

1979 FARM EXPENDITURE SURVEY DESIGN AND
ESTIMATION PROCEDURESJ.E. Phillips¹

The Farm Expenditure Survey was developed to provide annual expenditure estimates for the Western Grain Stabilization Act which is an income stabilization program for grain farmers in the prairies and Peace River district of British Columbia. This paper describes the design of the 1979 survey which incorporated a stratified two-stage design in the area sample and a single take-all stratum in the list sample.

1. PURPOSE AND HISTORY

The Farm Expenditure Survey (FES) was developed to provide expenditure estimates for the Western Grain Stabilization Act which is an income stabilization program for grain farmers in the prairies and Peace River district of British Columbia. This area has been divided into 10 soil zones, which are made up of crop districts, by Agriculture Canada. The FES estimates are to be provided at both the soil zone and province level.

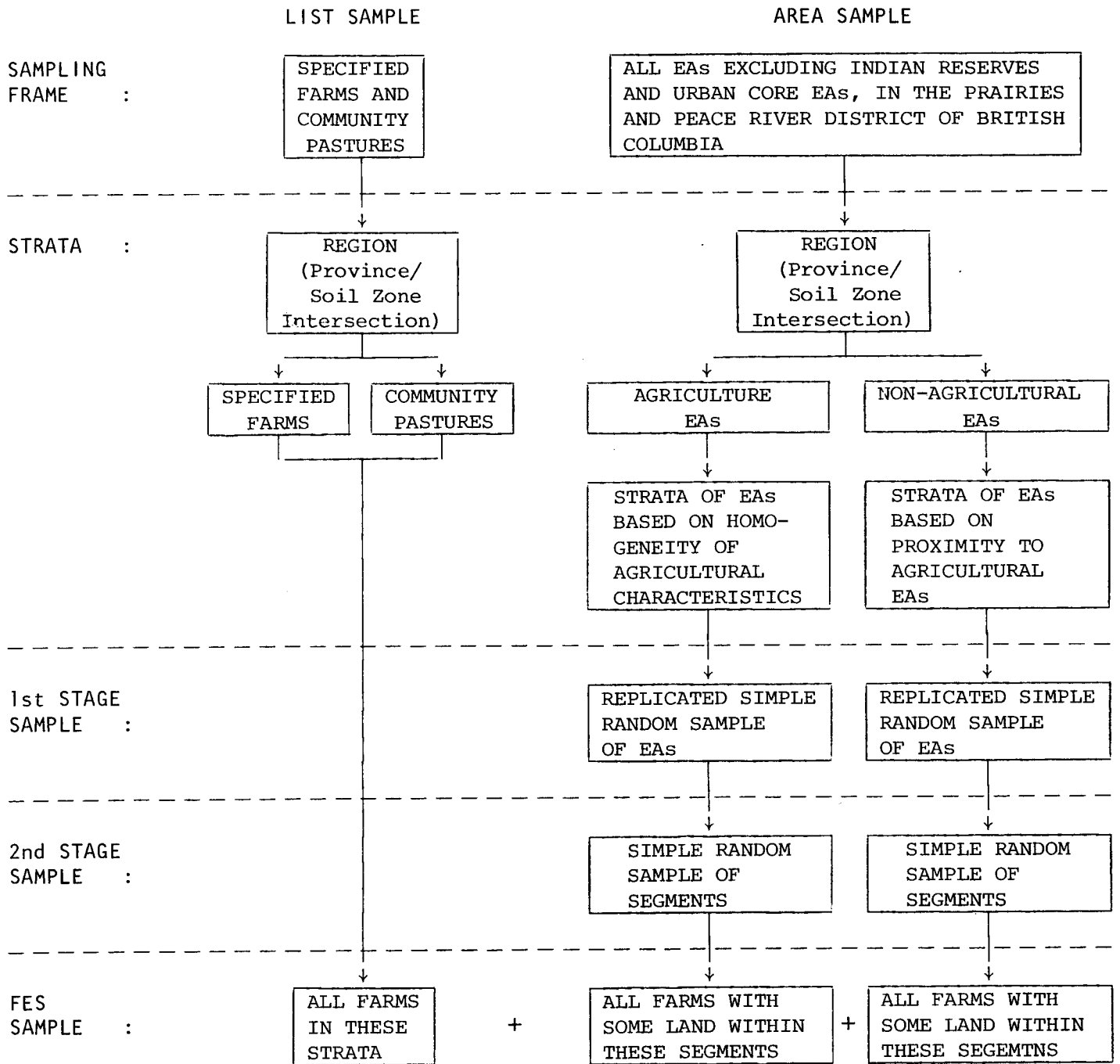
A pilot survey was carried out in March 1976, and full-scale surveys were carried out in March 1977 and 1978. This paper describes the design for the 1979 survey which incorporates the design used for the 1977 survey with some modifications which were introduced for the subsequent surveys.

