CANADA'S POTENTIAL CROPLAND MARGIN*

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Introduction

Canada's agri-food strategy is directed at expanding agricultural production and sales [1]. This apparently simple growth strategy is likely to accelerate some fundamental changes in the types of investment in, and production from, Canada's land base. Some of the increased production will be met by expanding the present area of land in crop use. However, strategies for expansion are likely to be hindered as the area available for crop use in the future diminishes. In future, the agricultural industry in Canada will have to accommodate both the demands for a higher level of production and an impending limit to its areal growth.

A measure of the margin of land available for the further expansion of cropland area in Canada is needed. This measure will enable the size of the margin of potential cropland still available for crop use to be monitored. The size of the margin can provide an indication of the imminence of resource exhaustion, enabling agricultural planners to anticipate some of the possible effects.

This study shows that Canada has about 10 million hectares of land in Canada Land Inventory (CLI) classes 1, 2 and 3 that is not currently in cropland use or built-on. This area is the potential cropland margin: the area not currently used for crops but potentially usable if the present rural land uses release the land. Ten million hectares is equivalent to about 38 percent of the cropland

*The views expressed in this paper are those of the author and do not necessarily represent the opinions of Agriculture Canada.

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area in 1981. A similar study was done by the United States Soil Conservation Service in the 1970s. It showed that the United States has a potential cropland margin of about 45 million hectares, an area equivalent in size to about 28 percent of the U.S. cropland area [15]. The margin in Canada, therefore, is proportionally larger than that in the United States.

In this study, the potential cropland margin is defined conservatively. The focus is restricted to the areas of land in classes 1, 2 and 3 of the CLI Soil Capability Survey as being those most capable of supporting the growth of crops [24]. The area of built-on land (including urban and rural settlements, rural transportation and farmstead areas) that has taken up land in classes 1 to 3 is measured and removed from the total base of classes 1 to 3 land recorded by the CLI, since land that is built-on is considered to be permanently and irreversibly precluded from agricultural use. The margin is then calculated as the area remaining after the area of all cropland (excluding hayland but including summer fallow) has been subtracted.

Thus, estimates of the area of built-on land in Canada must be made before the extent of the potential cropland margin can be derived.

The Definition of Built-on Land

Built-on land is all land that fills the functions of transportation, residence, industry, commerce, and institutions that are generally associated with urban areas. Some economists and geographers [7; 30] call built-on land "urban" because it fills urban functions. However, the word "urban" is used with so many different associations in the literature that its use is avoided here, and the term "built-on" is employed instead.[1] It should be noted, however, that this term refers to the cover (or form) of the land rather than the function it fills, and thus is contrary to a basic principle of land use analysis that an area should refer to the use or function that it fills in meeting the needs of man [6; 7]

The measurements in this paper have, in fact, been made based on the *function* or purpose to which the land is put even though the terminology is clearly based on the form of the land uses. In the case of "built-on" areas, however, form (or cover) is closely correlated with the function, whether these functions are located in rural or urban settings [14].

The area of all built-on land in Canada is comprised, in this analysis, of urban and rural settlement land, rural transportation land (the area occupied by roads, railroads and airports) and farmstead areas. What the areas of land in these functions have in common (besides their functional similarity) is the surface modification that has been required to accommodate them. The surface modification either entails the construction of housing, or other buildings, or the construction of special surfaces on the land for road, railroad and airport use.

[1]In the United States the term "urban and built-up" is used to include residences, commerce, industry, recreation and transportation.

The area of land that is actually built-on is the area that is measured, together with areas of open land that are intimately associated with the construction. It is for this reason that gardens, urban parks, farmyards, lanes and roads are included in the respective components of built-on land, whether it is located in rural or urban settings. Also the area of rural transportation land (urban transportation land is included with urban areas) is calculated based on standard right-of-way widths that include areas of unsurfaced land that are closely associated with the transportation use.

