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DELINEATION OF THE CANADIAN AGRICULTURAL ECUMENE FOR 1991

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1. INTRODUCTION

The Agriculture Division makes extensive use of the ecumene concept in the presentation and analysis of data derived from the quinquennial Census of Agriculture. For the purposes of this work, the agricultural ecumene can be defined as the agricultural land base in Canada. The principal characteristic of such an ecumene is that it constrains the cartographical presentation of spatially referenced agricultural data to areas of recognized agricultural significance. This results in a more realistic portrayal of the spatial distribution and extent of agriculture within the country.

The agricultural ecumene is used in many several projects and publications which employ thematic maps in order to display agricultural data. The **1986 Profile of Canadian Agriculture** presents agricultural data at an aggregate level in a series of thematic maps, tables and graphs. In this publication, the ecumene serves as a fixed boundary agricultural zone within which the thematic data are plotted. The agricultural ecumene is also used as a base for cartographic presentations of remotely sensed crop condition data generated through the **Crop Condition Assessment Program**. These maps are generated on a weekly basis during the growing season for the Prairie provinces. Their purpose is to inform users on the development status of various crops within the agricultural ecumene.

This paper outlines the process of delineating the agricultural ecumene in Canada based on data obtained through the 1991 Census of Agriculture. The delineation was a joint project between the Agriculture and Geography Divisions at Statistics Canada, and was undertaken during May-July, 1993. The paper is structured into five sections. The study begins by establishing a context for the project. This is achieved through a brief discussion of the salient literature and the development of the ecumene concept within the Agriculture Division. Following this, the criteria selected for use in the delineation of the ecumene for 1991 are discussed. Third, the delineation process is detailed. Fourth, the main results of the exercise are evaluated. In the final section of this work, the main findings of the research are summarized, and recommendations for the further refinement of the delineation process are detailed.

2. BACKGROUND TO THE ECUMENE DEVELOPMENT PROCESS

This chapter develops the context of the study through a discussion of the use of census data in ecumene delineation, and through a consideration of the development of the ecumene delineation process within the Agriculture Division. The discussion emphasises the strengths of the Census of Agriculture as a data source for ecumene delineation. The Census provides detailed, spatially referenced data for all holdings producing agricultural goods intended for sale. The development of the ecumene delineation process is also discussed with respect to the strengths and limitations of the methodologies used in 1981 and 1986. This discussion later directs the development of the 1991 ecumene delineation methodology.

2.1. Defining the Census Farm

An important consideration with respect to ecumene development using Census data is the definition of a census farm. Careful consideration must be given to the definition of a Census farm because minor changes impact significantly on the number and characteristics of farms selected for inclusion in the Census universe. Table 1 summarizes the criteria used by several government statistical agencies to screen holdings for inclusion in agricultural censuses. The table indicates that most of these agencies employ minimum area or total sales criteria. The most commonly used minimum area is 1 acre or 1 hectare in size. Most of the governments that employ such a minimum also include holdings smaller than this provided that the economic output of the holding exceeds a minimum level. This minimum level was infrequently quantified in the literature.

Table 1. Criteria Used In Census Farm Identification.

Country	Year	Area	Sales	Other
USA	1987	-	>$1,000	-
New Zealand	1991	-	-	Any Area Used or Potentially Useable For Horticulture, Livestock, Cropping, or Forestry.
Sweden	1992	>2ha.	-	<2ha. if real estate assessed as agricultural.
Scotland	1991	>1ha.	-	<1ha. if agric. output exceeds min. value.
Eurostat	1990	>1ha.	-	<1ha. if agric. output exceeds min. value.
Israel	1975	>0.1ha.	-	-
Australia	1975	>1ac.	-	<1ac. if agric. output exceeds min. value.
Canada	1976	>1ac.	>$50	-
	1981	-	>$250	-
	1986	-	>$250	-
	1991	-	-	Any holding producing agricultural products intended for sale.

The definition used by the U.S. Bureau of the Census is of especial relevance as data comparability across North America is a perennial concern. In the U.S., a census farm is defined as any agricultural holding which generates, or expects to generate a minimum of US$1,000 total sales over the census year. As Table 1 demonstrates, this definition has never been used in Canada. The Canadian definition of a census farm employed both minimum area and total sales criteria in 1976. In 1981

and 1986, only a total sales criterion was used. For 1991, the definition changed again to include all holdings which produce agricultural produce intended for sale.

The changes in the Canadian definition over time do not impact significantly on the total value of agricultural output because the variability resulting from such changes affects only the number of low output holdings selected for inclusion in the Census. The same cannot be said for the number of holdings identified by the Census. For example, if a minimum total sales value of C$1,000 were used to identify farms on the 1991 Canadian Census of Agriculture, this would have excluded 9,269 holdings which reported total sales less than this value. These holdings represent 3.3% of the total number of farms identified in the 1991 Census.

The principal advantage of collecting agricultural data for all holdings regardless of size or output is that these data provide a more accurate account of the number and influence of small producers on the total agricultural output. In addition, this definition serves to identify much of the land devoted to agriculture. This point is important for the purposes of the current research as data on all agricultural land area and production should be available for use in the delineation of the agricultural ecumene.

2.2. The Spatial Resolution of The Census Data

A second consideration in using Census of Agriculture data in the delineation of an ecumene is the spatial resolution of the data. If the data are collected at a fine level of spatial resolution, then the ecumene may be delineated directly from data collected through the Census. The finest level of spatial resolution used in the Census of Agriculture is the Enumeration Area (EA). An EA is defined as the census coverage area assigned to one census enumerator. EA size is highly variable, and is influenced primarily by dwelling density. Thus, urban areas tend to have relatively compact EAs, and the sparsely populated areas, the largest. The average EA size in agricultural areas lies between these extremes.

The spatial resolution of the EAs is considered to be sufficient for the purposes of ecumene delineation. The 1991 Census of Agriculture identified 12,109 agricultural EAs nationwide. These EAs contained at least one agricultural holding. The number of agricultural EAs in each province is outlined in Table 2. Due to data quality limitations and confidentiality restrictions, the agricultural ecumene was not generated for the Yukon Territory and the Northwest Territories of Canada. Readers may refer to the **1991 Agricultural Profile of Canada** (Catalogue no. 93-350, p. 105) for a more thorough discussion of the limitations of the agricultural data collected from northern farms.