2. OVERVIEW OF DESIGN

The diagram contained in Figure 1 summarizes the sample design of the FES. Four of the ten soil zones cross provincial boundaries. In order to produce provincial estimates these four zones were split into two distinct parts by provinces. Therefore, for the design, the

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Figure 1: SAMPLE DESIGN FOR FES 1979



whole FES area was split into 14 regions which are intersections of soil zones and provinces. The sample design was independent within each region.

A list sample was used to pick up two types of farming operations. The first type was called specified farms. These were specialized farms which had extremely large values for items like crops or livestock compared to the other farms in the same region. These farms were included in the sample with a probability of 1.

The second type of farm operation picked for the list sample was federal and provincial community pastures, grazing associations and grazing reserves which had 2000 acres or more. Like the specified farms they were included in the sample with a probability of 1.

These community pastures were added in this way because they had caused problems in previous surveys in the enumeration and, later on, when the survey data was being imputed for missing or incorrect data. Any expenses incurred on pastures are paid for by the farmers themselves. Therefore, when enumerating these operations, it was not necessary to fill out the livestock and expense portion of the questionnaire since the farmers were already reporting this information. Since these operations are certainly not typical, because of large total land areas and no livestock or expenses, it would not be advisable to impute these values into other farms. Therefore it was decided to identify them before the enumeration, and treat them separately when imputing.

The design used for the area frame was a stratified two stage design within each region. The first stage was the selection of the primary sampling units (EAs) and the second stage was the selection of the secondary sampling units (segments). The EAs were separated into two major strata—agricultural and non-agricultural. An agricultural EA is one that has at least one farm with headquarters located inside the EA. The headquarters of a farm is defined as the main buildings or main gate.

The first stage involved further stratifying the two major strata into homogeneous groups of EAs. Then after determining the sample size to be allocated to each of these ultimate strata, a replicated simple random sample of EAs was selected from each.

The selected EAs were then divided into equal sized pieces of land called segments for the second stage. A simple random sample of segments was then selected from each EA.

Every farm that had some land located inside the selected segments and received sales of \$250.00 or more from agricultural products in the previous year was enumerated. All the specified farms were enumerated. Also every community pasture was included in the sample; however these operations were not enumerated. Instead a questionnaire was mailed to the head offices in charge of the overall operation of these pastures. Whenever a specified farm or one of the community pastures in the list sample happened to fall in one of the segments selected for the area sample it was not enumerated again and therefore did not contribute to the segment estimate.

Table 1 of Appendix A shows the final sample allocation by region and the expected number of farms for the total sample.

3. SAMPLING FRAME

The target population was all farms in the 3 prairie provinces and in Peace River district of British Columbia which received \$250.00 or more from the sale of agricultural products in the previous year.

3.1 Area Frame

The area frame was composed of all the 1971 Census Enumeration Areas (EAs) that covered the target area. All the urban core EAs (Census Metropolitan Area code = 1 or 2) and Indian Reserve EAs were eliminated from this frame. The census data was summarized at the EA level for use as the area frame. The design for the

area frame for the 1977 survey was based on the 1971 Census of Agriculture data. The 1976 census data became available in August 1977. This was too late to do a redesign for the 1978 survey based on this more up-to-date information. Also there was no information on expenditures collected in the 1976 Census and total sales was reported in broad ranges only. The 1971 Census provided data that was better suited to a design for an expenditure survey.

