ESTIMATION OF AGRICULTURAL PRODUCTION BY SAMPLE SURVEYS, THE U. S. EXPERIENCE

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Reprinted from the

PROCEEDINGS OF THE 41ST SESSION OF THE INTERNATIONAL STATISTICAL INSTITUTE

NEW DELHI, 1977

Bull. Int. Stat. Inst., 1977, **XLVII** (3) 407–424.

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1. Introduction

At the 36th session of the International Statistical Institute in Sydney, Australia, Trelogan and Houseman (1967) presented a paper describing the development and use of area sampling for agricultural surveys in the United States during the previous quarter century. This paper reports on the experience of the Statistical Reporting Service, U.S. Department of Agriculture in using a national system of probability sample surveys for estimating crop production during the past decade. Changes and progress toward continued improvement in area sampling following the theme of the Houseman–Trelogan 1967 paper will also be discussed.

2. Agricultural surveys

The program for current agricultural statistics administered by the Statistical Reporting Service (SRS) includes estimates of crop area, yield, and production; livestock numbers; prices; agricultural wage rates; farm numbers; and other items related to the United States agricultural economy.

For many years this program has been based on sample survey data supplemented by periodic check data from such sources as the census of agriculture and administrative records of total marketings. Before 1961 these statistical surveys were based largely on nonprobability samples, with most data collected by mail. Changes in U.S. agriculture after 1940, combined with advances in statistical sampling theory and technological developments in automatic data processing, converged in the 1950's and 1960's to provide the needed impetus for improving the underlying methodology of our program.

This improvement was based primarily on the implementation of a general purpose probability sample for the 48 conterminous states. This sample is enumerated in the late May and early June each year to provide an early-season base for area of spring planted crops, indicate harvested area for crops planted the previous fall, as well as the number of farms and livestock inventories. A subsample of corn, cotton, potato, soybean, and wheat fields identified in this survey is selected for objective yield surveys.

A second general-purpose survey is conducted as of December 1st each year also utilizing a subsample from the June Survey, with emphasis on livestock inventories and fall seeded area of winter wheat and rye.

These basic surveys use area sampling frames and enumeration by personal interview. However, modifications made during the past decade have increased the emphasis on probability sampling from list frames, generally in a multiple-frame design using both area and list frames. This paper is most concerned with the experiences associated with these changes and improvements of the past decade.

3. Sampling frames

3.1 *Area Frame*

When the original area sample was selected in the early 1960's two different area frames were used :

1) The Master Sample frame, King and Jessen (1945), and
2) A new land-use frame, for Florida, 11 western states and 12 states in the northeastern U.S., Huddleston (1965).

The Master Sample frame was constructed at Iowa State University in the 1940's with frame units classified into one of three types of land areas based on incorporation of cities and towns and the density of population. Three strata—open country, urban places and rural places—were identified in the frame materials. While these three strata plus geographic stratification were adequate for most of the Central and Southern states, studies during the 1950's confirmed the inadequacy of the Master Sample materials for the western states. Consequently, work was started in 1960 on a new land-use frame for 11 western states and was extended in 1964 to Florida and 12 northeastern states. This frame stratified land by agricultural use. The four basic strata in the western states were : cultivated land, cities and towns, nonagricultural land, and grazing land. Similar strata were used for the eastern states.

Success with the land-use frame developed by the Statistical Reporting Service during the 1960's, combined with changes in agriculture, has led to the development of land-use frames for most of the 24 states where the original area sample was drawn from the Master Sample frame. By 1978, the entire area sample will have been selected from the new land-use area frames. For area frame construction during recent years, we have standardized our definitions of land-use strata and sampling unit size within strata.

Present stratum definitions and size of sampling units used for current agricultural surveys are shown in Table 1.