2.3. The Types of Data Collected Through the Census

The type of data collected through the census is also of importance in the delineation of the agricultural ecumene. Data must be collected on several variables capable of describing the overall intensity of the agricultural operations identified as Census Farms. In this respect, the Census of Agriculture is an excellent data source. The most useful indicators of agricultural intensity are data on land area by type of use, and the economic value of agricultural productivity. These data can be used directly to assess the economic and physical size of the holding. For the purposes of producing an ecumene map, these data are aggregated to the EA level, and individual EAs are selected for inclusion in the ecumene based on specified minimum levels of agricultural intensity.

There are two areas of concern with respect to ecumene delineation based on Census of Agriculture data. First, the data on land area by type of use are reported by the respondents themselves. This may result in some reporting error due to miscalculation of farm area, and to the inability to differentiate between land types as the Census form requests. For example, the Census form asks respondents to provide the area of improved and unimproved pasture separately. Although definitions for each of these terms are provided, some variability in reporting will occur simply because the definitions are subjective. Another difficulty in providing land area may arise where land is being rented. In this situation, operators may only report the land used to grow crops, or for pasture, rather than the entire parcel of rented land.

Table 2. Number of Enumeration Areas With At Least One Agricultural Holding.

Ontario	2,970	Manitoba	717
Quebec	2,640	New Brunswick	544
British Columbia	1,531	Nova Scotia	527
Alberta	1,459	Newfoundland	289
Saskatchewan	1,263	Prince Edward Island	169

A second concern in the spatial analysis of the Census data is the bias resulting from the "headquarters rule". The headquarters rule attributes the data on the characteristics of an agricultural holding to the EA of the operator's principal residence, rather than the exact location of occurrence. This occasionally results in a misrepresentation of the spatial characteristics agricultural data in a defined region (Burroughs, 91). As an example of this, some rural EAs in Saskatchewan report a total area of farmland greater than the area of the EA. This is often because headquarters density is higher in one EA, with agricultural lands under the control of those holdings extending beyond the

boundaries of the EA. This phenomenon can cause substantial misrepresentation in studies which require spatial data at a fine resolution. However, the headquarters rule has only a minor effect on ecumene delineation since the degree of spatial resolution required is not as fine.

In broad summary, the Census of Agriculture is a useful data source with which to delineate the agricultural ecumene in Canada. A wide range of data are collected at a fairly fine level of spatial resolution, and the current definition of a census farm results in data capture on all holdings producing agricultural products intended for sale.

2.4. The 1981 Ecumene Delineation Methodology

A discussion of the methodology for deriving the 1981 agricultural ecumene is given in **A Profile of Canadian Agriculture** (1981), but will be briefly outlined here in order to illustrate the changes which have occurred in the methodology over time.

The 1981 ecumene was developed using an index which provided a meaningful representation of the agricultural intensity within each EA. Improved agricultural land as a proportion of total land was selected as the index value. Minimum index values were selected for each province such that the area of ecumene would approximate the actual area and distribution of farmland in that province.

Some exaggeration of the ecumene was observed for each province because the ecumene was mapped at the CD and CSD levels. Further distortion occurred when the ecumene was smoothed to reduce the visual complexity of the map. At the Canada level, the total farm area (of census farms) was 60% of the area of the ecumene.

2.5. The 1986 Ecumene Delineation Methodology

The ecumene delineation methodology used for 1986 is given full treatment in Haythornthwaite et al (1989). For this round of ecumene delineation, an attempt was made to develop a more fully automated methodology. The algorithm used to identify agricultural areas was executed in SAS, and the results plotted using ARC/INFO. The delineation was based on the Census Subdivision (CSD) level of spatial resolution.

There were three steps in the 1986 delineation procedure. First, an index was developed to measure agricultural activity within each CSD. This was derived as the ratio between total improved agricultural land area in the CSD, and total CSD area. In the second step, the CSDs in each province were ranked according to descending ratio value. Third, CSDs were selected for inclusion in the

ecumene until the cumulative land area equalled 150% of that province's total area of improved agricultural land in the province.

The automated approach was augmented by the use of other source maps which assisted in localizing ecumene pockets in large, marginal CSDs, and which identified known non-agricultural lands for exclusion from the ecumene. This methodology improved the accuracy of the results considerably. For 1986, the total farm area was 79% of the surface area represented by the ecumene at the national level.

The accuracy and utility of the ecumene delineation methodology has improved markedly over the period 1981-1986. These improvements were due in large part to technical advances in mapping capability. However, one potential limitation of the methodologies described above is that they employ a strictly land-based approach to the identification of agricultural areas. Specifically, the index values used in each round of ecumene delineation were based on area of improved agricultural land as a proportion of total land area. As the next section describes, there are difficulties in assuming the universal applicability of such an indicator of the existence of agriculture. In order to compensate for the detractions of this indicator, a new set of delineation criteria were developed for 1991.

3. THE 1991 ECUMENE DELINEATION CRITERIA

This chapter details the process of criteria selection for the 1991 round of ecumene delineation. The initial focus of the discussion is on the modification of the 1986 ecumene methodology for use with the 1991 digitized EA boundaries. Following this, two additional experimental approaches are discussed. These are the ratio of agricultural land area on census farms to total EA area, and the value of gross farm receipts at the EA level. The experimental approaches are of especial use in identifying agricultural activity on unimproved lands, and where agricultural production is not highly land consumptive. The fourth section gives an account of secondary data sources for use in ecumene delineation. These were consulted where the primary sources could not be used to delineate the ecumene boundary with sufficient accuracy.

3.1. The 1991 Ecumene Delineation Methodology

There are three steps in the 1991 GIS-based automated ecumene methodology. First, an index value of agricultural intensity is derived. For 1991, this index value is calculated as the ratio of the sum of **improved and unimproved agricultural lands**, to total EA land area. Improved land area consists of all lands devoted to crops, summerfallow, and improved lands for pasture or grazing as reported on questions 95-97 of the 1991 Census of Agriculture. Unimproved land consists of all unimproved lands for pasture grazing or hay as reported on question 98.

In the second step, EAs are ranked by descending index value within each Census Consolidated Subdivision (CCS). A CCS is a grouping of small CSDs within a Census Division (CD) with a land area greater than 25 square kilometres. A CSD with a population greater than 100,000 usually forms its own CCS (1991 Agricultural Profile of Canada: 124). Third, the ranked EAs are selected for inclusion in the CCS ecumene until the cumulative area exceeds the total CCS area of improved and unimproved agricultural lands by a specified proportion. Given the improved spatial resolution afforded by the digitized EA and CCS boundaries, the cut-off value will be lower than that used in 1986 (150%). The algorithm was computed using SAS, and the results plotted using ARC/INFO.

