficients of correlation between yields derived from census data and official estimates of the United States Department of Agriculture, averages of yields per acre reported by county correspondents, averages of yields reported by township correspondents, for stated years*

Crop and group of States[1]	Census yields and official estimates					Census yields and averages of county reports					Census yields and averages of township reports					County and township reports				
	1899	1909	1919	1924	4 years	1899	1909	1919	1924	4 years	1899	1909	1919	1924	4 years	1899	1909	1919	1924	4 years
Winter wheat:																				
Northern	0.954	0.967	0.929	0.883	0.945	0.973	0.939	0.883	0.791	0.919	0.973	0.931	0.893	0.836	0.900	0.994	0.952	0.949	0.858	0.958
Southern	.980	.950	.793	.947	.907	.939	.943	.864	.927	.878	.973	.566	.869	.894	.856	.915	.637	.958	.830	.878
Northern and Southern	.950	.966	.943	.818	.947	.931	.951	.926	.920	.929	.955	.889	.940	.925	.918	.956	.938	.977	.901	.955
Spring wheat:																				
Three States	—	—	—	—	.989	—	—	—	—	.958	—	—	—	—	.996	—	—	—	—	.976
Corn:																				
North Atlantic	.831	.710	.744	.873	.722	.610	.502	.636	.141	.532	.497	.435	.482	.625	.550	.263	.882	.724	.162	.668
North Central	.910	.913	.902	.913	.884	.811	.855	.853	.931	.848	.948	.891	.929	.930	.915	.872	.976	.934	.880	.937
South Atlantic and South Central	.905	.969	.909	.985	.930	.951	.882	.955	.950	.992	.986	.953	.844	.982	.978	.935	.803	.840	.927	.869
Far Western	.897	.455	.853	.872	.755	.340	.478	.622	.691	.600	.900	.782	.792	.830	.788	.310	.612	.310	.646	.507
United States	.964	.855	.956	.954	.915	.932	.803	.867	.982	.850	.960	.865	.875	.934	.891	.894	.899	.800	.845	.852
Oats:																				
North Atlantic	.853	.798	.835	.563	.691	.681	.395	.814	.175	.427	.854	.330	.832	.180	.572	.899	.971	.848	.755	.800
North Central	.950	.948	.975	.978	.944	.933	.875	.965	.972	.949	.960	.914	.946	.977	.942	.965	.906	.977	.948	.943
South Atlantic and South Central	.856	.903	.923	.966	.879	.727	.790	.918	.880	.830	.881	.774	.932	.960	.904	.808	.878	.899	.878	.876
Far Western	.897	.791	.830	.804	.805	.817	.446	.403	.221	.470	.896	.816	.360	.704	.806	.853	.801	.682	.577	.718
United States	.961	.899	.891	.927	.906	.929	.811	.742	.672	.795	.950	.872	.892	.875	.892	.947	.954	.803	.826	.890
Flaxseed:																				
Six States	—	.964	.944	.964	.928	—	.862	.894	.993	.822	—	.621	.897	.958	.883	—	.914	.953	.932	.914
Cotton:																				
Southern	.726	.981	.734	.911	.929	.877	.778	.955	.715	.875	.825	.977	.958	.665	.906	.786	.800	.966	.374	.818
Tobacco:																				
Northern	.917	.978	.999	.985	.942	.840	.876	.955	.804	.799	.946	.929	.948	.972	.916	.892	.965	.820	.785	.823
Southern	.655	.740	.917	.936	.848	.595	.574	.472	.089	.603	.749	.168	.871	.632	.576	.680	.089	.696	.127	.307
United States	.941	.972	.986	.980	.962	.928	.911	.914	.884	.885	.961	.913	.962	.909	.918	.936	.889	.914	.756	.858

1 States in the groups designated are shown in Tables 36–41.

In approaching the problem of a relative comparison of the different indications of yield per acre, simple correlation coefficients between the two series of yield per acre are calculated by States, for a given geographic division for each census year. Additional correlation coefficients are calculated for all the years combined for a geographic division; also other correlation coefficients for all States for any one year; and, finally, a single correlation coefficient for each crop in which all States for all years are included. These correlation coefficients appear in Table 44.

A comparison between the yields as reported by the county correspondents and the yields as reported by the township list was also made by means of simple correlation coefficients shown in Table 44.

These correlation coefficients are not corrected for the influence of the size of sample, which is small for any one group of States in a single year, and some allowance should be made for this when interpreting the results of their comparison.

WHEAT

For comparative purposes the States that are almost entirely winter-wheat States are divided into two groups (1) Northern and Great Plains States and (2) Southern States, whereas the States that have grown both spring and winter wheat, such as Iowa, Wisconsin, Montana, and the far Western States, are excluded from the comparison because of the possibility of confusion on the part of the farmer in reporting the two kinds of wheat separately either to the census enumerator or as a crop reporter. Separate comparisons are made for the three most important and almost exclusively spring-wheat States of North Dakota, South Dakota, and Minnesota. (See Table 36 for the States included in these three different groups.) The yield per acre of winter wheat as reported by crop reporters and as officially estimated by the department in the winter-wheat States is compared with the yield per acre of all wheat as reported by the census in these States, and spring wheat in the three spring-wheat States is compared with all wheat from the census.

Official estimates of yield per acre of winter wheat check more closely with yields derived from census data during the last four census years than when the two early census years, 1879 and 1889, are included in the comparison. The official estimates of the yields of winter wheat check within 1 bushel with the yields as derived from census data in 53 per cent of the cases, and within 2 bushels in 81 per cent of the cases, when all six census years are included in the comparison; but when the comparison is limited to the last four census years, these two indications check within 1 bushel in 63 per cent and within 2 bushels in 88 per cent of the cases. (Table 42.) In 1879 the estimates were based primarily on yield data as reported by county crop correspondents and weighted by county weights. By 1889 the reports from the part-time State agents supplemented the reports from the list of county reporters. By 1899 reports from the township list of reporters, unweighted, were included as an additional basis for the official estimates.