The 1976 Census data was used, however, to update the 1971 EA summary data on land acreages and livestock numbers. This information was used in the 1978 FES to determine whether an EA had changed from agricultural to non-agricultural and vice-versa and to update the stratification of the EAs. The same strata were used for the 1979 survey. Some of the EA boundaries had changed between the two censuses. This made assigning the 1976 EA data to the 1971 EAs more difficult. If there was a 1:1 correspondence between a 1976 and 1971 EA then all the 1976 data was assigned to that 1971 EA. If a 1976 EA corresponded to 2 or more 1971 EAs then the data was divided equally amongst the corresponding 1971 EAs.

After updating the EAs, the 1971 and 1976 values for total land, total cropland, the 6 major grains, total cattle, and total pigs were compared for each EA. If there were major changes the EA was assigned to a different stratum than in 1977—one which was more compatible with the updated information. Since some of the stratum population sizes were changed and the information was more up-to-date, the sample allocation between strata within the same region was recalculated for every region for the 1978 FES. This was achieved by determining the optimum allocation for several important items and then deciding on the final compromise allocation. The same allocation was used for the 1979 FES.

By using the 1976 census data to update the EAs some EAs were found to have changed from non-agricultural to agricultural and vice versa. Those EAs which had become agricultural since 1971 were assigned to the stratum with the lowest sales category. Those that had turned non-agricultural were put in the stratum which contained EAs which were in a municipality that did have some agricultural EAs in it.

The non-agricultural EAs were included in the area sample in order to cover that part of the population that had become agricultural since the 1976 Census was taken. Also for the Census, all of the farm's data was assigned to the EA in which the farm headquarters was located. Therefore it was possible for an EA to be classified as non-agricultural, i.e. to have no farm headquarters located inside its boundaries, and yet have some agricultural activity take place there.

3.2 List Frame

Since the FES was designed to produce estimates for expenditure items farms with large expenditure values were considered important. The 1976 Census did not collect data on expenditures but did ask for total sales by sales range. So all farms with sales of over \$100,000 (the largest sales range) were examined. Then 4 more additional criteria were established for selecting specified farms. These criteria were based on total cattle, total pigs, total of crops plus summer-fallow, and total chickens, and were established independently for each region. A rule for use with simple random sampling was employed to determine cut-off limits. In the optimal situation, any farm having a value for the item which exceeds the cut-off limit is then specified. The limits for each of the four items were calculated thus:

$$\text{limit} = \bar{Y} + \sigma \sqrt{\frac{N}{n}}$$

where \bar{Y} is the population mean for the item in the region,
 σ is the standard deviation for the item in the region,
 N is the total number of farms in the region,
 n is the number of farms in the sample for the region.

If there were too many farms exceeding these limits the limits were raised accordingly.

The community pastures and grazing associations selected for the list sample were all those in the prairies that were larger than 2,000 acres and for which we could get the exact land description. There were a total of 263, and most were located in Saskatchewan (see Table 1 of Appendix A). The list for Alberta was not completed because for many of the grazing associations the detailed land description was not available. This description was necessary because these operations covered such a large land area and would certainly have fallen in the area sample, causing overlap. The selected EAs were segmented so that none of the segments included any of these operations.

4. FIRST STAGE DESIGN

4.1 Stratification of Agricultural EAs

Within each region the EAs were divided into groups of homogeneous EAs called strata. Since the purpose of the survey is to produce expenditure estimates, it is best to stratify on expenditure items or those items highly correlated with them. The 1971 Census data was summarized at the EA level and this data was used for the stratification. The 1971 census provided data on only a few expenditure items but did have detailed sales data.

Several methods of stratification were applied and then compared by looking at the resulting variances of estimates for about 20 items. The four methods were:

- 1) a classification of EAs by setting limits on the value of certain physical items like crop acreages and livestock numbers,
- 2) a non-hierarchical cluster analysis on nine physical items (crops and livestock numbers),
- 3) a hierarchical cluster analysis on groups of EAs with similar values of sales,

4) a classification of EAs into 5 to 10 ranges of total sales.