TABLE 1. STANDARD LAND USE STRATUM NUMBERS, DEFINITIONS AND SIZE OF SAMPLING UNIT

Stratum	Substratum (1)	Definition	Sampling Unit Size (Hectares)
Cultivated Land	11	More than 75% Cultivated	130–260
	12	50-75% cultivated	,,
	13	50% or more cultivated	,,
	14	50% or more cultivated, 50% of total land irrigated	,,
	15	50% or more cultivated, 25-50% irrigated	,,
	16	50% or more cultivated, 10-25% irrigated	,,
	20	15–49% cultivated	260–520
	21	33-49% cultivated	,,
	22	10–33% cultivated	,,
Cities and towns	31	Agri-urban, more than 20 dwellings per square mile, residential mixed with agricultural	65
	32	Residential-commercial, more than 20 dwellings per square mile	25
	33	Resort, more than 20 dwellings per square mile	65
Range	41	Open range or pasture less than 15% cultivated	520–1040+
	42	Woodland range or pasture less than 15% cultivated	,,
	43	Desert range—less than 15% cultivated	,,
	44	Public grazing lands administered by the Forest Service or BLM—virtually no cultivation. Some small parcels of privately owned land may be included.	,,
Non-agricultural	50	Non-Agricultural	260-520

All substratum will not be used in every state, e.g. if substratum 20 is used, 21 and 22 will not be used.

The new samples selected from the land-use frame frequently have shown dramatic improvement in efficiency, both in terms of survey costs and variance reduction, when compared with the old sample selected from the Master Sample frame. While all gains are not attributable to the new frame, data shown in Table 2 illustrate the sampling efficiency of the new land-use frame compared with the old Master Sample frame.

3.2 *List Frames*

Although lists of farm operators have been used for current agricultural statistics for many years, they seldom have been adequate for independent use as a sampling frame. Studies in the early 1950's of the available lists revealed many serious defects when they were used as sampling frames. Since resources were not available for correcting these defects, the decision was made to go entirely to area sampling to improve the agricultural

TABLE 2. COMPARISON OF SAMPLE SIZE AND SAMPLING ERRORS FOR AREA SAMPLES SELECTED FROM TWO DIFFERENT AREA FRAMES

Crop-Acreage Planted	Illinois				Texas			
	Master Sample Frame		Land Use Frame		Master Sample Frame		Land Use Frame	
	Sample Size	Coeff of Var (%)	Sample Size	Coeff of Var (%)	Sample Size	Coeff of Var (%)	Sample Size	Coeff of Var (%)
Corn	350	4.1	300	2.4	1050	12.3	850	16.2
Cotton					1050	6.0	850	5.9
Soybeans	350	5.1	500	2.8	1050	23.2	850	25.5
Wheat	350	10.2	300	6.4	1050	9.7	850	7.0

statistics program. Early surveys revealed the susceptibility of area sampling to the "extreme value" or "outlier" problem particularly for livestock and specially (rare) crops. Use of "censored" estimators partially solved this problem; however, the primary solution came from using a list-frame in combination with the area sample. Trelogan and Housemen (1967) identified reasons for using the area frame, which is complete, with one or more incomplete lists of operators of large or specialized farms: "(1) The situation regarding the availability of lists is improving as a result of various administrative programs and improved equipment for handling lists; and (2) Our total program of agricultural statistics calls for many surveys during a year which are generally commodity oriented and conducted by mail. These surveys require special purpose sampling. Thus, lists are, and can be, used for many purposes other than in a multiple frame context along with the area sample surveys in June and December."

Since 1967 when the area sample was supplemented by use of a list of about 13,000 large livestock farms, multiple-frame sampling using more complete list frames has become the major design strategy for livestock estimates. For the 1977 June Survey the list frame for the 14 most important hog states contained more than one million farmers. Although multiple-frame sampling has not been as widely used for crop estimates, being limited to a few important specialty crops (e.g. white corn and potatoes) included in the national program, it is used for all crops and livestock to provide local statistics and improved state estimates in Texas. Results from these surveys will be discussed later in this paper.

Experiences in the last decade led the Statistical Reporting Service to seek funding to construct a nationwide "complete" list sampling frame. The first funds were approved by Congress in 1975.

Development of the computer software system necessary for this project is well underway and present prospects are for a list sampling frame of "all" United States farms to be completed by the end of 1978. This list frame will not only be as complete as possible for names and addresses of farm operators, but it will also contain extensive control information for each unit in the frame.

4. Survey design

The area sample used for current agricultural estimates is still a single-stage, stratified, random, general-purpose sample. During the past decade, sampling procedures have been modified to take advantage of new frames and knowledge about the population being sampled. Changes and improvements made during this period generally have reduced sample size for individual states, accompanied by decreases or no significant increases in sampling errors.