As can be seen from a description of the 1991 methodology, several changes have been made to the automated ecumene delineation approach. First, a much finer spatial resolution has been used. Second, the model is calibrated to improved and unimproved agricultural land area in each EA. This allows the model to identify a wider range of agricultural land types for inclusion in the ecumene. Third, the EA ranking is performed within each CCS rather than on the provincial level. This change gives increased representation to ecumene pockets at the margins of the agricultural ecumene.

It is also important to note that the 1991 ecumene delineation methodology employs a slightly different definition of improved lands. In the 1981 and 1986 rounds of the delineation, the variable used as an indicator of agricultural intensity was improved land used for crops, summerfallow, pasture, and other uses. The "other improved land" category was used previously to report area devoted to barnyards, greenhouses, home gardens, etc. For 1991, "other improved lands" was incorporated into "all other lands", with the result that the former can no longer be identified separately. This change will not significantly alter the results of the delineation because "other improved lands" do not normally comprise a significant proportion of the total agricultural land area for most holdings.

The above changes measurably improve the precision with which the agricultural ecumene can be delineated. However, this method is still limited in that it is calibrated to a strictly land-based definition of agriculture. This definition is suitable for the identification of highly land-consumptive forms of agriculture, but it is uncertain whether this definition adequately represents agriculture in all its forms across the country. In order to test the versatility of the 1991 methodology, the resulting ecumene was compared against those derived using other measures of agricultural intensity. These are the ratio of improved and unimproved lands to total EA area, and the value of gross farm receipts for each EA.

3.2. The Ratio of Agricultural Land to Total EA Area

Another useful method by which to delineate the agricultural ecumene is to plot the ratio of agricultural land on Census Farms to total EA area for each EA. In so doing, the analyst may

observe the agricultural intensity of each EA rather than those selected by the previous methodology. A minimum cut-off index can be selected for each province in order to reproduce closely the area of agricultural lands represented by the ecumene. Alternately, a single cut-off index can be developed and used as a discriminating criterion in the identification of agricultural areas across the country. Each of these approaches provides a useful check against the results obtained by way of the automated methodology.

3.3. The Value of Gross Farm Receipts For Each EA

The agricultural ecumene can also be derived through the use of data on the economic value of agricultural production. In this approach, the value of gross farm receipts for each EA was used as the indicator of agricultural intensity. Minimum cut-off values were used to eliminate those EAs with very low levels of agricultural activity by this measure. This may offer a more widely applicable method in which to identify agricultural activity because the mere existence of agricultural land is not an indication of significant agricultural output. Further, some agricultural operations may generate significant output on a relatively small land base (eg. greenhouses, feedlots). In such cases, these may be screened out using the automated technique developed above. Using gross receipts as an indicator of agricultural activity, these intensive operations would all be represented in the ecumene.

It is interesting to note that most provinces had several agricultural EAs with low levels of agricultural output. For example, there were 21 agricultural EAs with less than 1,000 dollars gross farm receipts in 1991 in the province of Saskatchewan. These EAs could contain areas of community pasture, or small hobby-farms with low economic output. Using this method, these EAs could be excluded from the ecumene based on their economic output rather than the amount of agricultural land in the EA.

3.4. Additional Sources Used in Ecumene Delineation

Before the process of ecumene delineation was initiated, a search for additional data sources was conducted. These sources assisted in the delineation of ecumene pockets within large EAs, and in the identification of parcels of known non-agricultural land for exclusion from the ecumene.

3.4.1. Remotely Sensed Data on Agricultural Activity

Remotely sensed data on the distribution of agricultural lands by land-use type may be an ideal data source for use in ecumene delineation, especially in marginal areas. Attempts were made to locate such data for any portion of the country. The results of the search revealed that several provincial and federal bodies are currently engaged in the production of remotely sensed land inventories, but

very few of these are completed. **The Saskatchewan Remote Sensing Centre** is currently involved in production, and will not have results until 1995 (Whiting, 93). **The Manitoba Centre for Remote Sensing** is also in the process of generating a remotely sensed land-use map for the province. Some maps were available for sale, but these were only for a small area of the province, and published at a 1:50,000 scale. These maps were not suitable for ecumene delineation in this province (Bush, 93).

Another source of remotely sensed data available for use was through the **Canada Centre For Remote Sensing** (CCRS). This agency produced a map depicting land-use type for 1976 (Brown, 93). This map is published as part of the National Atlas of Canada, and has a data resolution of 1 kilometre. The main detractions of this map are that it is now 15 years old, and it is published at a small scale, making it difficult to distinguish ecumene pockets in the marginal areas where such information is needed most. This map was used as a secondary check in the delineation process.

A final useful source of remotely sensed agricultural data was made available through the **Spatial Analysis And Geomatics Applications** Section (SAGA), Agriculture Division, Statistics Canada. SAGA produced maps of the 1985 crop and pasture land distribution for the prairie provinces in a joint project with the CCRS. Medium-resolution Landsat MSS imagery was manually delineated by land use class, and then digitized into ARC/INFO format (Korporal, 93). This source served as a useful check in the delineation of the 1991 agricultural ecumene for the Prairies.

3.4.2. Subject Matter Experts

In an effort to receive additional input to the ecumene delineation process, contact was established with several subject matter experts on the agricultural geography of Canada. The following individuals were consulted:

- Zepp, J. Provincial agricultural statistician for Saskatchewan.
- Sterling, C. Provincial agricultural statistician for Alberta.
- Honey, J. Provincial agricultural statistician for Manitoba.
- Wallace, I. Department of Geography, Carleton University, Ottawa, Ontario.
- Hathout, S. Department of Geography, University of Winnipeg, Winnipeg, Manitoba.

Unfortunately, none of these sources were able to provide additional useful information with which to delineate the agricultural ecumene for any portion of the country. This is primarily because very little additional detailed source data on agricultural distribution are available in mapped form.

3.4.3. Other Sources

In an effort to thoroughly exhaust all data sources of potential applicability to the ecumene delineation, less direct data sources were investigated. One very detailed data source was the 1991 Township Plans, which are published for some portions of the country. These plans record land by ownership, and location of significant features such as buildings, bush, or rivers in the township. This potentially useful source was abandoned however, because it was found to be extremely difficult to identify townships along the margins of the ecumene where the recorded data would be useful in determining the extent of agricultural activity. There was also a further problem with consistency in the type of data reported such that it was not always possible to identify whether a given parcel of land was under agricultural production.

The Canada Gazetteer Atlas identifies various federal, provincial, and municipal lands in each province. This source proved useful in the identification of large parks, military bases and training grounds, and Aboriginal reserves across the country. These known non-agricultural lands were excluded from the agricultural ecumene of each province where appropriate.