The first three methods gave almost equivalent results with the third giving slightly better results for the financial items. The fourth method was poorer except for the total sales item.

In comparing the four methods, it was apparent that the first method, which was developed for the Agriculture Enumerative Survey (AES), was designed to measure physical items and so might not be best for measuring expenditure items. The cluster analysis employed in the second and third methods enabled more variables to be used in stratifying and took into consideration the size and specialization of the EAs. Of the two techniques the hierarchical cluster analysis (method 3) was better at determining the number of clusters or strata to have, and in defining these clusters.

The method chosen was the hierarchical cluster analysis on groups of EAs with similar values of total sales (method 3). The first step in this method was to stratify the EAs into groups by total sales. These stratum boundaries were set to optimize the estimation of total sales. They were determined after applying rules for optimum boundaries under equal allocation to each stratum and also under optimum allocation to each stratum. In most regions there were 3 or 4 of these major strata. The stratum of EAs with lowest sales was left as one stratum representing the marginally agricultural areas. The other 2 or 3 major strata were then sub-stratified using the hierarchical cluster analysis.

The variables used for this analysis were the percentage of sales for 7 items to the total sales for the EA. The 7 items were wheat, oats, other grains, other crops, cattle, other livestock, and other sales. The hierarchical clustering program looks at all the EAs in the group and initially pairs off similar EAs. Then it joins similar pairs together and continues this iterative process of joining groups of EAs together until all EAs are in one group again. A

diagram of this whole process is produced, so that at any stage you can determine how many groups there were and what EAs were in them. The groups are joined together according to merging criteria. Three different merging criteria were used in every major stratum. These criteria were,

- 1) minimum increase in the within group sum of squares,
- 2) mean within group squared deviation in the new cluster is minimal, and
- 3) within group sum of squares in the new cluster is minimal.

The results of all three were then compared and a decision on the number and content of strata was made.

There were 3 exceptions to the stratification process. Region 1 in British Columbia, and regions 4 and 5 in Alberta were too small to stratify, and so there is just one stratum in each of these regions. Tables 3.1 to 3.3 of Appendix A give a description of the strata within a few regions.

4.2 Stratification of Non-agricultural EAs

The non-agricultural EAs were divided into 2 strata in each region except for region 1 in British Columbia and 8 in Manitoba which were left as one stratum each because they were too small. For the other regions the strata were defined according to whether or not the EA was in a municipality which had some agricultural EAs in it. Stratum 12 included EAs which were in a municipality with some agricultural EAs and stratum 11 included those that weren't.

Both regions 4 and 5 in Alberta had so few of these EAs that it was decided not to sample from them at all, and so there were no non-agricultural strata in these regions. The bias introduced by doing this was thought to be negligible. Tables 3.1 to 3.3 of Appendix A identify the non-agricultural strata in the regions given.

4.3 Sample Allocation

A small portion of the sample was assigned to the non-agricultural strata. The replicates in these strata had one EA each and there were usually only 2 replicates per stratum. The expected number of farms from these EAs was quite low.

Once the agricultural strata were defined in each region the next step was to determine what sample size was best for each region as a whole and then for each stratum within the regions. First the sample size (no. of EAs) was determined for each region so that expected coefficients of variation for important items were in the 3-5% range. These sample sizes were converted to the expected number of farms, by using the average number of farms enumerated per EA from the 1976 AES. A total sample of approximately 9,500 was desired and so the sample sizes were adjusted to achieve this.

Next the sample for each region was allocated amongst the strata in the region. This was determined by a compromise of the optimum allocations for several important items. Also the sample size for a stratum had to be divisible into equal-sized replicates. The allocation to the strata for some regions is given in Table 3.1 to 3.3 in Appendix A.

4.4 Replication

A replicate for the FES was an independent simple random sample of EAs selected without replacement from a stratum. Each stratum had at least two replicates and these were selected independently with replacement. This meant that an EA could be selected only once within a replicate but it could be selected in more than one replicate. One reason for replicating the sample was that it simplified the variance calculation. Also, having replicates in each stratum made it easier to spread rotation of the sample between and within the strata, since a whole replicate could be

rotated out without affecting the other replicates in the stratum. Retaining some common replicates between years allowed for better estimates of change over time and also for some consistency between the stratum estimates over several survey periods.