The yields from official estimates and from census check a little more closely on the basis of direct comparison in the Northern States than in the Southern States during the last four census years. This slight difference in favor of the Northern States becomes even more significant when the higher average yields per acre in the Northern States are taken into consideration, for a check within 1 bushel is a closer check when yields generally are above 12 bushels per acre, as in the Northern States, than when yields are generally below 12 bushels per acre, as in the Southern States.

The official estimates of yields check more closely with the yields derived from the census than do the reports from the samples of county or township correspondents. (Table 42.) The sample data check just about as closely with the census data in the Southern States as in the Northern States. There is not a great deal of difference, however, between the yields as reported by the county correspondents and the yields reported by the township correspondents in percentage of cases which check within 1 or 2 bushels of the yields derived from the census. A larger percentage of the yields from the township reporters check within 1 bushel, whereas a larger percentage from the county list check within 2 bushels.

In the three spring-wheat States the several indications of yield per acre check much more closely on an absolute basis than in the winter-wheat States. In over 90 per cent of the cases the official estimates of yield and the yields derived from the census check within 1 bushel, and in all cases they check within 2 bushels. The yields as reported by the township list check more closely with the census than do those from the county reporters.

The several indications check more closely with yields of spring wheat than with winter wheat, in part because the comparison is limited to the three most important spring-wheat producing States, where the crop is grown in large fields and where the acreage as reported by the farmers to the census enumerator corresponds closely with the acreage from which the reported production is harvested.

In the Northern States, which include the important commercal producing areas of winter wheat in the Great Plains region, therei is only a very slight tendency for the official estimates to be less than the yields as shown by the census. This slight tendency is apparent for the six census years combined as well as for the four more recent census years. (Table 42.)

Although both the official estimates of spring-wheat yield and the yields obtained from sample data check closely with the yields as derived from the census (Table 42), the general tendency is for both the official estimates and the sample data to be higher than the yields as derived from the census. This is probably due to the fact that crop correspondents in the spring-wheat States tend to exclude the yields of durum wheat from their estimate of spring-wheat yields.

From the Southern States the yields reported by the township correspondents as well as the official estimates tend to be above the yields as derived from census data in a greater number of cases than in the Northern States. This is probably accounted for by the fact that in the Southern States wheat fields are smaller and more irregular in shape than in the States of the North and of the Great Plains, while harvesting methods and utilization of the crop are less uniform.

The yields derived from the census and the official estimates check much more closely during each of the last four census years than during 1879 and 1889. It is also interesting that in 1879, 1909, and 1919 there is a marked tendency for the official estimates to be higher than the yields derived from the census, whereas, in 1889 and 1899, the tendency is in the opposite direction and, in 1924, there is no marked tendency in either direction. In general, the yields from the township list check more closely with the yields from the census than do the yields from the county reporters. The sample indications of yields tend to be lower than the yields from the census years 1899 and 1924 and higher in 1909 and 1919; the two indications of yield from sample data are consistent in this tendency to be above the census yields in certain years and below them in other years. It is especially interesting that only in 1924 did the official estimates fail to reflect the bias that apparently was shown by the two indications from the sample data.

In Minnesota, North Dakota, and South Dakota the official estimates of yield per acre of spring wheat and the yield as derived from the census check within 1 bushel in 14 of 15 cases compared. (Table 36.) The county samples and the census yields check within 1 bushel in 5 out of 12 cases, and the township sample checks within 1 bushel in 10 of the 12 available comparisons.

Official estimates of wheat yields and yields as derived from the census check within 1 bushel in 5 of the 6 census years in West Virginia and Kentucky; in 4 of the 6 census years in Kansas, Illinois, Indiana, Pennsylvania, New Jersey, Virginia, and Tennessee; in 3 out of 6 years in New York, Missouri, Maryland, and North Carolina; while the two indications have checked within 1 bushel in all three census years since Oklahoma became a State. Although in Ohio they check within a bushel in only 2 of the 6 years, they check within 2 bushels in all 6 years. In all 6 years these two indications also check within 2 bushels in Missouri, Nebraska, Kansas, and Tennessee.

The fact that the yields as derived from the census and the official estimates check as closely as they do in the Northern and Great Plains States and in the important spring-wheat States, as well as in the South, justifies the conclusion that on an average both are fairly close to the true yield per acre.

In any one year or, in any one State factors may be tending to make one figure higher or lower than the other, and these must be determined and allowed for, so far as is possible, in making an estimate of yield per acre. In making estimates from samples obtained from crop correspondents it is necessary to allow for the slight bias toward understatement on the part of the correspondents in these important wheat-producing States. In the less important wheat-producing States of the South, yields as reported by crop correspondents probably are closer to the actual yield than are those derived from the census data.

As might be expected, when the several indications are compared on the basis of the correlation between any two series, as shown in Table 44, it is again apparent that the yields from census data check more closely with the official estimates for spring wheat in the three important spring-wheat States, than with those for winter wheat even in the Northern States. The correlation coefficient between yields as derived from the census and the official estimates of yield for spring wheat is +0.989 in the last four census years and +0.996 for all six of the census years, indicating about 98 to 99 per cent of covariation between the two series of data (coefficient of determination or the percentage of covariation is taken as equal to the square

OATS

Official estimates as well as the sample indication of oat yields check much more closely with yields as derived from the census data in the North Central States, where the bulk of the crop is produced, than in other parts of the country. (Table 42.) In all sections of the country and in all the census years there is a pronounced tendency for official estimates of oat yields and the indications of yield from sample data to be higher than yields derived from the census. This tendency is somewhat less in evidence in the North Central States, than elsewhere. Again it is undoubtedly the old difficulty of the farmers reporting a larger acreage to the census enumerator than was actually harvested and threshed as grain. Since oats are primarily a feed crop and farmers utilize them on the farm in the most economical manner, the smaller the acreage per farm the less likely is the farmer to harvest and actually thresh his oats.

In spite of the marked tendency for the official estimates of oat yields to be higher than the yields shown by the census, these two indications check within 2 bushels in all of the 6 of the census years in Ohio and Illinois; in 5 of 6 years in Maine and Michigan; in 4 of the 6 years in New York, Indiana, and Minnesota; in 2 of the 6 years in Connecticut, Pennsylvania, North Dakota, Delaware, Maryland, South Carolina, Florida, Alabama, Mississippi, and Colorado; and within 2 bushels in 2 of the 4 census years for which estimates for South Dakota are available.