4.1 *Replicated Sampling*

In addition to the introduction of new land-use frames, "replicated" or "interpenetrating" sampling is the most significant change made in our area sample design during the past decade. The original sampling scheme for the area sampling was systematic selection within stratum using a single random start (geographic strata for the Master Sample frame; land use strata within geographic strata for the land use frame). The replicated scheme was started in 1973 and has been extended to all new state samples selected since that time. The replicated technique consists of drawing r samples or replications, where $r \geqslant 2$, of size k from N units in the population using the same selection procedures for each replication. Then $r \cdot k = n$, where n is the total sample size.

The interpenetrating design offers several advantages over the single systematic sample previously used by the Statistical Reporting Service. Replicated sampling permits computation of unbiased estimates of the sampling errors from the sample data. Sample dispersion is assured; however, the design gives somewhat less control on where the segments fall than with a single systematic sample. Another feature of the design is the creation of paper strata which provide geographic and land use stratification. The design offers more flexibility than a single systematic sample for periodically modifying the sample size and makes reallocation of the sample possible at any time without a complete redraw. Sample rotation may be varied from stratum to stratum and achieved by deleting or adding complete replications.

Additional samples will become available to increase sample size of a given survey or to create multiple samples as a by-product of rotation.

Results, Pratt (1974), of the 1973 survey in Nebraska for three methods of sampling are shown in Table 3. Within land use strata, both geographic stratification and replicated sampling are clearly superior to simple random sampling; however from a sampling efficiency viewpoint there is little evidence to indicate either method is superior to the other.

TABLE 3. COEFFICIENTS OF VARIATION FOR THREE METHODS OF WITHIN LAND USE STRATUM SAMPLING, NEBRASKA 1973

Item	Simple Random Sampling (Percent)	Geographic Stratification (Percent)	Replicated Systematic (Percent)
Cattle	5.4	5.0	4.8
Hogs	9.9	9.2	8.4
Corn	5.8	4.6	5.1
Soybeans	12.6	9.8	10.2
Wheat	8.7	6.9	6.0

4.2 *Size and Type of Sampling Unit*

New area frames have permitted the size of the sampling unit used for agricultural surveys to be specifically tailored for each survey. Sizes of sampling units for the June area survey are shown in Table 1. However, area frames used for most states permit selection and use of sampling units which are multiples (or fractions) of these sizes. For example, the sizes shown in Table 1 are well suited for collecting data using the "closed segment" definition, whereas larger sampling units will generally be more appropriate for the "open segment" definition. (The closed segment definition requires data to be collected for the items associated with the land which is completely contained within the sampling unit boundaries, while the open segment generally requires data to be collected for entire farms which have their headquarters located within these boundaries.)

5. Multiple frame sampling

The final change made during the past decade to improve the agricultural survey system is the increased use of multiple frame sampling. Combining list frames with the area sample for improving the precision of estimates was started for livestock data in the 1960's. During the past decade, this survey design has been expanded greatly for livestock surveys and is also being used to a lesser extent for crop area surveys. The most extensive use of the multiple frame techniques for crop area is the potato survey conducted in 12 states. This program was started in 1972 and is part of a larger system which includes a crop cutting survey for estimating total potato production each year.

Table 4 shows the area sample sizes, list sizes (universe and sample) and the strata used to subdivide the list universe.

TABLE 4. 1976 MULTIPLE FRAME POTATO AREA SURVEY

State	Frame 1	Frame 2: List			
	Area Sample Size (Segments)	Stratum Number	Stratum Definition (hectares)	Universe	Sample
California	1000	1	0–80	105	53
		2	81+	15	15
Colorado	400	1	.4–80	146	53
		2	81+	57	57
Idaho	398	1	.4–40	1106	77
		2	41–120	552	137
		3	121–280	228	114
		4	281+	84	84
Maine	150	1	.4–30	582	64
		2	31–80	349	88
		3	81–120	233	92
		4	121+	46	46
Michigan	350	Summer 1	.4–40	77	38
		Summer 2	41+	31	31
		Fall 1	.4–30	209	68
		Fall 2	31–80	60	30
		Fall 3	81+	48	48
Minnesota	343	Summer 1	2–80	55	18
		Summer 2	81+	12	12
		Fall 1	2–40	234	81
		Fall 2	41–80	103	50
		Fall 3	81–160	89	45
		Fall 4	161+	49	49
New York	350	1	.4–40	471	111
		2	41–80	102	70
		3	81+	74	74
North Dakota	400	1	.4–80	172	51
		2	81–140	101	45
		3	141–240	83	53
		4	241+	41	41
Oregon	350	1	.4–40	395	73
		2	41–120	71	48
		3	121+	23	23
Pennsylvania	350	1	.4–20	465	79
		2	21–40	79	26
		3	41–80	68	34
		4	81+	11	11
Washington	380	1	0–40	367	78
		2	41–160	177	75
		3	161+	57	57
Wisconsin	310	1	.4–40	291	52
		2	41–120	94	47
		3	121+	52	52