The National Atlas of Canada also provided some indirect sources with which to gauge the potential for agricultural activity by region. More specifically, the soils, and degree-days maps were occasionally used as checks to examine the approximate conditions necessary for the existence of agriculture in each region. Once these were calibrated with known agricultural areas in each province, these data were employed in the localization of ecumene pockets in large EAs. This approach had limited applicability in practice however, since these variables correlate most closely with crop-based forms of agriculture. Marginal agricultural areas devoted to livestock operations or sugar bush could not be approximated using this technique.

4. DELINEATION OF THE AGRICULTURAL ECUMENE BY REGION

This chapter details the method by which the 1991 agricultural ecumene was delineated for each province. Particular emphasis is given to the discussion of the relative weights of each of the data sources in the final delineation, and to the evaluation of the overall utility of each of the experimental methodologies developed for testing. Figure 1 presents a schematic of the generalized ecumene delineation process used for each province. A more detailed description of the specific steps taken for each province is provided in the four following sections.

4.1. The Prairie Provinces

The first region for which the agricultural ecumene was delineated was for the contiguous prairie provinces of Alberta, Saskatchewan, and Manitoba. This was done for two reasons. First, an up-

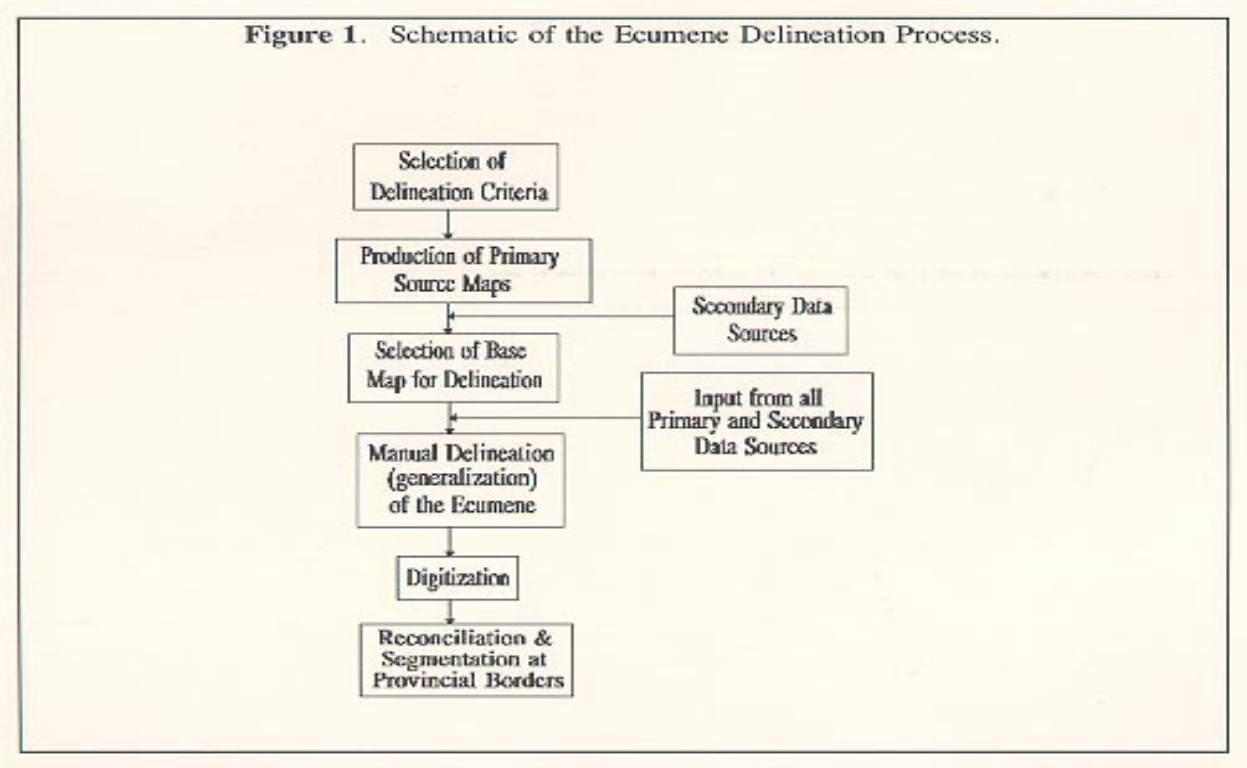
dated version of the agricultural ecumene of the prairies was required for the Crop Condition Assessment Program. Second, the prairie region is arguably the simplest area for which the ecumene can be delineated because the agricultural lands in this region are located largely within one extensive zone. The availability of additional source materials such as the 1985 remotely sensed prairie ecumene, and the National Atlas of Canada also made this region a suitable one in which to begin the delineation process.

The following sources were used in the delineation of this ecumene:

- the 1991 automated methodology based on improved agricultural lands only.
- the 1991 automated methodology based on improved and unimproved agricultural lands.
- a map of all agricultural EAs.
- a map of the agricultural index by EA based on improved lands.
- the 1985 remotely sensed map on area under crops and pasture.
- a soils map.
- a growing degree-days map.
- the Canadian Gazetteer Atlas.

Delineation of the prairie ecumene was instructive in that several observations were made which would be used to refine the process for the remaining provinces. The first observation was that the automated approach calibrated to improved and unimproved agricultural lands proved to be a superior measure of the extent of agricultural lands within this region. When only improved lands were used to calibrate the model for the prairies, large tracts of land in southwest Saskatchewan and southeast Alberta were not identified as agricultural lands. These areas are however, used extensively as grazing lands and should be included in the agricultural ecumene for this region.

There was some concern in moving toward an automated ecumene methodology calibrated according to both improved and unimproved agricultural lands. For the Prairies, it was thought that this approach would likely identify the extensive areas of unimproved pasture lands indicated above, but it was uncertain whether the margins of the ecumene would be extended markedly under this new definition. It was found that the pasture lands within the ecumene were identified, but the margins of the ecumene did not extend noticeably from their position when based on improved lands only.



Another measure used in the ecumene delineation process was the map of the agricultural index by EA for this region. The results generated by this experimental approach strongly reinforce those obtained through the 1991 automated methodology. The ecumene boundaries generated by these two methodologies were closely correlated when a minimum index value of 25% agricultural land on census farms was selected. This indicates that this methodology may also be used to generate the agricultural ecumene, but its success is dependent upon the selection of a properly specified minimum index value.

The soils and degree-days maps were examined in order to determine the extent to which the margins of the automated ecumene followed any spatial distribution by soil type, or any specific isoline of average growing degree-days. The result of this investigation was that there was fairly close association between the critical growing degree-days isoline and the margins of the automated ecumene. The relationship between the ecumene margin and soil type distribution was less closely correlated.