It is important to note, however, that jurisdictional boundaries are not a basis for measuring settlement areas. In many cases, jurisdictional boundaries include areas of rural land uses, such as woodland and agricultural land. By restricting the definition to built-on land and its affiliated spaces, rural land uses are excluded from this category.

The definition of built-on land does not include the area around many large towns and cities that have come under urban influence, nor the areas under such uses as reservoirs,[2] power lines and pipelines, which some people feel are urban in nature. The shadow effects of urban places on agriculture may influence the degree to which the land is used for agriculture, but this does not mean that the land is entirely precluded from agricultural use. Similarly, the area over or under many transmission routes is at least partly used for other purposes as well. To avoid difficulties arising from ambiguity in use, these areas are excluded from the measurements used here.

The important nature of the area of built-on land considered in this paper is that it competes with agriculture for space to varying degrees. Rural settlements, farmsteads and rural transportation uses tend to take land from possible agricultural production as much as large urban settlement areas do.

[2]The major difficulty in assessing the area under reservoirs is a lack of data on the number or area of land occupied by reservoirs. Another problem is that many natural lakes perform the function of reservoirs, yet could hardly be considered competitive with agriculture for land.

Estimating the Area of Built-on Land in Canada

In the 1960s, the Canada Land Inventory (CLI) conducted a land use survey of the entire area of Canada inside the CLI boundaries [24; 11; 26; 38]. Among the areal data gathered by this land use inventory was the area of urban and rural settlement land (cities, towns, villages, hamlets and isolated non-farm areas). These data were collected on functional boundaries rather than jurisdictional boundaries. The CLI Land Use Survey provides the only comprehensive estimate of the total area of urban and rural settlement land in Canada, and it employs precisely the same definition as that used in this study.

Unfortunately, the high cost of conducting land inventories has prohibited further land use surveys of this sort. To estimate the changes that have occurred since the survey was undertaken, an index of changes in the combined area of urban and rural settlement land in Canada was created, using the Census of Canada housing stock figures for the years 1951, 1961, 1971 and 1981 [19; 21; 35].

This methodology is new. Other authors [7; 8; 18] have used a known ratio of the average area of urban and rural settlement land per 1000 population to estimate urban and rural settlement areas from a known or projected population size. The major weakness of the approach is that the area of urban and rural settlement land per 1000 population (the inverse of the commonly used density figure) is assumed to remain constant, whereas in reality it is subject to change when the household formation rate alters and when other exogenous influences, such as density regulations and housing designs, change. To accommodate these types of change, the urban and rural settlement area per 1000 population (viz. the land provision) is modified by the use of an index based on the relative numbers of single attached and single detached dwelling units.

The resulting estimate of the total urban and rural settlement area in each year reflects the changing composition of the housing stock, which acts as a surrogate for the changes in population density (or its inverse, the land provision) over time.[3]

The original equation for the index is:

$$a_{ij} = P_{ij} \times \frac{a_{66j}}{P_{66j}} \times \left\{\frac{N_{ij}}{P_{ij}} \times \frac{P_{66j}}{N_{66j}}\right\} \times \left\{\frac{Nd_{ij}}{N_{ij}} \times \frac{N_{66j}}{Nd_{66j}}\right\} . \qquad (1)$$

[3]Land provisions vary widely among centres of the same size [13] but show a consistent pattern of change with settlement size [9]. Rates of land conversion per 1000 people show considerably larger variations [29]. The estimates here apply to the aggregate area of all settlements in the urban hierarchy, so the land provisions are averages for the entire settlement hierarchy.

where a_{ij} = estimated area of all urban and rural settlement land in year i, province j;
P_{ij} = population size in year i, province j;
a_{66} = urban area in 1966 (base year);
P_{66} = population size in 1966;
Nd = number of detached housing units;
N = total number of attached and detached single housing units;

and where $\frac{N_{ij}}{P_{ij}} \times \frac{P_{66j}}{N_{66j}}$ is an index to account for changes in the number of single housing units per 1000 population (single housing units generally occupy the greater proportion of an urban area);

and $\frac{Nd_{ij}}{N_{ij}} \times \frac{N_{66j}}{Nd_{66j}}$ is an index that allows for changes in the mix of attached to detached single family houses in the housing stock. A change in this mix will alter the density of an urban area.