A similar approach has been used since 1971 for white corn area estimates in the 10 most important producing states. Yield estimates for white corn are based on grower reports rather than crop cutting type surveys.

In 1968 a multiple frame survey was implemented in Texas to provide local (county) statistics for some 65 crop and livestock characteristics. A brief description of this system of surveys was reported by Hartley (1973), who served as a consultant in the development stage. This local data program has resulted in significant improvements in the precision of state level estimates. Table 5 provides a comparison of the sampling errors (coefficients

TABLE 5. COEFFICIENTS OF VARIATION, JUNE 1975, TEXAS MULTIPLE FRAME SURVEY COMPARED WITH 1975 AREA FRAME SURVEY

Crop	Multiple Frame C.V. (Percent)	Area Frame C.V. (Percent)
Alfalfa hay	14.1	28.2
Other hay	5.8	7.5
Barley planted	19.4	41.4
Barley harvested	23.6	42.8
Corn planted	7.2	14.8
Corn harvested	7.2	14.9
White corn planted	13.4	35.3
White corn harvested	13.6	35.6
Cotton-Upland	3.4	5.7
Flax planted	17.0	58.2
Oats planted	6.6	10.0
Oats harvested	8.1	13.7
Peanuts	12.6	28.4
Rice	10.6	22.1
Rye planted	12.5	26.3
Rye harvested	27.2	16.0
Sorghum planted	3.6	5.8
Sorghum harv. grn.	3.6	5.9
Soybeans	15.8	30.8
Wheat planted	4.9	6.1
Wheat harvested	3.5	5.9

of variation) of crop area estimates from the area frame survey and multiple frame surveys.

6. Survey operations, misc. pub. no. 1308 (1975)

The general-purpose area sample, as supplemented with list frames for selected crops, provides a planted area base near the beginning of each crop year (June) as well as harvested area for fall seeded small grain crops. This sample also enables the selection of a probability sample of fields which are used to make objective yield surveys of major crops at monthly intervals during the growing season.

6.1 *Organization and Training*

Enumeration of the general purpose area sample, commonly referred to as the June Enumerative Survey, is one of the major data collection tasks in the program of current agricultural statistics administered by the Statistical Reporting Service. However, it has been so well planned and integrated into the total program that it scarcely causes a ripple in the day-to-day routine of the agency.

The Statistical Reporting Service is organized with centralized direction from Washington, D.C. and decentralized operations through 44 field offices serving all 50 states. For surveys, such as the June Enumerative Survey, plans, instructions, and budgets are developed in Washington. In each field office, professional statisticians serve as the state supervisors. The state office hires and trains local individuals or enumerators to do the actual field work. Many of the enumerators are part-time farmers who can arrange to leave someone in charge of the farm while they work on the survey. Other enumerators include farmers' wives or persons who have a good knowledge of agriculture. Although enumerator jobs are strictly part-time with total annual employment limited to 180 days, many members of the enumerator staff have worked for more than 10 years and some have worked as enumerators for as long as 20 years.

Training for the June Survey involves a two-stage program. First the Washington staff trains the state supervisors, in two or more regional schools of 3 to 4 days duration. Then the state supervisors train the enumerators, typically in a 2 to 3 day state school. Larger states, such as Texas, and California, may hold as many as four training schools.

The state supervisor assigns and oversees enumerators and checks returned survey questionnaires in the state office for completeness and consistency.

The data are converted to machine readable form, usually by keypunching, for computer editing and summarizing. All states are linked by a data communications network that uses the same generalized editing and summary system for this data processing. This enables the use of a large-scale centralized computer with operations decentralized to the states. The Washington staff combines the state summaries to compute regional and national totals, again using the same computer, to cut down on the time-consuming task of transmitting data by mail.