Although the oat yields indicated by the sample data are generally higher than those shown by the census, the correlations (Table 44) between census yields and township yields are fully as high, +0.89, as for corn yields. In the North Central States the correlations between sample data yields and census data are higher with oats than with either corn or wheat. The correlations between county and township indications of yield (Table 44) are higher for oats, +0.89, than for corn, +0.85, but not so high as for wheat. The correlation for wheat might be expected to be higher, since the far Western States are omitted from the comparison for wheat, whereas they are included in those for oats and corn.

FLAXSEED

Official estimates of flaxseed acreage, yield per acre, and production were not made until 1902, and consequently only three census years are available for this comparison of crop-yield indications. Since the average yield per acre of flaxseed for a State seldom exceeds 12 bushels, the absolute comparisons of the several indications of yield per acre are placed on the basis of checking within 0.5 and 1 bushel instead of 1 and 2 bushels as with the other grain crops. There are at present only four States—North Dakota, South Dakota, Minnesota, and Montana—where the growing of flaxseed is at all important. It is of very minor importance in the other two States, Iowa and Kansas, included in this study. Wisconsin, Missouri and Nebraska have produced a little flax during the period covered by this study, but in these States the crop is of such minor importance and the acreage so small that it is practically impossible to obtain reports on it from the crop correspondents.

Official estimates of flax yields check less closely with the yields indicated by census data, in successive census years. (Table 43.) The

number of States in which these two indications check within 0.5 bushel is 67 per cent of the total number of States growing flax in 1909, 33 per cent in 1919, and only 17 per cent in 1924. The percentage of States checking within 1 bushel declines from 100 per cent in 1909 to 67 per cent in 1919, and to only 33 per cent in 1924. No such trend is apparent in the yields obtained from county or township reporters.

In practically all instances where the official estimates or sample indications fail to check with the census yields within 0.5 bushel, they are higher than the census yields. This would seem to indicate that either there is a plus bias in the reports of the crop correspondents and perhaps in the official estimates as well, or that the sample is not fully representative of the lower-yielding areas of flax production. Flax is considered primarily a new-land crop, and wilt-resistant varieties that permit its production on land that has been under cultivation for some time have been developed only in recent years. This may account in part for the decreasing tendency of the official estimates and census yields to check in successive census years.

Introduction of wilt-resistant varieties has tended to increase the yield per acre in the older farming sections of the States from which the bulk of the crop reports are received, while at the same time the acreage of flax has also expanded westward into less humid areas, especially in North Dakota and South Dakota. There is always some lag in the adjustment of acreage weights where the acreage of a crop is expanding and there is also difficulty in obtaining regular crop correspondents in new farming sections. As a result, the lower-yielding sections of expanding flax acreage would not be fully represented, either in the reports of yield or in the system of weights used; the weighted averages of 1919 and 1924 would tend therefore to be too high and might be expected to be higher than the yields calculated from census data. Census indications of yield per acre should be highly reliable with the flax crop because it is not fed or used on the farm in any way except for seeding purposes.

In these six States the yield as reported by the county reporters check much more closely with yields as derived from the census (Table 42) when considered on an absolute basis than do the official estimates or the reports from the township list. In 1909, the yields derived from the census data and those obtained from the county reporters check within 0.5 bushel in 80 per cent of the States for which county data are now available, while the two indications check within 1 bushel in all five States. In 1924 they check within 0.5 bushel in the five States for which a report from the county list is now available, whereas in 1919 they check within 0.5 bushel in only one State, and within 1 bushel in only one-half the number of States. In North Dakota and South Dakota the yields as reported by the county list as well as those from the township list check within 1 bushel with the yields derived from the census data in all three census years.

However, the correlation between official estimates and yields derived from the census is somewhat higher than the correlations between census yields and either of the sample indications. (Table 44.) Although the correlation between official estimates and census yields is higher than that between yields reported by the two lists of crop correspondents, the correlation between the latter is higher than that between yields derived from census data and either of the sample indications. The census yields and those reported by the county ... correlation of +0.993 in one year, 1924.

This comparison of yield data for flaxseed shows (1) that the several indications of yield per acre check about as closely with this crop as could be expected for any crop and (2) that in making estimates of the yield per acre of flaxseed the statistician must be on his guard against a sample that is not fully representative of the lower-yielding sections of these States.

COTTON

Comparing official estimates of yields per acre of cotton and sample data yields with those obtained from census data probably is less satisfactory than making similar comparisons for any other crop. Each year since 1902 the Census Bureau, through special agents, has obtained the data on cotton ginning direct from the cotton gins. As might be expected serious difficulties have been encountered in making a farm-to-farm enumeration that will check exactly with ginning figures of cotton production. Consequently such adjustments must be made in tabulating and summarizing the data that a reliable indication of yield per acre is not likely to be obtained by dividing the production by the acreage.

The production of cotton as reported by the census is not necessarily from the acreage as reported by the census. In 1900 difficulty and confusion arose from the fact that production was reported both in bales and pounds of lint. In 1909, the first census after ginning reports had become well established, more cotton was enumerated than was reported as ginned, because of a duplication of reports on the production of cotton, when the same field of cotton was in some instances reported to the enumerator twice, once by the landlord and again by the tenant. This difficulty arose largely from the construction of the schedule on which data from cropper tenants and data for the whole plantation became difficult to separate and distinguish.

With the funds available it became necessary in many of the States to base the yields per acre largely on the estimates of the Department of Agriculture, and the acreage of cotton became a derived figure, obtained by dividing the total production ginned by these estimates of yield per acre. In this analysis cotton yields from census data in 1909 appear to check more closely with the official estimates than for any other census year. In 1909, yields per acre derived from the census and official estimates of yield, check within 10 pounds in about 69 per cent of the States, and in other years such a close check as 10 pounds occurs in less than one-third of the States, except in 1919 when they checked within 10 pounds in 46 per cent of the States. (Table 43.) The correlation between these two indications (Table 44) is very high that year, +0.98, in comparison with about +0.73 in 1899 and in 1919, and +0.91 in 1924.