Equation (1) reduces to:

$$a_{ij} = \frac{a_{66j}}{Nd_{66j}} \times Nd_{ij} \qquad (2)$$

This index, then, supplies estimates of the total settlement area (i.e., urban and rural settlement areas).

The area of land in farmstead use was estimated by multiplying the number of farms by a standard factor based on the size of the farm and the province in which it was located.

In a similar manner, the number of airports in each province was multiplied by a standard factor representing the types and sizes of the airports [4; 2; 31].

Road and railroad lengths were multiplied by standard right-of-way widths to obtain estimates of the areas of land in use (from tables of engineering standards supplied by the Transportation Association of Canada). The standard areas and widths[4] have been carefully checked against those used by the United States [12; 17]. This methodology is based on that in use in both Britain [7; 8] and the United States [17; 18].

[4]The standard factors were: for airports, the area varied from 200 ha per international airport to 2.4 ha for private airports; for roads a 30-meter width was used except for earth roads where a 20-meter width was employed; and for railroads a standard area of about 3 ha per km was used.

The Area of Built-on Land in Canada

Table 1 gives the estimates for 1981 derived by this methodology. The total area of built-on land in Canada covers about 5.8 million hectares, or 0.6 percent of the total land surface. About 47 percent of this is rural transportation land; 44 percent is devoted to urban and rural settlement use; and about 8 percent, to farmstead areas.

Table 1

THE AREAL COMPOSITION AND SIZE OF BUILT-ON LAND IN CANADA, 1981*

	Total built-on area	Rural transportation area	Urban and rural settlement area	Farmstead area	Total built-on land provision
	000s ha		— percent —		ha/1000 pop.
Newfoundland	128.0	38.0	61.6	0.4	225
Nova Scotia	174.9	55.2	42.6	2.2	206
Prince Edward Island	33.9	79.0	13.3	7.7	276
New Brunswick	350.6	25.2	73.5	1.3	503
Quebec	795.4	42.0	52.0	6.0	123
Ontario	1183.3	45.1	45.5	9.4	137
Manitoba	397.8	56.9	29.4	13.7	387
Saskatchewan	744.4	72.8	9.7	17.5	768
Alberta	1418.4	41.0	51.7	7.3	634
British Columbia	521.4	42.1	53.3	4.6	190
Territories	29.8	73.8	25.5	0.7	433
Canada	5777.9	47.2	44.5	8.3	237

* See text for definitions. The total built-on area is the sum of rural transportation area, urban and rural settlement area and farmstead area.

Source: Updated from [19].

The data are also presented for each province. Several provinces show high proportions of their total area of built-on land in transportation use. These regions of Canada tend to be either sparsely populated or predominantly agricultural, with well-developed agricultural networks (e.g., P.E.I.). The predominance of the rural transportation area in the composition of the whole of the built-on area underlines the importance of the effects this land use can have on the transfer of land from agricultural use, and confirms the reasoning for including it in the anlaysis.

The change in the area of each component of the built-on area from 1951 to 1981 is plotted in Figure 1 for Canada as a whole. From about 1966 to 1976, the settlement area has been divided into two components: that containing large settlements of 25,000 population or more; and that containing smaller settlements. The

dotted lines mark projected extensions to the areas, based on current trends.