4.5 Sample Selection

For the 1977 FES a simple random sample was selected for each replicate within strata. However for the agricultural strata five different samples were selected for each region. The estimates for 14 items for each of the 5 samples were compared with the census total for the region. The sample chosen for the survey was the one that compared the best with the census total over the most items.

This same procedure was used for the 1978 and 1979 surveys when a rotation of the sample was done. (Details on rotation are given in Section 7.)

5. SECOND STAGE DESIGN

Every EA that was selected in the 1st stage was divided into equal-sized pieces of land called segments. In the prairies and Peace River district of British Columbia most of the land is laid out in 1 square-mile areas called sections. This made segmenting the EAs easier and wherever possible the segments were made up of 3 sections (3 square miles). This procedure also aided in identifying and locating the segments during field enumeration.

For EAs that were not sectioned off or that were towns, the segments were formed by following natural boundaries such as highways, rivers, railway lines, etc.

From every selected EA, one segment was randomly selected, without replacement, for every 30 segments in the EA.

6. ESTIMATION PROCEDURES

The list frame specified farms and community pastures were selected with a probability of 1. Therefore they were given a raising factor (or blow-up factor) of 1 and their values were added directly into the corresponding province and region estimates.

For the area frame, every farm that had land located inside a selected segment and that received \$250 or more from the sale of agricultural products in the previous year was enumerated. In order to produce an overall estimate for the region and then for the province, the data for these farms were blown-up to represent first the EA in which they were located and then the stratum that each belonged to. This was done by multiplying the data by a raising factor for each replicate.

The raising factor has 2 components. The first, which blows up the data to the EA level, is the inverse of the probability of selecting the segment.

The second component, which blows up the data to the stratum level, is the inverse of the probability of selecting the EA.

The final raising factor is just component 1 x component 2.

There are three types of estimates possible with this design. The FES uses the weighted estimate. For this estimate all sample farms are used in the calculation of estimates, but their data is multiplied by a weight which is calculated at the farm level thus:

$$\text{weight} = \frac{\text{total land operated inside the segment}}{\text{total land operated}} .$$

The disadvantage of this method is that since the weight is calculated from the total land operated it might not be ideal for items that are

not highly correlated with land. The other two estimates possible have definite disadvantages which are explained in the footnote¹.

Within a region, the estimate for the i^{th} replicate in stratum h is

$$\hat{Y}_{hi} = \sum_{j=1}^{n_{hi}} y_{hij} \times \text{weight} \times \text{raising factor}$$

where y_{hij} = value of the item for the j^{th} farm in replicate i of stratum h

n_{hi} = number of sampled farms in the i^{th} replicate of stratum h .

The estimate for stratum h is

$$\hat{Y}_h = \sum_{i=1}^r Y_{hi} / r \quad \text{where} \quad r = \text{number of replicates in stratum } h.$$

The region and province estimates are just the sum of all the strata estimates in the same region or province.

The variance of the estimate is calculated at the stratum level. It is the mean of the sum of squared deviations of the replicate estimates from the stratum estimate divided by the number of replicates minus 1.

$$\hat{\text{Var}} (\hat{Y}_h) = \sum_{i=1}^r \frac{(\hat{Y}_{hi} - \hat{Y}_h)^2}{r(r-1)}$$

The province and region variances are just the sum of all the strata variances in the same province or region. The stratum variance for

¹The open estimate uses only those sample farms which had their headquarters located inside the segment. No weight is applied. The disadvantage of this method is that only about half the farms are used which means that the estimates will be less precise.

The closed estimate uses all sample farms but the data used is just for that portion of the farm inside the segment. This estimate is not feasible for the expenditure items collected for the FES since it would be very difficult to allocate a portion of expenses to just that part of the land inside the segment.

the specified farms and community pastures strata is zero since a complete census is done for the list frame.

The percentage coefficients of variation for estimated items are calculated at both the region and province levels and allow comparison of the variances for different and unrelated items.