In 1924 the census enumeration showed less cotton that had been accounted for by the ginning reports, and consequently adjustments were made which tended to impair the reliability of the yield-per-acre figure derived by dividing total production by the acreage enumerated. The census of 1919 is apparently the most satisfactory of the last three census years when cotton ginnings have been available to the Census Bureau as a check on the accuracy of the enumeration of cotton acreage and production. In 1919 the correlation between the census yields and the yields from the county sample and between census yields and yields from the township sample were both +0.95, as compared with those in 1924, when the county-census correlation was +0.71 and the township-census correlation was +0.66. The county-township yields showed a correlation of +0.97 in 1919, the highest for any of the four census years. (Table 44.)

The further difficulty encountered in comparing cotton yields is that the unit of measure for the census is the bale, or fraction thereof, whereas pounds of lint cotton are used for the official estimates and yield questionnaries of the Department of Agriculture. The bales per acre shown by the census were converted to pounds of lint on the basis of bale weights, by States, as published by the census, with allowance of 22 pounds for tare on each bale. Definite data on bale weights were not available by States for 1879 and 1889, and consequently it was necessary to interpolate for the separate States on the basis of the usual deviations of the weight per bale for each State as compared with the average for the United States.

Although because of the limitations of the data only very broad generalizations concerning cotton are justified, it is evident, from Tables 42 and 43 that the official estimates of the yield per acre as well as the yields reported by the crop correspondents, check with the yields derived from the census more closely in the South Central States than in the Atlantic Coast States. The indications derived from census data are consistently higher than those from sample data, indicating considerable bias on the part of crop reporters' estimates, a bias apparently more pronounced in the Atlantic Coast States than in the States farther west. With the greater amount of bias it is not surprising to find that the official estimates are apparently on a lower level relative to the census indications of yield in the South Atlantic States than in the South Central States.

The tendency toward a downward bias on the part of the sample data and the official estimates apparently has become much more pronounced since the beginning of reports of the ginnings of cotton during the decade from 1899 to 1909, although it is also apparent that the official estimates and the yields derived from the census check more closely during the last three or four census years than during the first two, 1879 and 1889. In Texas the official estimates of yield and the yield derived from the census check within 10 pounds in 5 of the 6 census years and within 20 pounds in all of them. In Mississippi the two indications check within 10 pounds in the last 4 census years and within 20 pounds in 1879 and 1889. In Alabama they check within 10 pounds in 3 years, and within 20 pounds in all of the last 5 census years.

Among the Atlantic Coast States Georgia has the best record with three census years, 1889, 1899, and 1909, when the official estimates and the census yields check within 10 pounds, but the official estimates are below the census yields in 1919 and 1924. In both of the Carolinas the official estimates are below the census yields in all six of the census years, and in only one year in each State do the indications check within 20 pounds.

In making official estimates of cotton, emphasis has always been placed on making an estimate of production that would check closely with the ginning figures of production; prior to the ginning reports elaborate data were gathered on shipments by railroad and by boat from each cotton State, to serve as a final check on the production estimates. The current estimates of production are based in part on an interpretation of the current ginning reports made public twice a month during the season of harvest. The later in the season the forecast of production is made, the greater is the dependence placed on the ginnings up to that date as an indication of final production. By the first of December, when the preliminary estimates of yield per acre are made, that indication of production which consists of the acreage of cotton multiplied by yield per acre, is not considered very significant in comparison with the indication of production derived from an interpretation of ginning data.

The low correlation of +0.726 in 1899 (Table 44) between official estimates of yield and yields derived from the census can be attributed primarily to the low official estimates in Missouri and Virginia, both States of minor importance in cotton production, where the official estimates are much lower than the indications from the township and county samples as well as lower than the census. The same situation occurred again in Missouri in 1919.

The low correlation +0.715 in 1924 between yields derived from census data and yields from county reporters is due largely to low yields reported by the county sample in Missouri and Arkansas. These same low reports explain the low correlation between the county and township indications for that year.

TOBACCO

In about one-half of the States in the census years 1899, 1909, 1919, 1924, the yields of tobacco derived from the census data check within 50 pounds with the official estimates of yield; in three-fourths of the States these two indications check within 100 pounds. (Table 42.)

These two indications check within 50 pounds and 100 pounds about as frequently in the Northern States as in the Southern States, although yields per acre tend to run somewhat higher in the North. In 1919 the official estimates and the census yields checked within 50 pounds in all of the seven important Northern States growing tobacco, showing a correlation coefficient of +0.999. (Table 44.) These two indications apparently show (Table 43) an increasing tendency to check in successive census years, due in part to the increasing importance of tobacco as a farm crop, to the development of better methods of handling sample data, and to more effective use of information concerning the quantity of this crop sold. The larger the acreage and the more important a crop becomes in a State, the more accurate and reliable will be both the census enumerations and the sample data concerning yields per acre. In the earlier census years, 1879 and 1889, the official estimates of the yields of tobacco and the yields derived from the census check within 50 pounds in only a few States—New York, Maryland, and Kentucky in 1879, and Ohio and Virginia in 1889. On the other hand, in five States, Kentucky, Tennessee, North Carolina, Indiana, and Wisconsin, these indications check within 50 pounds in each of the last three census years.

In 1899 and 1909 the yield samples from the county correspondents check more closely with the census on the basis of a direct comparison (Table 43), whereas in 1919 and 1924 the yield samples obtained from the township list check more closely. It will be recalled that the reports from the county list, although small in number in comparison with the township list, were weighted by counties. The township samples were not weighted in 1899 or 1909, so far as can be determined now, but by 1919 the more important crops were being weighted by crop-reporting districts. With the development of a strong list of field correspondents and the appointment of full-time field statisticians in practically all States in the decade from 1910 to 1920, it is reasonable to expect that the list of county correspondents was not so well maintained nor were new recruits added so promptly when old reporters dropped out. This apparent tendency is not in evidence with crops such as corn, oats, wheat, and cotton, which are produced more generally. The problem of obtaining a representative sample is usually much more difficult with a crop of localized production, like tobacco, than with the more generally grown crops, and it is possible that a small sample properly weighted would be more accurate than a large sample not weighted.

