1987 CENSUS OF AGRICULTURE COVERAGE EVALUATION ESTIMATION

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1. BACKGROUND

1.1 Census of Agriculture Data Collection

The agriculture census is the major source of data for the Nation's agricultural production. It is the only source of uniform, comprehensive data on agricultural production and operator characteristics for each county, state and the Nation. Report forms for the 1987 Census of Agriculture were mailed to farm and ranch operators in late December 1987 to collect data for the 1987 calendar year. All those who received a census form were asked to return their report forms by February 1, 1988. Those not responding by that date were contacted by letters or telephone calls. Upon receipt by the Bureau of the Census, the forms were checked for completeness and accuracy.

1.2 Evaluation of Census of Agriculture Coverage

A coverage evaluation program for a census is an important means for assessing completeness and accuracy of data. The purpose of this paper is to present the objectives, sample design, and estimation for the 1987 Census of Agriculture Coverage Evaluation Program, and plans for future research in coverage evaluation estimation. Data from the 1987 program will provide independent measures of the number and characteristics of farms not on the census mail list, misclassified farms, and overcounted farms. The program also aids the identification of separate problem areas for future improvements in developing the census mail list and in collecting and processing the data.

Although the goal of each census is to include all farm units, continuing change in operational units, inadequacies of source lists, difficulty in communicating census definitions and concepts, and other factors contribute to census error and incompleteness. An evaluation of coverage has been conducted for each agriculture census since 1945. Several procedural modifications resulting from coverage evaluation findings have been introduced into various censuses.

Coverage evaluation programs are designed to measure errors in the mail list and in farm classification. Mail list error includes a measurement of farms which were not enumerated during the census and, thus, are not on the census mail list and measurement of "farms multiply enumerated"--the first error contributes to census undercount; the second to census overcount. Classification error includes a measurement of "farms classified as nonfarms" and of "nonfarms classified as farms"--the first error contributes to census undercount; the second error contributes to census overcount. For all sizes of farms, the list error of "farms not on the mail list" dominates other errors. This component varies considerably by state. Estimates of these components of error will be provided in a separate report in the census publication series. In addition, a net coverage error will be provided.

1.3 1987 Census of Agriculture Coverage Evaluation Program

The 1987 Census of Agriculture was designed to provide both state-level and regional-level estimates rather than only regional-level estimates of farms not on the mail list during the census. This required an increase in sample size above the 1982 level. Rather than construct its own area frame, select a sample, and conduct a field enumeration survey, the Census Bureau's Agriculture Division entered into an agreement with the USDA, National Agricultural Statistics Service (NASS). In this agreement, the Division provided specific requirements for the 1987 June Enumerative Survey data collection to ensure the resulting data would be appropriate for the census coverage evaluation program. These requirements included specification of additional items for the data collection, an increase in agricultural screening in the agricultural urban stratum of the sample, and a 20 percent increase in the sample size in the agricultural urban stratum of the sample. The Classification Error Survey was used to measure classification error and list duplication error. This independent sample, selected from the census mail list, was designed to provide regional estimates of the true number of farms with a designed coefficient of variation of 15 percent. This design provided more reliable regional-level estimates than were published in 1982.

2. 1987 COVERAGE EVALUATION PROGRAM

The coverage evaluation provided an estimate of undercount and overcount. For a variety of reasons some farms are not enumerated by the census. The difference between census count and true size of the population is defined as net coverage error. The census count may be greater than the true size (an overcount), but usually the error is such that the census count is less than the true size (an undercount).

2.1 Objectives

The 1982 Census of Agriculture, had a net undercount of 9.1%. This includes about 259,944 farms not on the mail list (or 10.6% of the 1982 farms), 76,554 farms classified as nonfarms (or 3.1% of the 1982 farms), and 113,623 nonfarms classified as farms (or 4.6% of the 1982 farms).