7. ROTATION OF THE SAMPLE

Since the FES is to be run every year, part of the sample is rotated out and replaced each year so that the same farmers are not continually asked to respond. It is not feasible to change the whole sample every year because good estimates of change over the years are only possible if part of the sample is retained. 30% of the 1977 sample was rotated for the 1978 survey and 20% for the 1979 survey. It is expected that 25% will be rotated out in the following two years. This means the entire sample will be replaced by the 1981 survey.

The rotation for the 1979 survey was spread as equally as possible between the strata. The replicates to rotate out were randomly selected from the replicates that had been in the survey since 1977.

It should be noted here that since it is entire replicates that are rotated, an EA could be rotated out in an old replicate and then rotated back in a new replicate. Should this happen, however, a different segment is selected at the second stage of selection where possible.

8. SUMMARY

The FES will continue to run annually as is required by the Western Grain Stabilization Act. Until 1982 or 1983, its design will remain more or less fixed, possibly with minor modifications made each year. Once the 1981 census results are available, however, there will likely be a complete redesign of the survey to make use of the more up-to-date data source.

RESUME

L'enquête sur les dépenses agricoles a été développée pour fournir des estimations annuelles des dépenses afin de répondre aux exigences de la Loi de stabilisation concernant le grain de l'Ouest. Cette loi établit un programme de stabilisation des revenus des cultivateurs de céréales dans les prairies et dans le district de Peace River en Colombie-Britannique. Cet article décrit le plan de l'enquête de 1979, qui a utilisé un plan d'échantillonnage stratifié à deux degrés pour l'échantillon choisi de la base aréolaire et une seule strate à tirage complet pour l'échantillon choisi d'une liste.

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APPENDIX A

TABLE 1: Sample Allocation by Region

Region		# of Specified Farms	# of Community Pastures	Agricultural Sample		Non-Agricultural Sample		Total Expected # of Farms
Prov	Soil Zone			EAs	Expected # of Farms	EAs	Expected # Of Farms	
BC	1	3	-	30	162	2	1	166
ALTA	1	4	1	80	512	4	3	520
	2	10	1	151	1012	8	6	1029
	3	16	13	120	840	8	6	875
	4	7	5	25	185	-	-	197
	5	3	5	15	135	-	-	143
	6	12	0	98	666	4	3	779
	Total		52	25	489	3350	24	18
SASK	4	8	71	92	708	4	3	790
	5	5	60	126	895	8	6	966
	6	11	58	122	817	7	5	891
	7	10	25	129	955	5	4	994
	Total		34	214	469	3375	24	18
MAN	8	3	7	84	538	2	1	549
	9	8	9	180	1332	8	6	1355
	10	3	8	74	326	4	3	340
	Total		14	24	338	2196	14	10
Total	103	263	1326	9083	64	47	9496

TABLE 2: 1979 FES Specified Farms
- Limits for Selection

(among those with sales > \$100,000)

Region Soil Zone/ Province	Total Cattle	Total Pigs	Crops and Summerfallow	Total Chickens
01/BC	1,606	1,000	13,620	-
01/ALTA	1,454	1,760	11,595	11,193
02/ALTA	2,416	2,654	9,963	71,500
03/ALTA	5,100	2,500	10,231	80,000
04/ALTA	2,990	1,600	11,860	18,000
05/ALTA	2,480	1,000	11,210	15,800
06/ALTA	1,517	1,586	10,900	35,000
04/SASK	1,557	4,400	10,383	22,700
05/SASK	2,300	5,300	-	42,000
06/SASK	1,000	1,022	-	26,320
07/SASK	1,060	1,200	11,460	64,000
08/MAN	980	1,210	7,025	-
09/MAN	1,350	5,000	7,904	60,000
10/MAN	1,500	1,400	-	12,000

TABLE 3: Variables Used in the Stratification
of Agricultural EA's

The number in brackets denotes the relevant field number on the 1971 Census of Agriculture Form 6.