6.2 *Quality Control*

In addition to the training activities, a number of other quality controls are used for the June Enumerative Survey to ensure data accuracy. These include careful selection of enumerators, detailed instruction manuals, close field supervision, built-in questionnaire checks, and comparison of reported area to area measured on aerial photos. In addition a re-enumeration of a subsample from the June Enumerative Survey is conducted each July. This survey provides a quality check on the accuracy of the original enumeration and is used to update estimates of crop area planted for crops planted subsequent to the June enumeration. The re-enumeration in 1976 included 9 percent (11,491 interviews) of the tracts (a tract is defined as a portion or subdivision of a segment that is under one management) enumerated in the original June Survey. Crop area estimates published at the end of June are updated (if required) to include the later information and re-published in the August 1 Crop Report.

6.3 *Scheduling and Publishing*

The timing of the June Enumerative Survey, and all surveys used in the current agricultural statistics program, is dictated by the schedule of release dates for crop, livestock and price reports. For example, the June Enumerative Survey which is conducted during the last week of May and the first week of June to collect data on pigs that are published about June 23 and the data on planted area that are published about June 30. The actual date and hour for releasing these and other statistical reports is published late each year for all of the coming year. The schedule is strictly adhered to by the Statistical Reporting Service.

7. Objective yield surveys

At the time plans were developed for the area sampling program, there was general recognition that crop yield estimates needed to be strengthened if major improvements in crop production estimates were to be realized.

The area sample provided, for the first time a probability sample of fields from which data could be collected by observation or from farmers to generate independent estimates of crop yields. This sample of fields has been used for making monthly forecasts of yield and production during the growing season and for making estimates of final yield and production at season's end. Forecasts and estimates are considered by the Statistical Reporting Service to be two distinct concepts. A forecast of yield is an assessment of prospective yield in advance of crop maturity, while an estimate of yield is made when a crop is mature and ready for harvest. In the context of a "current" statistics program, forecasts of crop production in many instances are considered more important and receive more public attention than do the final estimates. Therefore, improving U.S. agricultural statistics has not only involved better sampling methodology, there has been much concern with reducing forecast error, particularly for crop yields. Objective yield surveys for collecting plant counts and measurements during the growing season have been one of the primary means for reducing forecast error during the past decade.

7.1 *Sample Field Selection*

The probability area sample conducted in early June provides information on area planted to various crops. The December Survey indicates area planted to winter wheat. In these surveys, all fields in each sampling unit are delineated on aerial photographs. The kinds of crops and area in each field are recorded. For each crop in the objective yield survey program, a subsample of fields is selected with probabilities proportional to size. Within each sample field, two small plots are selected, using random coordinates. These plots are marked with small stakes so they can be located, usually monthly, during the growing season to obtain data needed for making forecasts. When the crop is mature, the plots are harvested to estimate biological yield. After the farmer harvests the fields, the enumerator returns to measure harvesting losses, that is, the amount left in the field. Houseman and Huddleston (1966).

The following Table 6 for 1976 shows the scope of the current objective yield program in the United States for major field crops. Other objective yield surveys, primarily for tree crops (citrus, filberts, cherries, almonds, etc.) are conducted using nonfederal (state government, or private sources) funding.

8. Quality of estimates

It is difficult, and perhaps inappropriate, for those who have been intimately involved with the planning and implementation of the current probability

TABLE 6. OBJECTIVE YIELD SURVEYS 1976, CROPS AND STATES COVERED, SAMPLE SIZE AND COEFFICIENTS OF VARIATION

Crop	No. of States in Survey	No. of Sample Fields	Approx. Size of Plots in Hectares	Approx. Size of Population: Harv. Hectares in Millions	Approx. Size of Population: Percent of U.S. Total	Coeff. of Var. of Estimated Yield per Hectare (Percent)
Corn	20	3400	0.0009	26.6	92.6	0.9
Cotton	14	2510	0.0006	4.4	99.9	1.2
Fall Potatoes	12	2100	0.0006	0.4	93.9	1.0
Soybeans	14	1675	0.0002	17.5	87.4	1.4
Spring Wheat	5	630	0.00003	8.2	95.0	2.2
Winter Wheat	15	1880	0.00004	17.9	89.3	1.3

system of surveys to judge or measure its success in terms of quality of the resulting statistics. It is, I think, fair to say that the system has met and in many cases exceeded the goals established in the early 1950's. There is greater confidence within the Statistical Reporting Service and the data-user community in the quality of current agricultural statistics for the United States. The system produces independent, unbiased estimates, and thus the current U. S. agricultural statistics program no longer depends on the quinquennial census of agriculture for national "benchmark" data. In fact, the June Enumerative Survey was used as the basic measure of coverage for the 1969 and 1974 Censuses of Agriculture.