The objectives of the coverage evaluation program for the 1987 Census of Agriculture were:

- o To provide state estimates of the number of farms not on the mail list and their characteristics for state census publications.
- o To provide national and regional estimates of the number of operations incorrectly classified, of the number of duplicate farms, and of the number of farms not on the census mail list.
- o To provide national and regional estimates of selected agricultural characteristics of undercounted farms.

The 1987 June Enumerative Survey (JES) and the 1987 Classification Error Survey (CES) were used to meet the above objectives. The JES was used to estimate the number and characteristics of farms not on the mail list during the 1987 census. State level estimates of farms not on the mail list and their characteristics were published in Table G of Volume 1, Geographic Area Series, Appendix C. The CES was used to estimate the number and characteristics of farms incorrectly classified. Regional level estimates were published separately, and in addition to, the not on the mail list estimates, in the separate census coverage evaluation report, Volume 2, subject series, Part 2, Coverage Evaluation. This publication will be available in early 1990.

2.2 Coverage Error Model

Any farm universe total (T) for some characteristic can be represented as the census published number (C) for the characteristic plus the undercount (U) for that characteristic minus the overcount (OV) for that characteristic; i.e.:

FARM UNIVERSE	=	CENSUS PUBLISHED FARMS	+	FARMS UNDER-COUNTED IN CENSUS	-	FARMS OVER-COUNTED IN CENSUS

$$T = C + U - OV \qquad (1a)$$

The undercount (U) can be split into a component consisting of farms not on the census mail list (NML) and a component consisting of farms on the census mail list that were incorrectly classified as nonfarms (MCF). Substituting into equation (1a):

$$T = C + NML + MCF - OV \qquad (1b)$$

The estimate is based on the Petersen Coverage Model (See Wolter, JASA, June 1986) and uses the JES and CES sample estimates. The estimation procedure is discussed in Section 5.

3. JUNE ENUMERATIVE SURVEY

As indicated earlier, JES was used to measure the number of farms not on the census mail list. The JES is an annual personal enumeration area sample survey conducted by NASS to measure planted acreage of crops and numbers of livestock, using approximately the same reference period as the census.

3.1 Sample Design

NASS develops, uses, and analyzes area sampling frames for conducting surveys to gather information regarding crop acreage, cost of production, farm expenditures, crop yield and production, livestock inventories, and other agricultural items. An area frame for a state consists of a collection or listing of land parcels defined on factors such as ownership or based simply on easily identifiable boundaries. The basic stratification employed by NASS involves dividing the land in a state into about six or eight land use strata such as intensively cultivated land, urban areas, agricultural urban areas, rangeland, and others. Each strata is further divided by grouping agriculturally similar areas into substrata. The agricultural urban strata were of particular interest for measuring farms not on the census mail list. Such strata are usually located around a city where the city merges into the rural area and include small rural towns. They often contain small acreage farms or off-farm residences of farm operators. These types of operations are characteristic of operations missing from previous censuses.

Land parcels or area segments are the primary sampling units selected within each stratum. An average segment contains the residence of 1 or 2 farm operations. The size of a segment depends upon a multitude of related factors such as the survey objectives, estimation methodology, data collection costs, data variability among segments, length of survey interviews, population density, concentration of cropland, and availability of identifiable boundaries for the segments. Tracts consisting entirely of residential areas with no agricultural activity are designated as residential tracts. These tracts are more predominant in the agricultural urban stratum, but do occur in other strata.

Because residential tracts often have residents whose farm operation is outside the segment or who operate small farms, we requested more intensive screening procedures than NASS presently used in these tracts. Within such tracts, the enumerator was required to compile a listing of all houses, to systematically sample households according to a given procedure, to ask questions that screen for agricultural activities of household members, and to inquire whether these residents know any neighbors that have agricultural activity. The objective of the subsampling procedure was to provide a systematic method for obtaining information about all tract residents. Prelisting and prescreening were conducted in the fall of 1986 for all residential tracts with 11 or more households in the 1986 JES sample. In May of 1987 previously screened tracts were updated and all remaining residential tracts were listed and screened.