As a final check on the positioning of the margins of the prairie ecumene, results from the 1985 remotely sensed ecumene were contrasted against those generated through the 1991 automated methodology. In general, there was a high level of association between these ecumenes though they were derived through entirely different means. The close association between these data sets is attributable to the improved spatial resolution of the 1991 automated ecumene methodology.

The base map used for the delineation was that produced by the 1991 automated ecumene methodology, and the final delineation gave primary weighting to the results obtained through this method. This map plotted the ecumene according to several pre-determined cut-off levels. The final ecumene was manually drawn so as to include all agricultural EAs by descending index value until the cumulative area of the ecumene exceeded 130% of the area of improved and unimproved agricultural land in the CCS.

The finer spatial resolution used by the 1991 automated methodology allowed the margins of the ecumene to be refined considerably (Figure 2). Figure 2 also identifies several known non-agricultural lands within the ecumene such as parks and military lands. These were identified through the Canadian Gazetteer Atlas, and excluded from the ecumene.

Several main points may be noted in summary of this section. First, the automated approach generates more realistic ecumene boundaries when calibrated on improved and unimproved agricultural lands. As was shown for the prairie provinces, the automated methodology calibrated on improved lands only failed to identify large tracts of known agricultural lands in Saskatchewan and Alberta.

Second, the map depicting all agricultural EAs was not particularly useful in the delineation process. This approach cannot be used to generate an agricultural ecumene since the area of the ecumene will consistently exaggerate the total agricultural land area in each region.

Third, it is recommended that the experimental methodology based on the percentage of agricultural land in each EA be retained for use in the delineation process. This map proved quite useful in the delineation of the prairie ecumene, and could also find application in other provinces. Fourth, the soil and climate maps were of little value in the delineation of the ecumene in this region. These sources were excluded from the delineation of the ecumene in the remaining regions because they could not be used to identify areas of significant agricultural activity.

These findings were used to further refine the ecumene delineation process for subsequent provinces.

4.2. British Columbia

The agricultural ecumene of British Columbia was delineated by an approach somewhat different from that used for the prairies. In an effort to capture additional data for use in ecumene delineation in marginal areas, a further experimental methodology was developed. This was to plot the value of total gross farm receipts for each agricultural EA. This technique takes a unique approach to the

identification of agricultural areas in that the discriminating criterion is not land-based. As a result, all EAs with significant agricultural output will be identified, regardless of the ratio of agricultural land in that EA.

Several sources were used in the delineation of the agricultural ecumene of British Columbia:

- the 1991 automated methodology based on improved and unimproved agricultural lands.
- the ratio of agricultural lands in each EA (improved and unimproved lands).
- the value of gross farm receipts by EA.
- the Canadian Gazetteer Atlas.

The agricultural ecumene of this province is characterized by the existence of several pockets of agriculture, rather than extensive regions or zones (Figure 2). The two most extensive agricultural areas are located in the Peace River and the Okanagan Valley districts.

Through an evaluation of the results generated by each of these methodologies, it was determined that the most appropriate base-map for the delineation was the one depicting the percentage of agricultural land by EA. This map was chosen over the one generated by the 1991 automated methodology because it more clearly identified the spatial distribution of agricultural activity in the province.

The agricultural index, and the gross receipts maps were used as the primary sources with which to delineate the ecumene for this province. The area of each ecumene pocket approximates the area of agricultural land in each EA, as well as taking into account the level of economic output in each of the agricultural EAs. EAs were excluded from the ecumene if very low agricultural output (less than $5,000) was reported. Second, EAs exceeding the minimum total farm receipts were selected for inclusion in the ecumene, with areal representation weighted by the agricultural index value in the EA.

The most significant changes to the ecumene (Fig. 2) resulting from the 1991 delineation process were the elimination of several small ecumene pockets in the interior of the province, and a slight expansion of agricultural area in the Okanagan Valley.

4.3. Ontario And Quebec

The delineation of the agricultural ecumene of Ontario and Quebec are considered together since the main agricultural lands in these provinces are situated in one continuous zone extending from

southern Ontario through to Quebec City. Figures 2 illustrates the agricultural ecumene of these provinces in 1991.

The experiences gained from the delineation of the ecumene in the other provinces served to refine the selection of source materials from which the ecumene could most readily be derived. For each of these two provinces, the following source materials were used to delineate the ecumene:

- the 1991 automated methodology based on improved and unimproved agricultural lands.
- the ratio of agricultural lands in each EA.
- the value of gross farm receipts by EA.
- the Canadian Gazetteer Atlas.

The most appropriate base-map for delineation of the Ontario ecumene was determined to be the one generated by the 1991 automated methodology. This map very clearly identified the principal agricultural lands of this province, which extend from the Windsor City region, to the Quebec/Ontario border. Additional source maps were used to refine the delineation of the ecumene pockets outside the principal agricultural areas.

The source map indicating the level of gross farm receipts by EA was of particular value because it revealed the existence of a significant level of agricultural activity in the area directly south, and southeast of Algonquin Provincial Park. The map of the percentage of agricultural land by EA confirmed that several of the EAs in this region had some agricultural lands, but the index values were too small to be included by the 1991 automated technique. Another factor which may have elevated the level of gross farm receipts in this area is local involvement in the maple products industry. The sales of such products are included in the value of the gross farm receipts, yet the activity occurs almost exclusively on lands other than those classed as improved or unimproved agricultural lands.

The Canadian Gazetteer Atlas was used to identify several tracts of non-agricultural land within the principal zone of agriculture. These lands were excluded from the ecumene.

An examination of the same selection of source maps for the province of Quebec revealed that the gross farm receipts map was most appropriate for use as the base-map for the delineation of the agricultural ecumene in this province. Again, the 1991 automated ecumene methodology successfully delineated the principal agricultural areas in the southern part of this province, but failed to identify other pockets of significant agricultural activity outside this area.

The level of agricultural activity in the ecumene pockets was identifiable through the use of the gross receipts and the agricultural index maps. It was observed that the ecumene pockets often contained fairly large parcels of agricultural land in absolute terms, but were assigned relatively low index values because of the large size of the EAs in these regions. The source maps were also used to identify pockets of very low agricultural output with the main ecumene, and these were excluded from the ecumene during the final delineation.

4.4. The Atlantic Provinces

The final area for which the agricultural ecumene was delineated was the Atlantic region. This region comprises New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland. The following source materials were used in the delineation process:

- the 1991 automated methodology based on improved and unimproved agricultural lands.
- the ratio of agricultural lands in each EA.
- the value of gross farm receipts by EA.
- the Canadian Gazetteer Atlas.