Before discussing several independent studies on the accuracy of current agricultural statistics, I would like to review the factors that led to the decision to improve the program of current agricultural statistics.

In 1953, a panel of consultants was formed to guide the Agricultural Estimates Division (now the Statistical Reporting Service) in developing a research program to improve its estimating and forecasting work. Here are excerpts from the Panels' May 17, 1954, report :

> "... The collection of statistical reports issued by the Division is unusually comprehensive in scope and coverage and, within the limitations of the methods employed and the constraints imposed by the pressing time schedules that have to be met, is of commendably high quality. ... It is nevertheless true that the statistical output of Agricultural Estimates is subject to certain basic weaknesses arising primarily from the methods of data collecting employed ... The statistics

product of the Division is not as sound as it could be because : (1) the vast array of estimates and forecasts, both state and national, prepared by Agricultural Estimates derives largely from information procured from samples self-selected from a population that is itself not precisely defined, and (2) the information collected from respondents is not subject to systematic objective checks, ...

In an effort to compensate for the basic inadequacies in the methods of data collection and measurement, various adjustments have been evolved over the years. For items for which enumerative or check data are periodically available, indications are expanded by utilizing the relation. between past check data and past sample indications. For other items, weighting procedures, in some cases extremely involved, have been developed. The system as a whole allows a considerable amount of free play; judgments and appraisals by the professional staff enter into all stages of the estimating process. A certain degree of flexibility is undoubtedly desirable in any comprehensive estimating system so that defects in the data may be corrected or reduced whenever dependable information from other sources is available for this purpose. However, it appears to us that the statistical activities of Agricultural Estimates are excessively dependent on judgment and we are not convinced that the adjustments that are made really succeed in overcoming the inadequacies of data.

It would appear that on the whole sounder procedures have been developed for estimates of magnitudes for which check data become eventually available. It is to be noted, however, that the adjustments in current use are based on the assumption of continuance of the relationships to the check data that have been observed in the past. This is under any circumstances not a completely dependable assumption although it may not be possible to dispense with it entirely. This assumption becomes particularly vulnerable when the system producing sample indications is itself not under control and when unusual changes are occurring, i.e., at just those periods in which good estimates are needed most urgently. We note further that even under optimal conditions the regression procedure produces estimates or forecasts based on a small sample of observations, not in excess of 30 or 40 years. Assuming that a high degree of relationship is observed, the estimating or forecasting interval is still likely to be wide if there is considerable annual variation. Less can be said in defense of expansion procedures consisting of direct application of sets of weights intended in one way or another to correct for biases and unrepresentativeness which the data collection procedure permits to enter. One-shot empirical studies designed to determine the existence of bias are of limited usefulness in appraising the dependability of such procedures in a continuing operating program.

In the panel's view, expert judgment cannot fully and consistently compensate for the basic shortcomings in the methods of data collection and measurement. The system, as experience demonstrates, does not provide the amount of insurance that is now possible against serious and costly errors. This is not to deny that definite improvements can be attained without departing too markedly from current procedures. Such improvements are probably possible and one of our specific recommendations is, in fact, directed toward the exploration of such possibilities, particularly in state estimates and forecasts. The panel considers it, however, extremely unlikely that such relatively minor adjustments can be sufficiently effective and that anything short of fundamental changes in the procedures could produce the desired results.