The trends of change in the components of the built-on area (Figure 1) provide insight into its growth. Farmstead areas have

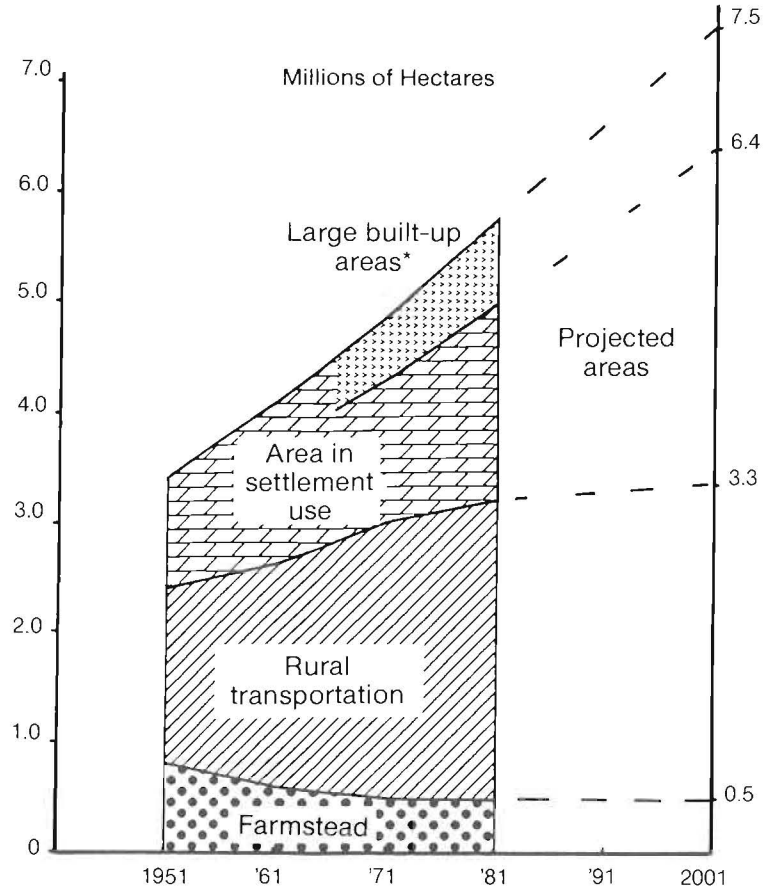

Figure 1

THE COMPOSITION OF CANADA'S TOTAL AREA OF BUILT-ON LAND.=

* Built-on land consists of urban and rural settlements (including large, built-up areas), rural transportation land, and farmstead areas.

** Large built-up areas (settlements with 25,000 population or more) are a part of the settlement area. Data for these areas are available for 1966-1976 [40], thus allowing them to be shown as a subcategory of the total settement areas.

Sources: see text; [20].

never been a major part of the category, and their importance is declining. However, the rural transportation area has been the predominant cause of growth in the 1960s (a pattern echoed in the United States [5]), although its contribution is now declining. More recently, the major cause of expansion has been the increase in urban and rural settlement areas. This shift influences the amount of good quality land that is converted to built-on land uses, because the pattern of growth has changed from one which is essentially linear to one which is nodal. The location of settlements tends to be on land that is of good quality for agriculture, a tendency that may well exacerbate the loss of land from agricultural use [22].

These estimates of built-on land are the prerequisite to a calculation of the size of the potential cropland margin, and it is important to ensure that projections of the changes in this area are as accurate as possible.

Estimating the Margin for Cropland Expansion

The margin to be calculated is defined as the total area of land in the CLI land classes 1, 2 and 3 (good quality arable land) minus the area already in crop use, and minus the area of classes 1 to 3 land that has been permanently built-on by some form of settlement or rural transportation use. However, this computation requires the recognition of several assumptions and simplifications.

1) Most authors agree that land in classes 1 to 3 of the CLI is the best area available for agriculture. Class 4 land, however, is of marginal use for arable purposes [24; 28].[5]

2) Land actually in crops, as enumerated by the Agricultural Census [34] only roughly corresponds to land in classes 1, 2, or 3. The only way to get a precise correspondence between land use and land quality is to conduct a survey that sets out to gather both sets of information (as, for example, some of the surveys in the United States have done [39]). In fact, not all the crops listed in Table 2 are necessarily found on the area of classes 1 to 3 land. Hay, in particular, can frequently be grown on land in classes 4 and 5. For this reason, and because the area is significantly large in all provinces, the area of hayland is excluded from the computation of the margin.