In order to increase the reliability of the estimates of farms not on the mail list, NASS retained in the sample 20 percent of the agricultural urban segments from 1986 that had been scheduled to be rotated out of the sample in 1987. This provided a 20 percent overall increase in the number of agricultural urban segments across all states as well as an

increase in the residential tracts in the sample. In several states, additional minor increases were made in the number of agricultural urban segments to meet census sample size requirements. Periodic NASS sample redesign in several states for the 1987 JES incorporated desired census changes.

3.2 Census Processing of the 1987 June Enumerative Survey

The data file received from the JES data collection consisted of names, addresses, and agricultural identifier data on all sample area segment residents that had any indication of agricultural activity. The requested supplemental data items included identifying information and whole farm agricultural data. An initial match of this data file to the census mail list identified all JES area sample records and assigned a special code for census processing. All JES sample records not on the census mail list were mailed a census form. A JES data file was created for each state that contained the JES identifier, segment, tract, and weighting information and the matching census file number for sample cases on the census mail list.

During the census, potential duplicate records were clerically matched using the additional identifier data. Agricultural data such as number and type of crops, livestock, total value of products sold, and land usage were used to determine the farm status of area sample cases that did not respond to the census and to resolve cases where the JES and census farm status differed. In order to identify the final status of each JES sample record, coverage classification codes were assigned during census processing to identify each component of the farm universe. The coverage classification code for each record defined the farm status--in-scope or out-of-scope--and relationship to the census mail list--match or nonmatch. Both the match and nonmatch farm record constituted the sample for deriving estimates of farms not on the census mail list. Data were then keyed, edited, and reviewed for accuracy and consistency.

4. CLASSIFICATION ERROR SURVEY

The CES was designed to measure classification error and list duplication error. Additionally, the CES measured characteristics of farms incorrectly classified as nonfarms.

4.1 Sample Design

The sample for the CES was an independent, regionally stratified systematic random sample from the census mail list of 4.1 million names and addresses. Initially a systematic sample of 18,200 names and addresses was selected from the census mail list with a sampling rate that varied by census geographic region: 1 in 75 in the Northeast, 1 in 519 in the Midwest, 1 in 187 in the South, and 1 in 259 in the West. All operations ineligible for selection included operations in Alaska and Hawaii, operations with expected sales of $500,000 or more, and multi-unit or abnormal operations. (Abnormal operations include Indian reservations, research farms, experimental farms, institutional farms, etc.)

4.2 Data Collection for Classification Error Survey

The classification sample was selected from the final census mail list and identified in the mail list by unique evaluation codes. At designated cut-off dates, the census report form check-in status was obtained for all sample addresses using the census data base. Two mail groups of census respondents from the classification sample were selected with mailout for the two groups of respondents in March and July, respectively. The mail data collection procedure for each group required a postcard followup two weeks after initial mailout, a form followup four weeks after initial mailout, and a telephone followup six weeks after initial mailout for nonrespondents only. A technical review of sample questionnaires was conducted to classify operations as either farm or nonfarm.

4.3 Census Processing of Classification Error Survey

Farm status was determined by comparing data on the CES report form (A90) with the final census farm status. In order to determine the final status of each sample record, coverage classification codes were assigned during census processing to identify each component of the farm universe. The coverage classification code for each record defined the relationship (match or nonmatch) between the census farm status and the CES farm status.

5. COVERAGE ESTIMATORS

Separate estimates were computed for farms not on the census mail list, farms classified as nonfarms, nonfarms classified as farms, and duplicate farms. Analogous to section 2.2, any farm universe total, T_x for some characteristic x of farms in the United States can be represented as the census published number for that characteristic, C_x, plus the undercount for that characteristic, U_x, minus the overcount for that characteristic, OV_x; i.e.:

$$T_x = C_x + U_x - OV_x \qquad (2a)$$

This can further be broken down into the following components:

$$T_x = C_x + NML_x + MCF_x - OV_x \qquad (2b)$$

where NML_x is the component of undercount for the characteristic for farms not on the census mail list, and MCF_x is the component of undercount for the characteristic for farms incorrectly classified as nonfarms.