An examination of the source maps revealed that the 1991 automated technique constrained the agricultural ecumene to only a few small pockets in the entire region. By contrast, the agricultural ratio and gross receipts maps indicated a much wider spatial distribution of significant agricultural activity. Again, one of the principal causes of this discrepancy is that the value of the agricultural index was often too low to be selected for inclusion by the automated technique. The base-map used in the delineation of the ecumene for this region was the map depicting the agricultural index value of each EA. The gross receipts map was also used extensively to identify agricultural intensity in areas where such activity occurs on agricultural lands other than those classed as improved or unimproved.

Certain peculiarities of the EA and CCS boundaries also affected the spatial distribution of the ecumene pockets in this region. One of these areas is eastern Prince Edward Island, where there are several contiguous CCSs each containing only one EA. Under such conditions, the area of improved and unimproved agricultural lands must exceed 70% of the total area of the CCS in order to be included in the ecumene. As a consequence of this, these EAs were not included in the ecumene even though each had a fair proportion of total area under agricultural lands, and the economic output from each parcel was significant.

A variation of the delineation process was employed for the province of Newfoundland. During the 1986 delineation process, the agricultural ecumene for this province was exaggerated significantly in order that the ecumene pockets in this province would be visible at publication scale. After

experimenting with different options for 1991, it was decided to reuse the 1986 ecumene for Newfoundland. It should be noted that, due to an increase in total farm area in that province between 1986 and 1991, as measured by the Census of Agriculture, the ecumene is somewhat less exaggerated than previously. The completed ecumene for this region is illustrated in Figure 2.

4.5. Generalizing And Digitizing The Ecumene

For each of the regions identified above, the final agricultural ecumene was delineated by hand on a base-map selected as most appropriate for the task. Manual delineation served to generalize the ecumene boundary, as well as to provide a method by which information from other sources could be incorporated onto the base-map. The information provided on the primary and secondary source maps was used as a guide in the final delineation. Each region was delineated separately, and the final ecumene was delivered to Geography Division for digitizing. Following digitization, the ecumene was reconciled in areas where it crossed provincial boundaries. The ecumene was also segmented at these boundaries in order that the ecumene for individual provinces could be extracted for use separately.

5. DISCUSSION OF THE RESULTS

In this chapter, the main results of the ecumene delineation process are presented and discussed. The discussion takes a broad approach in that both applied and research components were integral to the completion of the project. The discussion turns first to a consideration of the overall management of the project. Following this, a quantitative evaluation of the results of the project is undertaken.

5.1. Resource Requirements And Overall Project Management

As a general comment, the overall execution of the project was efficient and timely. The region by region approach to the delineation of the ecumene was highly efficient in that it allowed the methodology to be refined rapidly in the early stages of the project. This resulted in improved model specification, and a reduction in the number of source maps produced for each region. This approach also allowed customizing the delineation methodology for each region.

Another step taken to reduce the cost of the project was to delineate the ecumene on a regional level rather than for separate provinces where feasible. In so doing, the number of ecumene maps was reduced from ten individual provinces to five regions. This step resulted in a further cost reduction during the generalization phase of the project because it was not necessary to reconcile the ecumene across provincial boundaries within any of the regions. Only one additional map combining Ontario and Quebec was required to complete the ecumene reconciliation process.

The resources required for the successful completion of the project were distributed as follows:

- 35 days of technical operations requirements (Geography).
- 10 days of project management and geographic analysis (Geography).
- 10 days of background research and ecumene delineation (Agriculture).
- 10 days to generate the supporting documentation (Agriculture).

Total = 65 days

It is important to recall that the project consisted of both experimental and applied components. The experimental phase of the project required that several methodologies be considered for use in the delineation of the ecumene. As a result, resource consumption was higher than if only one methodology had been pursued. Should future research progress to a stage where there is confidence in the results produced by only one methodology, then the resources required for ecumene delineation would be significantly reduced.

5.2. Improvements in Ecumene Accuracy

In this section, the accuracy of the agricultural ecumene is assessed through an examination of the results obtained through two quantitative measures. These results indicate that there has been a significant increase in the accuracy of the delineation methodology for 1991. This improvement is attributable to the higher spatial resolution of the base-maps used in the project, and changes in the inputs on which the delineation is based.

For the 1981, and 1986 rounds of ecumene delineation, the measure used to assess ecumene accuracy was the ratio of total farm area to the ecumene area in each province. In order to evaluate any trend in the accuracy of the ecumene by this measure, Table 3 incorporates these data together with the results for 1991. Under this measure, the improvement in the accuracy of the 1991 ecumene relative to the 1986 is mixed. At the national level, the index value increases from 79 in 1986, to 80 in 1991. The Atlantic provinces show considerable increase in the accuracy of the ecumene, and the index values for the Prairie region increase slightly. The results for Quebec, Ontario, and British Columbia act to offset the direction and magnitude of the change at the national level, as the index value decreases in each of these provinces over the same period.

There are however, difficulties in using the previous measure in evaluating the accuracy of the ecumene. First, it is important to note that for each period, the ecumene was derived based on a variable other than "total farm area", yet this variable is used as the numerator in deriving the index. For 1981 and 86, the variable upon which the delineation was based was **improved agricultural lands**. The 1991 ecumene was delineated based primarily on the distribution of **improved and**

unimproved agricultural lands. As a consequence of this inconsistency, the index values cannot detect changes in the accuracy of the ecumene with any precision.

Table 3. Ratio of Total Farm Area to Ecumene Area (%).

	1981	1986	1991	Ecumene Change *
Canada	60	79	80	100
Newfoundland	3	10	13	100
Prince Edward Island	37	46	100	43
Nova Scotia	19	25	27	91
New Brunswick	16	23	28	76
Quebec	31	53	43	116
Ontario	45	60	56	103
Manitoba	73	88	93	95
Saskatchewan	87	91	95	94
Alberta	73	93	94	99
British Columbia	22	55	45	121

* 1991 ecumene as a percentage of the 1986 ecumene.

Sources: Profile of Canadian Agriculture: 1981, 1986.
Agricultural Profile of Canada, 1991.

The interpretation of the results obtained by this measure are further confounded because they are extremely sensitive to changes in the area of the ecumene in each province. In order to demonstrate this, a Pearson Product Moment Correlation was performed on the ratio of the index values between 1991 and 1986, for each province, and the corresponding ratio between the size of the ecumene for the same years. The result was a strong negative correlation. Those provinces where the change in the size of the ecumene was most significant also experienced the greatest change in the value of the index.