In 1899 the official estimates did not check as closely with the yields derived from census data as did the sample data from the county reporters; by 1909 the estimates checked about as well as the county sample; and in 1919 and 1924 the estimates checked much more closely with the census on an absolute basis than the township sample. Information concerning the sales of tobacco was probably given greater consideration than in the earlier years.

In the Southern States the cases are equally divided into two categories (1) those in which the official estimates are lower than the yields as derived from the census, and (2) those in which the official estimates are higher. This situation also exists when the data for the six census years are combined for comparison, as well as for the last four census years, and for each individual year of the last four census years. The deviations of the yields reported by the township from the census yields also show an equal division for the four years combined although in individual years there is considerable variation. The apparent absence of any material bias in reporting yields of tobacco may be due to the early maturity of the crop and early sales. The crop is entirely marketed in several of the Southern States before the yield inquiry is made in the fall. Consequently, farmers are well informed concerning their own yields and, with the crop rather well out of their hands, there is little incentive to understate the yield per acre when reporting to the department.

In the Northern States there is a tendency for both the official estimates and the sample data to be higher than the yields derived from the census data thereby indicating bias in the individual observations. The bias is more in evidence with the township sample of yields than with the county sample.

Official estimates of tobacco and yields as derived from the census show a higher correlation than do winter wheat, oats, corn, or cotton, although the correlations between sample data of yield and the census yield are about the same as with the other crops. (Table 44.) The correlation between the county samples and the township reports is lower for tobacco than for oats, winter wheat, spring wheat, or flax, but higher than for cotton, and about equal to that for corn.

Although the yields as derived from the census and the official estimates of yield tend to check with greater absolute accuracy with the passage of time, the correlation coefficients between county and township reports shows no tendency to become larger in the later census years. The official estimates of yield are more highly correlated with yields derived from the census, +0.962, than is the case of the county sample, +0.885, or the township sample, +0.918. Although the official estimates and sample data show less indication of bias in the Southern States than in the Northern States, less correlation is shown in the North between official estimates and census yields, and between county data and census yields, and for yields obtained from the township correspondents and the yields derived from the census. The two sample indications of yield of tobacco (Table 44) show very low correlations in the Southern States, whereas in the North there is a substantial correlation between them. In fact, with the six crops considered in this analysis, it is only in the case of tobacco in the South that the county samples and township samples show really low correlation. This would indicate that these samples are small and, having considerable dispersion, are consequently subject to high probable errors and are not likely fully to represent the important tobacco-producing areas.

In several of the Southern States in which the tobacco acreage is small and highly localized, it is difficult to obtain an adequate sample that is fully representative. Fortunately other samples as well as check data from sales are available as a basis for estimates of production.

GENERAL CONSIDERATIONS IN REGARD TO COMPARISONS OF YIELD ESTIMATES

Official estimates of yields per acre check sufficiently well with the yields derived from census data, when allowance is made for the inherent limitations of such data, to justify the conclusion that, for important crops in all but the smallest States and the far Western States, these two entirely separate indications of yield undoubtedly approximate closely the true yield per acre. The differences between them for a given crop are seldom more than might be expected from the application of the principles of sampling as made earlier in this study. Bias is likely to be present in the reported yields of important cash crops, especially when such crops are practically the only source of farm income, as with cotton. A small sample is to be trusted only within rather wide limits, and lack of representativeness is a constant source of error in the sample data of yield per acre, as in the case of tobacco in States of small tobacco acreage. These difficulties have apparently been recognized by the Crop Reporting Board for many years, for with most crops the official estimates check more closely with yields as derived from census data than do either of the direct sample indications; and with all the crops studied, the correlation between census yields and official estimates, is higher than that between census yields and sample indications of yield per acre.

From this analysis it may be concluded that when reports are received from a well-maintained and active list of county reporters and these reports are weighted by the importance of the crop in each county, the resulting weighted average of these reports is usually a very satisfactory indication of the average yield per acre in a given State. With generally grown crops such as corn, oats, and wheat, reports for several counties could be missing from any of the large and more homogeneous States without seriously affecting the resulting average of yield per acre. But with crops of highly localized acreage, such as tobacco or cotton in Missouri and Virginia (where they can be grown in only a few counties) there is grave danger that

reports on yield might not be received from one or two counties which would represent from one-half to nine-tenths of the acreage in that State. As a result, the reported yield from the county sample would not be representative of the important producing areas, and it might easily be in serious error.

In the smaller States having only a few counties, a sample containing reports from all the counties would be subject to a very high probable error, and estimates based on such samples would not be reliable. This difficulty is pronounced in the New England States and in the far Western States, where conditions are extremely varied.

Fundamentally the method of estimating the yield per acre of a crop primarily from sample data obtained from voluntary crop correspondents is the same to-day as in 1879, when the acreage and production of crops was first enumerated as a part of the Federal census of agriculture. During the last 50 years the size of the yield sample, however, has been greatly increased.

The development of the crop-reporting service along the lines it has taken has been logical. Additional lists were developed to serve as a check on each other; trained agriculturalists were appointed in each State or group of small States, who could travel and observe crop conditions and make reports which act as a further check on the sample returns. But with the major crops in the important producing States the old system of carefully selected county crop reporters, with from one to five assistants in each county, was a highly efficient method of obtaining a reliable indication of the yield per acre of such crops. It was fully as reliable an indication as the unweighted returns from the larger list of township correspondents started in 1896. In fact, the yield sample from the county list, when that list was well maintained and active, was a much more reliable indication of yield per acre than might be inferred solely from the number of observations.

With generally grown crops, and in fact with practically all crops except the most localized and those the yields of which per acre differ greatly as between counties, the present method of weighting by crop-reporting districts the returns from the township list and those from the list of field-aid reporters is a logical outgrowth of the earlier situation in which there were a small number of weighted reports from the county list and the larger, unweighted sample from the township. Weighted and unweighted averages of the returns from two separate lists are a protection from errors in computation, which must always be guarded against, as well as a means of greatly improving the representativeness of a sample that is not distributed in proportion to its relative importance geographically in a State.