The coverage error model assumes the following: a) both the census, which is observable, and the universe of the JES, which is not observable, attempt to enumerate accurately the complete universe of farms, and farms reported on either list are true farms;

b) the event of being included by the census is independent of being included in the survey; c) the probability of being missed by either the census or the survey is the same for all farms within a given size category; and d) every farm in the complete universe of farms has, independently of every other farm, the same chance of being listed in the census and, independently of listing in the census, the same chance of being listed in JES. The properties of this model and its derivation are discussed by Wolter, (JASA, June, 1986). Since JES and the census may have incomplete lists, each farm in the universe can be placed into one cell in the following matrix:

	June Enumerative Survey Farms		
Census Farms	In Survey Universe	Out of Survey Universe	
On Mail List	N_{11}	N_{12}	N_{1+}
Not On Mail List	N_{21}	N_{22}	
	N_{+1}		

where,

N_{11} = the number of farms on the census mail list and in the JES universe resulting from the match of the JES area sample farms to farm records in the census,
N_{12} = the number of farms on the census mail list but not in JES,
N_{21} = the number of farms in JES but not on the census mail list resulting from the match of the JES area sample farms to farm records in the census,
N_{22} = the number of farms not on the census mail list and not in JES,
N_{1+} = the number of farms on the census mail list adjusted for classification error,
N_{+1} = the number of farms in the JES.

The estimator of N_{12} is:

$$\hat{N}_{12} = N_{1+} - \hat{N}_{11} \tag{3}$$

The estimator of N_{22} is:

$$\hat{N}_{22} = (\hat{N}_{21} * \hat{N}_{12})/\hat{N}_{11} \tag{4}$$

The maximum likelihood estimate of total farm count provided by the model is:

$$T = [(\hat{N}_{11} + \hat{N}_{12}) * (\hat{N}_{11} + \hat{N}_{21})]/(\hat{N}_{11})$$
$$= N_{1+} + (N_{1+}) * (\hat{N}_{21}/\hat{N}_{11}) \tag{5}$$

Then, total T_x for the characteristic x can be estimated by:

$$\hat{T}_x = C'_x + (\hat{S}_x) * (N_{1+}/\hat{N}_{11}) \text{ where,} \tag{6}$$

where,

S_x = the unbiased sample open-segment estimate of the total of the characteristic x for farms not on the mail list but in the JES sample,
C'_x = the total value for farms in the census with the characteristic x adjusted for classification error; note that C'_x is equal to N_{1+} when characteristic x is number of farms,
N_{1+}/N_{11} = ratio of number of farms with characteristic x.

The ratio of the census farm count to estimated farms in both the JES area sample and the census was computed separately for total farms with sales of less than $2500 and for total farms with sales of $2500 or more within each published geographic area. Each ratio was then multiplied by the estimate of the total for that sales break. Both breaks were then summed to produce totals. Both estimated census farm count for a given characteristic, C', and the census value of the characteristic, C'_x, were adjusted for farm classification error; i.e.

$$C' = C + MCF - OV, \text{ and} \tag{7}$$

$$C'_x = C_x + MCF_x - OV_x \tag{8}$$

where,

C_x = the total value of characteristic x for the census,
MCF_x = the total value of characteristic x for misclassified farms,
OV_x = the total value of characteristic x for overcounted farms.

The estimated number of incorrectly classified farms and the estimated number of overcounted farms for characteristic x were unbiased sample estimates from the CES. These estimates were, likewise, computed separately for farms by the two previously specified sales groups within each published geographic area and summed to produce characteristic totals.