The Task Ahead

The basic task facing Agricultural Estimates is to develop and put into operation an efficient system of producing timely national and state estimates and forecasts that have measurable and controllable accuracy. In the panel's view this can be attained only by: (1) shifting to well-designed objective sampling procedures (which may consist of both area and list sampling) and (2) supplementing and replacing wherever necessary subjective judgmental indications by efficient objective measurements. Objective sampling and objective measurement appear to us to be the essential features of a sound statistical system. *Our general recommendation is that the research undertaken by Agricultural Estimates be geared specifically to introduce these features into the operation system.*"

The methodological improvements envisioned by the 1954 panel have, by and large, been made and in most cases exceeded, in today's program. As indicated earlier, it is somewhat difficult to measure the degree of improvement from methods implemented during the past two decades, particularly since many recognized problems still remain to be solved. The following summaries of three independent studies offer a partial indication of the quality of current agricultural statistics in the U.S.:

Results from a study by Gunnelson, Dobson, and Pamperin (1972) showed that accuracy of USDA crop forecasts increased moderately over the 1929–1970 period. This study compared initial forecasts and subsequent revised forecasts with estimates of final production published about one year after the growing season. The accuracy of forecasts was judged according to accuracy improvement expected during the growing season as more information becomes available according to the following criteria :

"1. A given forecast should improve upon the accuracy of information contained in previous forecasts that were developed on the basis of less information.

2. Forecasting error should be smaller for crops with shorter forecasting periods and under conditions when crop production changes relatively little from year-earlier levels. Revised crop forecasts also should be more accurate than earlier forecasts.

3. Forecasts should be free of systematic error or "biases"."

The summary of this study states that :

> "USDA crop forecasts have become more accurate over time and exhibit desirable properties when appraised by the three criteria. Although this study revealed no serious inadequacies in the crop forecasts, the analysis identified a few persistent inaccuracies in the forecasts. Specifically USDA tends to : (1) underestimate crop size, (2) underestimate the size of changes in production from year earlier levels, particularly when changes are large, and (3) under compensate for errors in previous forecasts when developing revised crop production forecasts. ... The study indicated that progress in improving the accuracy of crop forecasts has been gradual and the results can be considered somewhat modest."

Dobson in discussing this study was credited with the following quote in *Wall Street Journal* article (August 11, 1975), "The 4·5 percent error for all wheat and feed grain forecasts in the 1960's compares with a 10 percent error in the 1930's. And the government's corn production forecasts were nearly 18 percent off the mark in the 1930's, but by the 1960's the error was down to 3·9 percent".

In a similar study limited to wheat for the period 1966–1975, Warren (1977) in comparison with a 90/90 criteria (defined as meaning that at least 90 percent of the forecasts of production for a country will be in error by less than 10 percent) found that :

"The accuracy of the SRS (USDA) July 1, August 1, and September 1 forecasts of total production of all wheat in the United States during this period (1966–75) far surpasses the 90/90 criteria.

— at least 99 percent of the SRS forecasts of the acreage of all wheat and of all winter wheat to be harvested for grain in the United States would be in error by less than 5 percent. Also at least 96 percent of the predicted acreages of all spring wheat to be harvested for grain would be in error by less than 5 percent.

— SRS yield forecasts attained 90/90 accuracy by July 1 for winter wheat, by August 1 for all wheat, and by September 1 for spring wheat...

These findings indicate that any significant improvements in the accuracy of SRS forecasts will have to be made through the development of improved yield forecast procedures."

Steyaert (1977) completed a study in which he investigated "some aspects of the quality and characteristics of crop data determined and published by the Statistical Reporting Service". In this study he compares the preliminary (end of growing season), first revision, and final revision estimates for corn, wheat and soybeans for the 1944–1974 period. These comparisons are made for both the national estimates and for major state estimates. Conclusions from this study generally support the thesis that quality (in terms of both precision and bias) of these crop statistics has improved during the past decade. The author listed the following conclusions pertaining to national level statistics for this study:

"(1) For years subsequent to 1967, a comparison of preliminary, first revision, final revision SRS estimates and also Census data does not disprove SRS claims that crop estimates are within 1 to 2 percent at the national level. (2) The forecasts of major crops issued by SRS tend to improve as more information is gained during the crop season, but there is a tendency for the forecasts to underestimate first revision estimates. (3) Preliminary and first revision data at the national level have historically overestimated all wheat production by 0·5 to 1·5 percent and underestimated corn for grain production 1 to 2 percent on a consistent basis relative to the final revision. These systematic relative changes are not statistically significant."

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Key Words

Agricultural Surveys, Probability Sampling, Area Frames, List Frames, Multiple Frame Sampling, Training Objective Yield Surveys.