Some of the crops shown in Table 2 are frequently found on organic soils or on other soils which, according to the CLI classifi-

[5]As an initial step in this examination of the adequacy of land resources, the CLI land class areas have been employed. The CLI land classes incorporate climatological information in their definition. However, a more refined use of climate data to delimit areas of agricultural land can be used [see 33: 36; 41].

Table 2

THE AREA OF THE MAJOR CROP COMPONENTS OF THE CROPLAND CATEGORY, 1981*

	Grain crops	Fodder crops**	Field crops†	Fruits††	Vegetables and nursery	Total hayland	Total crop area excluding hayland	Summer fallow
				— (000's ha) —				
Newfoundland	0.1	0.3	0.5	0.1	0.5	3.2	1.5	0.4
Nova Scotia	19.4	5.7	2.4	10.8	3.3	71.1	41.6	5.1
Prince Edward Island	73.6	3.9	28.4	0.5	1.7	50.1	108.1	3.0
New Brunswick	25.8	5.2	22.9	3.8	3.5	69.3	61.2	5.2
Quebec	524.3	184.8	33.3	13.2	34.3	965.4	789.9	53.1
Ontario	2,037.7	299.6	153.2	32.1	67.2	1,042.1	2,589.8	63.3
Manitoba	3,700.2	86.6	127.1	0.2	2.3	508.9	3,916.4	598.3
Saskatchewan	10,760.9	192.1	80.0	-	0.9	706.6	11,034.7	6,704.5
Alberta	6,679.1	302.9	44.8	-	5.8	1,408.6	7.032.6	2.205.5
British Columbia	195.4	48.4	7.9	17.1	9.1	290.2	277.9	63.5
Canada	24,016.6	1129.7	496.3	78.0	128.6	5,115.5	25,849.2	9,707.9

* Census cropland area is the sum of the first six columns. Cropland here excludes the area in hayland, which can use CLI classes 4 and 5. Summer fallow is included because it is resting land in short-term cycle with crops.

** Includes corn for silage.

† Field beans and peas.

†† Berries, tree fruits.

- Too small to record.

Source: [34].

cation system, are either excluded from classification or fall into a land class other than 1, 2 or 3 (such crops include tobacco, blueberries, and many vegetable crops). Nonetheless, the area of these more specialized land uses is so small relative to the total areas in this estimation that the discrepancy is not expected to influence the overall result.

3) Just as not all the land uses included in the analysis lie on classes 1 to 3 land, so not all land in classes 1 to 3 is available to crops. Some of this land is currently committed to parks, pasture or woodland. However, this analysis regards land in such rural activities as more readily convertible to agriculture, should the need arise, than land in urban uses.

4) When using the Canada Land Inventory data there is always an assumption that the data have been gathered on a consistent basis. In fact some discrepancies have been introduced during the inventory [20]. In British Columbia, for instance, organic soils were included in the areas of CLI classes, but in other provinces they were omitted. In Canada as a whole, the area of organic soils is estimated to be about 20 million hectares, at least some of which is probably suitable for crop growth.

The figures used in this analysis are for "unimproved" areas; that is, no assumption was made at the time of the inventory that there would be any improvement to the land base through irrigation and/or drainage (this particularly affects the area of soils in Alberta and British Columbia). Because of this "unimproved" status, the omission of organic soils, and the restricted definition of usable land (as classes 1 to 3), the margin calculated here is a low estimate.

5) A convenient date of 1971 was taken for the CLI data in order to coincide with estimates of the urban areas. The CLI soil capability data generally excluded settlement areas but, because the data were gathered from maps at a scale of 1:250,000 [28], it often included the areas of farmsteads, rural settlement and rural transportation land that were too small to be identified at this scale. Thus an allowance had to be made for the areas of these land uses that probably occupied land in classes 1 to 3 in 1971.