Seven variables, expressed in terms of percentage to total sales (227), have been used in the hierarchical cluster analyses:

1. Wheat sales (207)
2. Oats sales (208)
3. Other grains sales (209)
4. Other crops sales (210 to 216)
5. Cattle sales (217)
6. Other livestock sales (218 to 222)
7. Other sales (227 minus sum of variables 1 to 6 = 223 to 226)

The following summaries appear also in strata specifications:

Grains other than wheat (variables 2 and 3)
Grains (variables 1 to 3)
Total crops (variables 1 to 4)
Livestock other than cattle (variable 6)
Total livestock (variables 5 and 6)
Others (variable 7)

TABLE 3.1: First Stage Design Specifications
Soil Zone 2 - Alberta

Stratum Specifications		Stratum Code	No. of Repli-cates	No. of EAs Per Repli-cate	Popula-tion Size	Sample Size
Total Sales	% Sales					
§ AGRICULTURAL EA's						
≥1,000,000	Livestock Other than Cattle ≥ 30% or Others ≥ 50%	1	2	2	9	4
	Cattle ≥ 60%	2	5	2	17	10
	Remaining EAs	3	4	3	23	12
<1,000,000 & ≥ 500,000	Others ≥ 30%	4	4	2	23	8
	Cattle < 40%	5	3	3	20	9
	Remaining EAs	6	7	4	66	28
< 500,000 & ≥ 25,000	Cattle ≥ 60%	7	6	3	59	18
	Cattle ≥ 30%	8	9	4	116	36
	Remaining EAs	9	6	4	49	24
< 25,000	--	10	2	1	85	2
Total					467	151
NON-AGRICULTURAL EA's						
No Agricultural EA in Same Municipality		11	2	1	65	2
At Least one Agricultural EA in Same Municipality OR EA was Agricultural in 1971		12	6	1	134	6
Total					199	8

TABLE 3.2: First Stage Design Specifications
Soil Zone 6 - Saskatchewan

Stratum Specifications		Stratum Code	No. of Replicates	No. of EAs Per Replicate	Population Size	Sample Size
Total Sales	% Sales					
§ AGRICULTURAL EA's						
≥ 750,000	Cattle ≥ 50%	1	4	2	15	8
	Remaining EAs	2	4	4	37	16
< 750,000 & ≥ 400,000	Cattle ≥ 40%	3	4	3	43	12
	Grains ≥ 60%	4	4	3	33	12
	Remaining EAs	5	6	4	61	24
< 400,000 & ≥ 20,000	Cattle ≥ 40%	6	4	3	49	12
	Grains Other Than Wheat ≥ 30%	7	5	4	72	20
	Remaining EAs	8	4	4	65	16
< 20,000	--	9	2	1	76	2
Total					451	122
NON-AGRICULTURAL EA's						
No Agricultural EA in Same Municipality		11	2	1	74	2
At Least One Agricultural EA in Same Municipality OR EA was Agricultural in 1971		12	5	1	98	5
Total					172	7

TABLE 3.3: First Stage Design Specifications
Soil Zone 9 - Manitoba

Stratum Specifications		Stratum Code	No. of Repli-cates	No. of EAs Per Repli-cate	Popula-tion Size	Sample Size
Total Sales	% Sales					
\$						
AGRICULTURAL EA's						
≥ 900,000	Livestock Other Than Cattle > 35%	1	5	2	16	10
	Cattle ≥ 35%	2	4	4	29	16
	Remaining EAs	3	4	3	22	12
< 900,000 & ≥ 400,000	Livestock Other Than Cattle > 25% OR Others > 25%	4	7	5	83	35
	Grains ≥ 45%	5	5	5	50	25
	Remaining EAs	6	9	3	69	27
< 400,000 & ≥ 20,000	Crops Other Than Grains > 40%	7	2	2	21	4
	Total Crops < 30%	8	3	4	75	12
	Remaining EAs	9	9	4	116	36
20,000	--	10	3	1	90	3
Total					571	180
NON-AGRICULTURAL EA's						
No Agricultural EAs in Same Municipality		11	2	1	42	2
At Least One Agricultural EA in Same Municipality OR EA was Agricultural in 1971		12	6	1	124	6
Total					166	8