The estimate of total number of farms not on the mail list is:

$$\hat{NML} = \hat{N}_{21} + \hat{N}_{22} = \hat{N}_{21} * [N_{1+}/\hat{N}_{11}] \tag{9}$$

The component of the undercount of some characteristic x for farms not on the census mail list, NML_x, was estimated by:

$$\hat{NML}_x = (\hat{S}_x/\hat{N}_{21}) * (\hat{N}_{21} + \hat{N}_{22})$$
$$= (\hat{S}_x/\hat{N}_{21}) * \hat{N}_{21} * (N_{1+}/\hat{N}_{11})$$
$$= \hat{S}_x [N_{1+}/\hat{N}_{11}] \tag{10}$$

As previously mentioned, state level estimates of counts and selected characteristics of farms not on the mail list were published in the state census volumes. As estimates of classification error were not available at the state level, the estimated farm counts used in the state census volumes were not adjusted for classification error. The bias resulting from this procedure was considered to have less impact on mean square error than the increase in variance incurred by using a synthetic estimation procedure to provide state level estimates of classification error.

Data for the estimates of farms not on the mail list were obtained through open segment enumeration. This requires the collection of all livestock and crop data for all farm operations where the farm operator lives within the segment boundaries. The open segment sample estimate of the state total for a characteristic x is:

$$\hat{S}_x = \sum_{i=1}^{2} \sum_{j=1}^{n_i} e_j \left(\sum_{k=1}^{m_j} s_{ijk} \right) \quad (11)$$

i = sales group (<\$2500 and greater than or equal to \$2500),
j = segment within group,
k = farm within segment ,
n_i = number of sample segments in i^{th} group,
e_j = expansion factor or inverse of the probability of selection for the j^{th} segment,
m_j = number of farms in j^{th} segment,
s_{ijk} = value of farm k in j^{th} segment, i^{th} sales group with characteristic x.

6. VARIANCE ESTIMATORS

6.1 Farms Not on the Mail List

The variance for a characteristic x for farms not on the mail list was developed using a Taylor Expansion of the ratio estimator. The variance for $\hat{NML}_x$ was estimated as follows:

$$\hat{V}_{NMLx} = (\hat{NML}_x)^2 \left[\frac{\text{Var } \hat{S}_x}{\hat{S}_x^2} + \frac{\text{Var } C_x}{C_x^2} + \frac{\text{Var } \hat{N}_{11}}{\hat{N}_{11}^2} \right] \quad (12)$$

where,

$\hat{S}_x$ = the total value of farms not on the mail list with characteristic x,
C = the total value for farms in the census with characteristic x,
N_{11} = number of farms on the census mail list and in the JES universe with the characteristic x.

$$\text{Var } \hat{S}_x = \sum_{i=1}^{2} W_i^2 \sum_{j=1}^{n_i} n_i/n_{i-1} * \left[e_j \sum_{k=1}^{m_j} X_{ijk}^2 - \left(\sum_{k=1}^{m_j} X_{ijk} \right)^2 / m_j \right] \quad (13)$$

where,

$(\text{Var } C_x)/C_x^2$ is the squared relative standard error of census farm count; Var C accounts for the variance derived from the nonresponse component of the census value. (14)

$$\text{Var } \hat{N}_{11} = \sum_{i=1}^{2} W_i^2 \sum_{j=1}^{n_i} n_i/n_{i-1} * e_j \left[\sum_{k=1}^{m_j} X_{ijk}^2 - \left(\sum_{k=1}^{m_j} X_{ijk} \right)^2 / m_j \right] \quad (15)$$

where,

W_i = post-strata weight
(W_1 < \$2500 TVP)
(W_2 > \$2500 TVP),
e_j = segment weight,
n_i = number of segments in strata i,
m_j = number of farms in segment j,
k = farms in segment,
s_{ijk} = value of NML farm k in j^{th} segment, i^{th} sales group,
x_{ijk} = value of included farm k in j^{th} segment, i^{th} strata.