6) Not all land that was built-on in 1971, or that has been built-on since then, is in classes 1, 2 or 3. There is, to date, only one study that has examined the quality of land taken up by urbanization [40]. The study measured the amount of land in CLI classes 1 to 3 that was taken up by the expansion of large urban places between 1966 and 1976. These measurements are reported in Table 3, column 1, as proportions of the total area converted to urban use during that period. The proportions were applied to the area of all built-on land for 1971, and to the increase in this area between 1971 and 1981, in order to derive estimates of the amount of class 1 to 3 land included in these categories.

Table 3

CALCULATING THE POTENTIAL CROPLAND MARGIN*

	Area of CLI Class 1-3 Land				
	Published large settlement proportion*	Published inventory estimate, c. 1971**	Modified estimate of area, c. 1971***	Estimate of area, 1981†	Potential cropland margin - area for potential expansion††
	Percent	(000s ha)			
Newfoundland	0.3	5.5	5.4	5.3	3.4
Nova Scotia	42	1,234	1,194	1,185	1,138
Prince Edward Island	99	418	389	387	321
New Brunswick	25	1,516	1,492	1,474	1,408
Quebec	51	2,371	2,180	2,104	1,261
Ontario	78	7,888	7,386	7,313	4,660
Manitoba	92	5,301	5,047	5,028	518
Saskatchewan	78	17,600	17,082	17,067	(672)
Alberta	66	10,729	10,383	10,112	874
British Columbia	20	949	904	888	547
CANADA†††	62	48,011	46,154	45,596	10,044

* Class 1-3 land as a percentage of land taken up by large settlements, 1966-1976 [40].

** Sum of unimproved areas in classes 1, 2 and 3 [28; 27; 10].

*** Inventory area minus estimate of area in rural transportation and farmstead uses (see text).

† Column 3 minus estimated are taken up by the expansion of all built-on land areas between 1971 and 1981.

†† Column 4 minus estimated area in cropland use [34], excluding the area in hayland, but including the area in summer fallow.

If the Canadian margin is calculated as the strict total of the margins in each province, rather than being calculated independently, then it would be approximately 10.7 million hectares. The different is due to the negative figure for Saskatchewan, which should not be included.

††† Provincial figures will not add to Canadian totals due to roundings in computations.

The final equation for this computation is as follows:

$$M = C - a(Ur + \Delta U) - (A_{81} + SF) \qquad (3)$$

where M = margin, or remainder of land in classes 1 to 3;
C = CLI total area of land in classes 1, 2 and 3;
a = proportion of the area taken up by major cities that is in classes 1, 2 or 3 (column 1, Table 3);

Ur = area of built-on land in rural areas included in C because of the scale at which measurement was made;
ΔU = area of land built-on between 1971 and 1981 (Table 1);
A_{81} = area in cropland use (1981 Census) minus hayland;
SF = area in summer fallow (1981 Census) included because it is assumed to be cropland resting in a short cycle.

The margin (M), or remainder, from the calculation is given in Table 3, column 5. At the provincial level it is very noticeable that Saskatchewan has a negative value, indicating that some of the crops of Saskatchewan are grown from an additional area made up either of "improved" land (i.e., through drainage and/or irrigation), or by using class 4 land and accepting a lower yield per hectare, a higher risk of crop failure, or a higher input cost per hectare.

It is also noticeable from Table 3 that the margin in the east of Canada is larger than that in the west. In part, the smaller figures, such as those for Prince Edward Island and British Columbia, are the result of their small absolute areas of classes 1 to 3 land. However, in many of the prairie provinces, the relatively small size of the margin is primarily a consequence of their comparative specialization in extensive crop production. This distribution of the Canadian potential cropland margin may change with the abolition of subsidies such as the Crows Nest Pass freight rate.