In order to better reflect changes in the accuracy of the ecumene over time, a new measure is proposed. This measure more directly reflects changes in the accuracy of the ecumene because it is based on the variable from which the ecumene is derived. For 1981, and 1986, the index value

was changed to the area of improved lands as a percentage of the ecumene. The 1991 index is based on the area of improved and unimproved agricultural lands as a percentage of the ecumene. These values are directly comparable as each series indicates the degree to which the resulting ecumene for each period reflects the area of the variable used in its derivation. These new index values are presented in Table 4.

Table 4. Ratio of Land Type to Ecumene Area (%).

	1981*	1986*	1991**	Ecumene Change #
Canada	51	54	72	100
Newfoundland	7	3	7	100
Prince Edward Island	36	32	75	43
Nova Scotia	17	10	12	91
New Brunswick	16	9	13	76
Quebec	29	31	29	116
Ontario	47	43	46	103
Manitoba	59	61	86	95
Saskatchewan	67	69	91	94
Alberta	50	58	88	99
British Columbia	17	21	35	121

* based on improved agricultural land as a percentage of the ecumene.
** imp. and unimp. agr. land as a percentage of the ecumene.
# area of the 1991 ecumene expressed as a percentage of the 1986 ecumene.

Sources: Agricultural Profile of Canada: 1981, 1986, 1991.
Piamonte, K. et al (1978).
Haythornthwaite, T. et al (1989).

Under this new measure, there has been a substantial improvement in the accuracy of the ecumene for 1991. The change has been on the order of 18 percentage points at the national level, with a range of -2 for Quebec, to 43 percentage points for Prince Edward Island. The increased accuracy of the ecumene for each of the prairie provinces is substantial, and is due to the inclusion of the extensive areas classed as "unimproved" agricultural land.

There was also positive change in the accuracy of the ecumene for most of the provinces with lower index scores (New Brunswick, Nova Scotia, British Columbia, and Newfoundland). The lower index scores for these provinces is partially attributable to the existence of significant levels of agricultural activity on agricultural lands classed as other than improved or unimproved. In these provinces, the ecumene was extended beyond the areas of prime agricultural land in order to indicate the existence of agriculture practised on other land types. This increased the value of the denominator of the index equation, affecting a decrease in the index value.

The final way in which to gauge the significance of the methodological developments on ecumene delineation is to examine the change in the area of the ecumene from 1986 to 1991. These data are presented in the second part of Table 4. At the national level, the 1991 ecumene area is essentially the same as that for 1986. This aggregate value masks substantial changes in the area of the delineated ecumene for some of the provinces over the same period. Most notably, the area of the ecumene has been significantly reduced for Prince Edward Island (43%) and New Brunswick (76%). The changes in each of these provinces has little to do with observed change in the area under agriculture, but rather the way in which the agricultural areas were identified and delineated. In each of these provinces, the reduction in the size of the ecumene is associated with a substantial increase in its accuracy under the previously defined measure.

The 1991 ecumene was larger than that for 1986 in only three provinces: Ontario (103%), Quebec (116%) and British Columbia (121%). In each case, large parcels of previously unidentified agricultural lands were included in the 1991 ecumene either because the source maps indicated the presence of agricultural lands, or because of a significant level of economic output from agriculture in these areas.

It is also instructive to note that the level of statistical association between the change in ecumene accuracy over the period 1986-1991, and the change in the ecumene area, is not as strong using the index proposed above. The results of a Pearson Product Moment correlation confirm this. The general conclusion drawn from this is that the proposed index is a more independent measure of ecumene accuracy. As such, it will reflect the real change in ecumene accuracy to a greater extent that the method used previously.

6. CONCLUSIONS AND RECOMMENDATIONS

The final section of this work outlines the main findings on the delineation of the agricultural ecumene in Canada. The evaluation considers both the overall execution of the project and the quality of the final product. Recommendations for further work on the development of an automated ecumene methodology are also presented.

The first main theme of the study was to demonstrate that census data can be used effectively in the delineation of the agricultural ecumene for Canada and its regions. First, the census collects data on all holdings which produce agricultural products intended for sale. This represents a large part of the total agricultural production within the country. Second, the Census of Agriculture collects a wealth of information which can be used in the delineation of the agricultural ecumene, and in the development of thematic maps to be plotted on the ecumene. These data include land area by type of use, gross agricultural receipts, capital value of land and buildings, data on all crops and livestock, etc. Third, the census data are spatially referenced to the Enumeration Area level of resolution. Although EA size is a function of dwelling density, the average EA size in agricultural areas is sufficiently small to permit an analysis of the spatial distribution of agricultural characteristics.

The second focus of the study was to conduct further research into the method used to delineate the agricultural ecumene in Canada. The research revealed that there had been significant improvement in the spatial resolution of the delineation methodology by 1986. The technical aspects of the delineation process were further refined for 1991, with the completion of a digitized boundary database at the EA level of spatial resolution.

In order to capitalize on these technical developments, further research was conducted on the conceptual basis of the ecumene delineation process. First, it was found that the accuracy of ecumene delineation could be improved by calibrating the automated methodology to improved and unimproved agricultural lands. It was also determined that greater detail on the intensity of agricultural activity could be achieved by producing additional maps for use as checks against the results generated through the automated approach. In particular, it was found that the maps on gross farm receipts, and agricultural lands as a proportion of total EA land were useful source maps.

Third, the overall success of the research effort was evaluated through an assessment of the management of the project, and an analysis of the improvement in the accuracy of the ecumene. The project was judged to be well managed, with no delays or difficulties in the production of the source maps, or the final product. There were more maps produced than originally anticipated, but these were necessary in order to adequately explore certain methods for ecumene delineation. This extra work resulted in overall improvements to the final product.

The study revealed that the accuracy of the ecumene increased markedly as a result of the methodological refinements to the delineation process. This improvement was reflected both in the change in the total area of the ecumene in each region, as well as the spatial configuration of the ecumene. The final ecumene was generalized to reduce visual complexity, and resembles fairly closely the total farm area in Canada.

The research also identified several avenues for further investigation into the ecumene delineation process. These avenues were not explored in the current research because of time constraints. However, it is suggested that these be pursued as time permits, or when the agricultural ecumene is revised based on results from the 1996 Census of Agriculture.

Despite the improvements made in the ecumene delineation process, there are still certain limitations in this process. First, the automated approach failed to identify agricultural activity in areas where the land-base is relatively small. It also failed to identify agricultural activity occurring on agricultural lands other than those classed as improved or unimproved. As a result of these detractions, the final ecumene must still be delineated manually in order to incorporate information provided on other source maps.