6.2 Percent Farms Not on Mail List

The percent not on mail list is defined as:

$$P_x = \hat{NML}_x / (\hat{NML}_x + C_x) \quad (16)$$

A ratio estimator was also used to compute the standard error of the percent not on mail list. The variance estimator V_p is defined as follows:

$$V_p = \left[\frac{NML_x}{NML_x + C_x} \right]^2 \left[\frac{\hat{V}_{NMLx}}{\hat{NML}_x^2} + \frac{\text{Var } (\hat{NML}_x + C_x)}{(\hat{NML}_x + C_x)^2} \right] \quad (17)$$

where,

V_{NMLx} is defined in (12) and,

where,

$$\text{Var } (\hat{NML}_x + C_x) = \frac{N_{1+} * \hat{N}_{+1} * \hat{N}_{12} * \hat{N}_{21}}{\hat{N}_{11}^3} \quad (18)$$

See (Wolter, 1983) for derivation.

6.3 Misclassified and Overcounted Farms

The variance for characteristics classified as misclassified (MCF) and overcounted (OV) on farms from the CES was computed as if a random stratified sample was selected from each region. Let V_g be the variance for MCF or OV for region g, then

$$\hat{V}_g = N(N - n) * 1/n \sum_{k=1}^{n} \frac{(y_k - \bar{Y})^2}{(n - 1)} \quad (19)$$

where,

N = number of census addresses for region g

n = number of sample addresses for region g

y_k = value of misclassified or overcounted farm k for region g,

$$\bar{Y} = \sum_{k=1}^{n} y_k/n \quad (20)$$

The variance for the United States is then

$$\hat{V}_{ov} = \sum_{g=1}^{4} V_g \text{ for overcounted farms, and} \quad (21)$$

$$\hat{V}_{MCF} = \sum_{g=1}^{4} V_g \text{ for misclassified farms.} \quad (22)$$

6.4 Undercount

The undercount estimate is the sum of NML from JES and MCF from the CES. The variance of the undercount was estimated as follows:

$$\hat{V}_U = \hat{V}_{NML} + \hat{V}_{MCF} \quad (23)$$

where $\hat{V}_{NML}$ is defined in (12) and $\hat{V}_{MCF}$ is defined in (22).

6.5 Estimated Total Variance Estimator

The variance for the estimate T_x is computed as follows:

$$\hat{V}_T = \hat{Var}\, C + \hat{V}_{NML} + \hat{V}_{MCF} + \hat{V}_{ov} \quad (24)$$

where $\hat{Var}\, C$ is defined in (14), $\hat{V}_{NML}$ in (12), $\hat{V}_{MCF}$ in (22), and V_{ov} in (21).

For all variance estimators, zero covariance was assumed. This assumption may not be valid in all cases. Further review of the variance estimation methodology is planned prior to the 1992 Census of Agriculture Coverage Evaluation Program.

7. FUTURE RESEARCH IN COVERAGE EVALUATION ESTIMATION

The 1987 Census of Agriculture Coverage Evaluation program publication will provide more data items with associated coefficients of variation at lower geographic level than that provided by previous census evaluation programs. This data will be available at the state and census divisional level for farms not on the census mail list and their characteristics, and at the regional level for incorrectly classified and duplicate operations. The data from the CES will be used to measure the extent of classification and list duplication errors and to identify causes.

The data from the program will also have important methodological applications. The estimates of farms not on the mail list with their associated coefficients of variation will be used to identify states where changes in the size or allocation of the area sample are desired and to review the applicability of the JES sample design for estimating farms not on the census mail list. Initial review of estimates identified variability in the size of the samples to estimate farms not on the mail list, in the coefficient of variation of farms not on the mail list, and the percent not on the mail list. These factors will need to be reviewed in relation to the JES sample design.

The NASS has begun to use more extensively a weighted area segment estimator in its' JES because studies have shown that its' precision is better than that of the current open segment estimator. During the 1987 coverage evaluation program data was received from NASS in six states that would permit later evaluation of the weighted area segment estimator for estimating farms not on the mail list. (Winters, 1986). The weighted segment estimator uses the whole farm data for the survey item being estimated, the total tract acreage (in the segment), and the total farm acreage for each farm operation with land in a sampled segment. The weights, based on the acreages, are then used to prorate the whole farm data for each identified survey item to derive the tract estimate. This research will provide important information for evaluating these two estimators in relation to the design of a census area sample that measures farms not on the mail list.

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