ESTIMATES OF YIELD PER ACRE, 1866 TO 1925

SIZE OF SAMPLE

The year 1866 marks the beginning of the present series of yield-per-acre estimates for important crops by States. From 1866 to 1882 the reports from the county correspondents were practically the sole basis of these yield estimates. Each county reporter was expected to have assistants, not to exceed five, who reported directly to him each month for that part of the county within which each lived. The Department of Agriculture undoubtedly endeavored to keep an active county reporter in each agricultural county of the United States, but it is not likely that returns were received from more than 60 to 75 per cent of all counties within a State for any one year. The August, 1881, report on cotton condition was based on returns from 56 per cent of the counties in North Carolina and 70 per cent of the counties in Georgia.

For the more important crops in the larger States a sample of this size stratified by counties would be fairly adequate in size, and differences in yield per acre for a given crop from year to year would be reasonably significant from a statistical standpoint. If samples of corn yields per acre in Iowa, in those early years, had had about the same dispersion as in recent years (25 per cent or less), a sample of 46 reports would have resulted in a relative probable error of 2.5 per cent, or with a sample of 71 reports the relative probable erorr would have been 2 per cent, as compared with less than 0.5 per cent with the larger samples now regularly obtained. Samples of cotton yields per acre with a 50-per cent coefficient of variation and 46 reports would have had a relative probable error of about 5 per cent; 71 reports would have reduced it to 4 per cent.

It is probable, however, that greater effort was made to obtain reports from each county when the yield-per-acre inquiries were made than was the case with the monthly condition figures. At least as early as 1872 the returns from the county reporters were weighted by the importance of a given crop in each county. This would bring about an improvement in representativeness, which would contribute more to attaining an accurate indication of yield per acre than a mere increase in size of the sample with crops of localized acreage such as tobacco, potatoes, etc. In the far Western States or in the small States of the East and South the sample from county reporters has been so very small that it would have been of value only as a general indication of the trend of yields per acre over a period of years.

In 1882, State statistical agents were appointed on a part-time basis in most States. Within a year or two these agents began to develop a small list of correspondents who reported directly to them each month. The estimates of the agent were based primarily on the returns he received from his correspondents; consequently the official estimate of the yield per acre of crops for a given State made by the chief statistician in Washington were based on two sources of information (1) the returns from the county correspondents and (2) the estimate of the State statistical agent. The additional reports obtained by the State agents probably doubled the size of the sample in most States. Many sources of information were increased and made available by the State statistical agents. For instance, threshers' returns of bushels threshed and acreage harvested were reported from Ohio. During the eighties, estimates of the yields on a large number of individual farms were obtained for the first time and were used as a check on the other sources of information. Since these yields would be higher than the average for a locality, they were used in a relative sense.[12]

In 1896 the department inaugurated the township list; within a few years this list included about 30,000 correspondents, or approximately one crop reporter in each township, or the equivalent. The addition of this large number of reporters increased the size of sample several times and undoubtedly materially increased the precision of the averages.

[12] B. W. Snow, in commenting orally to the writer on the general practice of handling the reports and making estimates in vogue during the years from 1882 to 1892, when he was connected with the department, stated that the returns of the county correspondents continued to be the primary basis of the official estimates and that the estimates of the State statistical agents were used merely as a check.

This increased number of reports was especially helpful in securing a sample representative of the crops that had a localized acreage. When there were only county reporters, if the acreage of rye, tobacco, or beans was limited to only a few counties, it might frequently be necessary to make an estimate of the average yield per acre for a State when no reports would be avaliable from the counties in which from 50 to 70 per cent of the crop was grown.

In the beginning the township returns were also weighted by counties, but this required so much labor that for years only a simple arithmetic average of the township returns was calculated. In comparatively recent years the township returns of yield per acre have been weighted by crop-reporting districts. The counties were grouped into crop-reporting districts in the decade from 1900 to 1910, and a system of district weighting was used by the State statistical agents in handling their returns, although some continued to weight by counties.

With the appointment of regional field agents and crop specialists on full time during the period from 1900 to 1910 and the building of lists of correspondents to report to these regional agents the size of yield-per-acre samples was further increased. Weighting by districts was practiced by most of these regional agents.

During the reorganization of the crop-reporting service, in 1914, the positions of part-time and full-time regional and statistical agents were abolished, and a full-time position of State statistician, as it exists at present, was created in practically all States. The appointment of the State statistician was placed under the jurisdiction of the Civil Service Commission, and the requirements were materially raised. There was also a merging of the lists of correspondents who had reported either to the State agent or to the regional agents into what has since been known as the field-aid list, which reported directly to the State statistician in each State. This list was greatly increased in size until it contained more correspondents than did the township list.

The yield estimates during the last 30 years have been based on samples of sufficient size to render the results highly stable except in the far Western States and in some of the smallest States. During the last 15 years the yield estimates have been on practically the same basis from the standpoint of size of sample as the estimates of recent years that were analyzed earlier in this bulletin.

The period from 1866 to 1930 may be divided, on the basis of size of sample, into about four periods as follows:

(1) 1866–1883. Returns were from county reporters only.

(2) 1884–1895. Returns from the county list were supplemented by returns from field aids, who reported to part-time State statistical agents in each State. Individual-farm acreage and production returns were used to some extent on a relative basis as an indication of yield per acre of crops.

(3) 1896–1914. Returns from county correspondents and field aids were supplemented by the addition of returns from the township list of crop correspondents. Regional agents with limited lists of correspondents developed after about 1904. Lists of ginners and other special lists were used in connection with cotton.

(4) 1915–1930. With the reorganization of the field service, the field-aid lists were consolidated, and the size of lists was greatly increased by the State statisticians. The county lists were merged with the township lists in 1925.