Abstract

Operation of a system of probability surveys for estimating crop production, while not without problems, has been successful in meeting the quality goals established during the planning phase of this system. During a period when agricultural statistics have come under increasing scrutiny because of the world food situation and because of changes occurring in total agricultural production the underlying methodology has been extremely valuable in providing reliable information on prospective as well as final crop production in the United States.

Many changes and improvements have been made since the original survey design went operational for the 48 conterminous states in 1967. Area sampling frames have been improved and updated. The present schedule calls for the area frame to be completely updated at least every 12 years.

A major effort to build and maintain a "complete" list frame of all farm operators was started in 1975 with completion of the original list building process scheduled for 1978.Such a list will need to be updated continually.

Other changes have included introducing "interpenetrating" sampling for the area frame, which has made sample selection and rotation of sampling units much easier. Standardization of land-use strata definitions has increased efficiencies of overall frame construction and sampling. Multiple frame sampling has been extremely useful in reducing sampling variation for speciality crops and will probably be expanded once the general purpose list sampling frame is available in 1978.

Most operational problems for large scale probability surveys have been solved and activities are routine. Improvements in yield forecasts and estimates through objective yield surveys

have been somewhat modest in comparison to improvements in acreage estimates from the area sample. Present research efforts are devoted to developing new models using additional environmental variables for measuring and predicting crop yields. We expect considerable improvements to come from this effort within the next decade.

Finally, independent analyses confirm that improvements in the quality of crop estimates have been made during the past two decades. Although these improvements are more modest than might be expected by some, they have met or exceeded the goals set at the time work was started to implement a probability system of surveys for current agricultural statistics.

Résumé

Le fonctionnement d'un système de sondages de probabilité en vue d'évaluer la production des récoltes, bien qu'il ne soit pas sans problème, a réussi toutefois à satisfaire la qualité visée par les buts établis au cours de la phase de planification de ce système. Au cours d'une période, pendant laquelle les statistiques agricoles sont l'objet d'un examen minutieux en raison de la situation alimentaire mondiale et en raison de changements qui ont lieu dans la totalité de la production agricole, la méthodologie fondamentale a été extrêmement utile, fournissant des informations sur la production des récoltes à venir, aussi bien que sur celle des récoltes définitives aux Etats-Unis.

Des changements et améliorations nombreux ont été faits depuis que le projet original de sondage est devenu opérationnel en 1967, dans les 48 états du continent des Etats-Unis. Les structures des zones échantillons ont été améliorées et modernisées. Le plan d'exécution actuel prévoit la mise a jour complète de la structure zonale au moins tous les 12 ans.

Un effort majeur pour développer et maintenir un système de liste "complète" de tous les opérateurs de fermes a débuté en 1975, et l'achèvement du processus de développement de la liste originaire est projeté pour 1978. Une telle liste devra être mise à jourcont inuellement.

D'autres changements ont compris l'introduction d'un échantillon de "interpénétration" dans la zone structurale ce qui a facilité la sélection d'échantillons et la rotation des blocs d'échantillonnages. L'unification des définitions appliquées aux couches destinées à l'usage agricole a augmenté le rendement de la zone échantillon dans son ensemble et aussi de l'échantillonnage. Le système de zones échantillons multiples a été très utile pour réduire a variété des échantillons de récoltes spécialisées et il sera probablement amplifié une fois que la liste des zones échantillons à u age general sera disponible en 1978.

La plupart de probléme se rapportant aux sondages de probabilité de grande envergure, ont été résolus et les activités sont devenues routiniaires. Les améliorations apportées aux prévisions de rendement et les prévisions de récoltes résultant de sondages objectifs ont été plutot modestes en comparaison des améliorations concernant les prévisions de superficie des zones échantillons. Les efforts de recherche actuels sont consacrés au développement de nouveaux models utilisant des variables d'environnement supplémentaires à fin de calculer et psédire le rendement des récoltes. Nous nous attendons a des améliorations considérables résultant de cet effort en moins de dix ans.

Finalement, des analyses independantes confirment que des améliorations ont été faites pendant les 20 derniéres années quant à la qualité des Services de Reportages Statistiques d'évaluations des récoltes. Bien que ces améliorations soient plus modestes que certains auraient espérées, elles ont repondu aux buts et même depassé ces buts établis lorsque le développement d'un sytéme de sondage de probacilitées pour les statistiques agricoles courantes, a été mis en oeuvre.