Figure 2 shows the area of land in crops and in summer fallow, and the area in CLI land classes 1 to 3 for Canada as a whole, from 1951 to 1981. Unlike built-on areas, crop areas can fluctuate from year to year. Nonetheless, the secular trend over these ten-year periods, shown in Table 2, shows a decline in crop area in the 1950s, and a steady rise in area throughout the 1960s and 1970s. It should be noted that the increase in cropland area is a net figure since some land has gone out of crop use during this period while other land has been brought into crop production. If no new land had been brought into crop production, then the total area of cropland would be expected to fall slightly as some of it was transfered to urban uses. In Figure 2, this would translate into a margin of more or less constant width.

The areas of cropland and built-on land have, in fact, been expanding over the last thirty years, and therefore the potential cropland margin has been declining in size. It is pertinent to note that the expansion of cropland areas has been primarily due to an increase in cropland area in the west of Canada that has more than compensated for the decline in the east. Most of the shift in

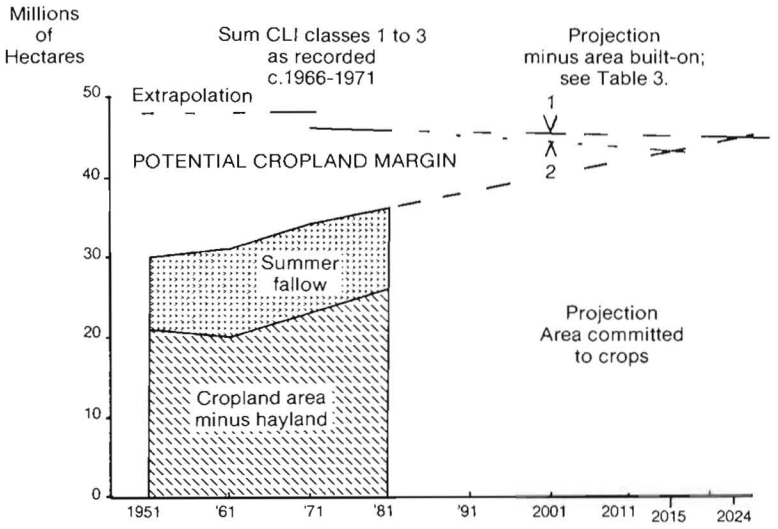

Figure 2
CANADA'S POTENTIAL CROPLAND MARGIN

Notes: Between the arrow points marked 1 and 2 lies the projected decline in the areas of classes 1 to 3 land due to urbanization from 1981 to 2001.
1. Using a minimum estimate of population in 2001 [35]; see text and Table 4.
2. Using a maximum estimate of population in 2001 [ibid].

Sources: Table 4; [35; 36].

cropland area appears to be the result of two important changes. The first is the advent of relatively new crops, such as corn, sunflowers, flaxseed and rapeseed, being grown in the prairies, and the second is an increase in the area of hayland in Canada, most of which occurred in the west. These areal trends are more fully documented up to the late 1960s by the Federal Task Force on Agriculture [16], which also correctly anticipated their persistence into the 1970s. Thus the potential cropland margin is now about 10 million hectares, which represents an additional 38 percent over the area in present cropland use.

Discussion

With the advent of a new policy thrust under the agri-food strategy to raise agricultural production, the area of cropland in Canada might well continue to increase in the 1980s. In fact, judging from the surpluses of some crops today, the most serious limit to the growth of agricultural production is the ability of markets to

absorb the output. If Canada succeeds in increasing its share of the world commodity markets, either by producing more cheaply or by providing more differentiated, quality or specialized products to new markets, there will be a stronger pressure on land resources.

It is entirely possible that the trends of cropland expansion in Canada will not continue in the future as they have in the past. The 1981 Census of Agriculture, however, shows a marked increase in cropland area for both the western and eastern provinces of Canada. Indeed, programs such as PIK (Payment in Kind) in the United States that pay farmers not to use cropland tend to indicate that further areal expansion of cropland in Canada is unlikely. The problem with interpreting the existence of such policies in the United States in this way is that the interpretation is not supported by recent historical events. Cropland expansion in Canada in the 1950s and 1960s continued unabated in spite of the fact that the U.S., under an acreage allotment program, paid farmers during these periods to keep land out of crop production [3; 17].