In order to improve the overall performance of the automated methodology, and to reduce the cost of ecumene delineation in the future, the following recommendations for further research and refinement can be made. One of the areas of concern in the delineation process was the confounding effect of boundary peculiarities on the identification of areas for inclusion in the ecumene. Specifically, the existence of CCSs comprising only one EA created a bias against the identification of agricultural activity in these areas. These EAs were flagged for inclusion in the ecumene only if a large share of the total area of the EA was agricultural land. This problem may be reduced or eliminated if the EAs are ranked within larger administrative units. This would increase the number of EAs in each areal sub-unit, thus increasing the probability that at least one EA will be selected for inclusion in the ecumene based on the area of agricultural lands within that larger unit. To this end, it is recommended that further research be conducted into the effects of using CD rather than CCS units in the ranking of agricultural EAs.

Another shortcoming of the current methodology is that it is biased against agricultural activities operating on a small land-base, or activities which occur on agricultural lands other than those classed as improved or unimproved. In the current research, these areas were readily identified on maps depicting gross agricultural receipts by EA. With this knowledge, an automated technique could be designed to rank EAs by the level of gross receipts until the EAs selected for inclusion equal the target land area specified by the analyst. This technique can be tested using several different levels of aggregation such as the CSD, the CD, and the provincial total.

The future cost of ecumene delineation may be further reduced should provision be made to sell or market the ecumene file to other agencies or private interests. This avenue should be explored in preparation for the 1996 round of ecumene delineation. A concern related to this is that resources be made available for ecumene delineation in advance of the next delineation in order to facilitate the planning of further research into this issue. A clear specification of resource availability reserved for delineation will enable the analyst to select the most appropriate avenues for exploration given the level of funding.

A final recommendation is that contact be maintained with the various agencies identified in this report, in order that the Agriculture Division stay abreast of developments in remotely sensed databases, as these may be of considerable use in ecumene delineation. Such databases offer higher spatial resolution than is currently available with census data, and the data are not subject to the bias resulting from the use of the headquarters rule used in the collection of census data. Using a remotely sensed ecumene, census data could then be plotted within more precisely defined agricultural regions.

These recommendations may result in further improvements to the automated ecumene delineation approach. First, improvements in the ecumene delineation process will reduce the cost of completing this necessary re-evaluation of the spatial distribution of agricultural areas in Canada. Second, additional research along the lines suggested above may yield a more flexible method by which the ecumene can be generated after the 1996 Census. Further improvements in the flexibility of the delineation methodology would enable the model to be re-specified rapidly for use in special studies, and in different agricultural regimes. And finally, continued research into the most appropriate methods for model specification will serve to develop a more complete understanding of the complexity of modern agricultural activity in developed economies.

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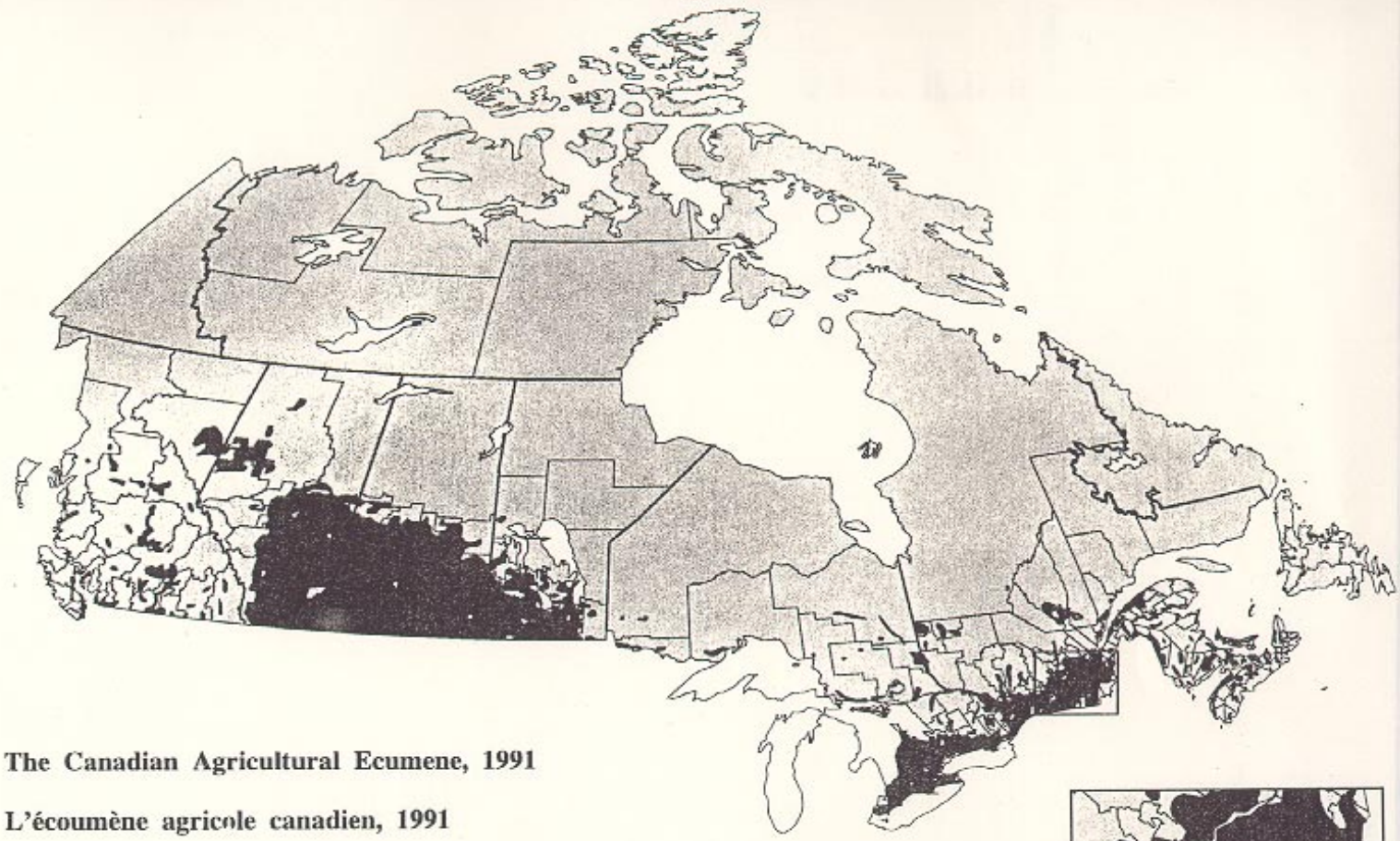
Figure 2.



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