REPRESENTATIVENESS

The crop reporters of the department have always been distributed either by counties or townships, and consequently this method of stratifying the sample has always not only aided the precision of the average but also the representativeness of the sample. By 1872 the county reports were being weighted by counties, and this improved the representativeness of the average of the sample. The returns from the field aids were usually weighted by the State statistical agents, by counties, and after the development of crop-reporting districts between 1900 and 1910 these returns were generally weighted by districts. The township returns were so numerous that weighting was not deemed necessary even with important crops until within about the last 10 years. Lack of geographic representativeness has probably not been a serious problem at any time in the case of the more generally grown crops in the States of major production.

BIAS

The understatement of yield per acre on the part of farmers has been a somewhat difficult problem in the case of such an important cash crop as cotton. In the first years of these reports on crop yields the inquiry was made as a percentage of the previous year, and in actual bushels and pounds per acre during the decade from 1860 to 1870. In commenting on these returns the statistician suggests that the yields themselves may be high, as they were obtained from better-than-average farmers, but that the crop reporters were well qualified to estimate the change in yield per acre on a percentage basis. From 1896 to 1925 the averages from samples obtained from county reporters show no tendency to be either higher or lower than those from the township correspondents. Differences between the averages from these two samples could easily be accounted for on the basis of the influence of the fluctuation of sampling or lack of representativeness.

There is apparently a break in the trend of the yield-per-acre series for corn for the United States in the early eighties; this has led many observers to conclude that some shift had been made in the method of estimating corn yields, beginning in 1881. In the North Atlantic States the break is abrupt, and in practically all sections the yields were unusually low during the period from 1881 to 1893. This break in trend was so abrupt that it led Whitney (*17 p. 50*) in his study of the trend of crop yields to conclude that "the only possible explanation is that the department's estimates were adjusted at that time in conformity with the facts determined by the census."

The census for the crop year 1879 made possible for the first time the calculation of a derived yield-per-acre figure from the enumerated production and acreage. In the North Atlantic States, where the break was most in evidence, the differences between the official estimates of corn yields per acre published in the year 1879, and the yields derived from the census were not sufficient to justify any change in method. (Table 37.) In Maine, Vermont, Rhode Island, and New York the yield figures from the two separate sources checked within a bushel. In New Hampshire and Connecticut the census was about 4.5 bushels higher than the department's estimates, and in only three of these States, Massachusetts, New Jersey, and Pennsylvania did the census yields run below the estimates of the department.

The late-season condition figures for corn tend to show somewhat

report, the chief statistician comments on the corn-yield situation during this period as follows:

> Seven years, 1881 to 1888, which were so lean that only one, 1885, made an average of 26.5, one falling to 18.6 in 1881, made the remarkably low average of 22.9 bushels. The period of 10 years, including the present, will make an average a little above 24 bushels, a reduction of fully 7 per cent from the average preceding 10 years. This is a difference so large, due evidently to meteorological causes and assuredly not to the depletion of fertility or deficiency of cultivation, that a periodic recurrence of such results might soon give some encouragement to the cycle theory.

When the fundamental relationships between weather factors and the yield per acre of corn are eventually worked out for several of these States it will be possible to test this series of yields during the period from 1870 to 1890 and to determine rather definitely whether there was any change in the method of estimating the yields of corn at that time (*16*).

CONCLUSIONS

The methods used by the Department of Agriculture in making estimates of crop production may be classified under three headings as follows: (1) Collection of sample data, (2) field travel and observation by the State statistician, and (3) collection and utilization of check data on quantity of the crop entering the channels of trade.

The present method of collecting sample data from voluntary correspondents is generally successful as a basis for estimates of yields per acre in the case of most crops of extensive acreage in important producing States. The yield estimates for many crops in a number of States could be improved by the further application of the principle of stratification, especially in those States in which conditions are extremely varied or in which crops tend to be localized. The stratification of the State into districts which have greater homogeneity than have the present districts would improve the representativeness of the weighted average for the State and reduce the influence of the fluctuations of sampling.

The township and field-aid lists of crop correspondents have been combined into one list which reports directly to the State statistician in each of several States (Pennsylvania, New York, New Jersey, the New England States, Virginia, West Virginia, Maryland, Delaware, Florida, Nevada, Utah, and California). A similar arrangement in the other Rocky Mountain and Pacific Coast States would tend to improve the accuracy of the estimates in those States. In districts of extreme variation and small samples, a comparison of the reports from the same reporters for two consecutive years would be helpful as a basis for estimating the change in yield from one year to the next.

Post-season inquiries of yields per acre for cash crops with a tendency toward cash-crop bias, such as the present March inquiry on cotton yields (Table 17), might well be extended to other crops such as commercial potatoes, tobacco, peanuts. field beans, and fruit and vegetable crops generally.

A more detailed and critical comparison of official estimates and the sample returns from crop correspondents with the yields derived from census data would throw additional light on the limitations of both the enumeration and the sampling method of obtaining crop yields per acre. It is necessary to determine the limitations of any method before much progress can be made toward its improvement.

A thorough and comprehensive study of yields as derived from the Federal census for the crop year 1929 as compared with the sample returns from the crop correspondents would be highly desirable. The inquiry concerning yields per acre made in connection with the regular April crop report and also an individual-farm inquiry on acreage and production made in the same month, have placed all the sources of yield-per-acre information on the same footing from the standpoint of memory bias. Such a study of the indications of yields per acre for the crops of 1929 might well be a joint study of the Bureau of the Census and the Division of Crop and Livestock Estimates, since both organizations are undoubtedly interested in fundamental research of this kind, which will form the basis of a better understanding of the available data and a starting point for further improvement in methods for both agencies.

On the basis of a scientific analysis of all the information available from both crop reporters and the census, it would be possible to establish yield-per-acre estimates for the crops of 1929 that could be used as a base for annual estimates for subsequent years until the next agricultural census is made.

The suggested annual sample census is needed primarily as a means of estimating changes in acreage and number of livestock on farms from year to year, but it would also serve as an extremely valuable check on estimates of yield per acre, which, with most crops, must be made earlier in the season. In cases in which reliable estimates of yields per acre of crops on a county basis are desired, the suggested sample census would supply the necessary data. The sample census would be especially helpful in those States in which it is now difficult to obtain an adequate and representative sample.

Extensive field travel and observation by the State statistician is essential, especially in States in which conditions are extremely varied and crops are highly localized. The greater the differentiation in a given universe of inquiry, or the smaller the sample, the more important does it become for the statistician to have full, detailed, and up-to-date knowledge of the universe of inquiry.

The importance of obtaining data that can be used as a check on the accuracy of the estimates of crop production can not be overemphasized. Additional facilities are needed for securing this type of information from all classes of common carriers for all agricultural commodities that are sold from the farm.

The results of this study, in common with other economic and statistical generalizations, can not be stated with the precision that is possible in the field of the more exact sciences, but they justify certain general conclusions concerning the adequacy and reliability of the official estimates of crop yields per acre. The relationships involved are complex, and when any factor is mentioned individually, the conclusions should be qualified with the statement "provided other things are equal."

Estimates of crop yields per acre for the 12 North Central or Corn Belt States are not only more reliable than those for any other part of the country, but are about as accurate as such estimates can possibly be when made on the basis of sample data obtained from voluntary crop correspondents. The estimates are least reliable in the Rocky Mountain and Pacific Coast States, and in some of the smaller Eastern and Southern States.

Estimates for such generally grown crops as corn, oats, wheat, and hay which have rather uniformly distributed acreage in the State where they are grown, are usually more reliable than crops of highly localized production such as commercial potatoes, beans, peanuts, and tobacco. The estimates for crops of relative little importance in a given State are much less reliable than are the estimates for the major crops.

Estimates for important and somewhat specialized cash crops, such as cotton, tobacco, commercial potatoes, peanuts, and beans, are likely to be less reliable than are the estimates of crops largely consumed on the farm or in the locality in which they are produced. Fortunately, this situation is not so serious as it might at first appear, as check data of the commercial movement of the crop are obtained for many of the crops that are sold. These check data available over a period of years make it possible for the statistician to correct for bias which may exist in the original sample material.

The explanation of these conclusions is found in the application of the fundamental principles of sampling and of statistical induction under given circumstances and conditions as well as on a direct comparison with yields derived from census data. The estimates for the major crops in the important North Central States are more reliable than elsewhere, as the universe from which the sample is drawn is more homogeneous and there is less dispersion in the yields per acre over a given State than generally prevails in other sections. The size of sample is fully adequate to reduce to a minimum the influence of the compensating errors of observation and the fluctuations of sampling. Most of the important crops in this area are generally distributed over a given State, thereby insuring geographic representativeness of a sample stratified by townships. Cash-crop bias and other forms of noncompensating errors in the individual observations are apparently much less serious than in most other sections of the country. Many of the crops are utilized on the farm, and even with the cash crops, such as wheat, flaxseed, and commercial potatoes, there seems to be little evidence of cash-crop bias. The reliability of the yield estimates from this large agricultural area is of tremendous importance in its effect on the reliability of the estimates of total production of such staple crops as wheat, corn, oats, barley, rye, flaxseed, potatoes, and hay.

The estimates of yield in small States are not so reliable, primarily because it is difficult to obtain a sample of adequate size. Sample data in several of the Rocky Mountain and Pacific Coast States are practically worthless as a basis for estimates of yield without careful interpretation and analysis by a statistician thoroughly conversant with the current situation.

With crops of highly localized production it is usually difficult to obtain a sample that is adequate in size and fully representative. Weighting by counties rather than by crop-reporting districts greatly improves the representativeness, provided there are a sufficient number of reports by counties to prevent possible distortion.

Understatement of the yield per acre on the part of the crop correspondent, found in the yield inquiries made prior to the selling of a cash crop like cotton, can never be eliminated from the sample data and must be allowed for by the statistician in making the estimate. Check data on production or on the quantity of a crop sold, such as being used to indicate the presence of this cash-crop bias. At present, it is extremely difficult to measure the extent to which this bias existed during past years, because it can not be accurately allocated as between the acreage and the yield-per-acre sample data. It is like a problem in joint costs in accounting. The measurement of bias in yield-per-acre data is contingent on the development of more accurate methods of sampling acreage. Until a fairly accurate measure of cash-crop bias can be developed on the basis of previous experience, this allowance for bias that the statistician is compelled to make is largely a matter of personal judgment and must be made in connection with any statistical inference based upon the type of sample data.

It is difficult to obtain a sample of adequate size in localities in which the farmers are foreigners who do not read and write English readily, in localities in which the general level of education is low, and in communities in which the farms are somewhat isolated. In some States the standard bushel is not the customary unit of measure, and consequently special schedules are used to prevent misunderstanding of the questionnaire.

During the last 20, or perhaps 30 years the estimates of crop yields per acre of most crops have been nearly as satisfactory as during the last 5 years. Prior to 1896 the estimates for minor crops were much less dependable than during the period since then, and they were least reliable during the period prior to 1882.

Estimates of yield per acre for the more generally grown crops could be made with a fair degree of reliability by crop-reporting districts in the important Corn Belt States. To make estimates of yield for minor crops by districts, or for any crop by counties, is not feasible on the basis of the present system of voluntary crop correspondents except in some of the Corn Belt States. Such estimates are necessarily so unreliable that they are being discontinued until such time as the suggested annual sample census becomes an established method of sampling acreage, production, and number of livestock on farms.

The official estimates of yields per acre for generally grown crops in important producing States check sufficiently closely with yield derived from census data, when allowance is made for the inherent limitations of data obtained by the enumeration method, to justify the conclusion that these two entirely separate indications of yield approximate closely the true yield per acre. The difference between these two indications of yield per acre are seldom more than might be expected from the application of the principles of sampling. The statistician must be on his guard against bias in the sample data when making an estimate of yield per acre for cash crops, which are the principal source of income in the localities where produced.

The reliability of the estimates of crop yields per acre is only one aspect of the larger problem of the reliability of the official forecasts and estimates of crop production. This bulletin is in the nature of a progress report; it deals with a phase of sampling that probably has a broader application in the general field of sampling economic phenomena than has any other work being done by the Department of Agriculture. Further work of this kind, now under way, should eventually make available (1) the results of similar studies concerning the sampling of acreage, of livestock numbers, and of retail prices paid by farmers, (2) the results of much more detailed studies relative to the problem of sampling in a given State, and (3) an appraisal of

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