Land is not generally a limit to agricultural production in Canada in any absolute sense. Some parts of Canada with special climatic characteristics that favour particular fruit crops are very limited in area. But on the whole, the appearance of a finite margin to cropland expansion will affect, primarily, the cost of agricultural production and the range of crops that can be grown. Fundamental to the definitions of the land classes of the Canada Land Inventory are two features. The first is that the range of crops that can be grown on the better classes of land is wider than that which can be grown on the poorer classes of land. As a result, bearing in mind the exceptions listed earlier, the opportunity for growing a variety of crops is inclined to diminish as the better quality land is exhausted. However, the margin described here provides little indication of whether this might happen in the future, because it is always possible for one crop to displace another, thereby forcing the more tolerant crops onto poorer classes of land. Only a much more refined definition of good quality land that is geared to assessing the particular soil and climate needs for fruit and vegetable production can determine whether the supply of this land for these crops is adequate.

The second feature of the Canada Land Inventory is that land can be categorized based on its physical limitations to production that are reflected in the yield of a single crop that is grown on several different land qualities under exactly the same economic and management conditions. Hoffman [23], for instance, showed that the difference in yield for common grain crops among land classes could be indicated by means of an index. Hoffman's index

demonstrated that yields from class 2 land would be 80 percent of those from class 1 land, and those from class 3 land would be 64 percent of those from class 1 land. Assuming linear relationships among the cost of inputs, the level of input and the output, the relative cost of producing a unit of output from class 1, 2 and 3 land can be estimated from Hoffman's indices. If one dollar is spent to produce a given yield on class 1 land, $1.25 would be needed to produce the same yield from class 2 land, and $1.54 to produce the same yield from class 3 land [32]. The exact magnitudes of these figures are open to some dispute, but they illustrate how the cost of production is expected to increase as production shifts from good to poor land classes. Another aspect of the measure of the change in cost is the level of risk associated with crop production. In general, the risk of crop failure increases, and effort to counter the risk is raised, as the quality of land declines.

Thus the effect of an impending limit to areal expansion is more likely to influence the cost of production than the physical ability to produce the desired quantities. However, it may also indicate that the emphasis placed by modern agricultural methods on minimizing the use of labour will change. As land and energy become as scarce as labour, the methods of production are liable to change to accommodate their scarcity [25].

Once the area of class 1 to 3 land identified in Figure 2 is taken up, areal expansion of production can only take place by (1) employing more class 4 land, (2) bringing class 4 land up to class 3 quality by investment, or (3) reducing the area of fallowed land in CLI classes 1 to 3. Tactics that would reduce the need for any expansion of the present cropland area include such possibilities as (1) raising productivity by investment in the research and development of new crop varieties, (2) increasing investment per hectare in capital items such as fertilizers, in order to raise production, (3) changing the methods of management and husbandry of the land so that rotational periods and the amount of idled land are changed, (4) changing the type of farm production from, for example, specialized farming to mixed farming [for other ideas, see also 25].

Reducing the amount of classes 1 to 3 land that is taken up by the expansion of urban areas would leave more of the margin intact for agricultural use. However, this action would tend only to delay slightly the time at which the margin is completely taken up, since the area converted to built-up uses is relatively small. Much of the expansion will stem from demands for land to accommodate the growth of existing settlement areas (Table 1), indicating that urban containment policies might be more rigorously followed in the future. When applied in conjunction with

agricultural policies, the concomitant loss of agricultural production can be tempered by gains from increased agricultural productivity.

The 10 million hectare margin illustrated in Figure 2 appears small, but it is not necessarily a cause for anxiety. Canada has approximately 71 million hectares of land in classes 1 to 4, and if this poorer quality class 4 land is considered, the margin would be about 36 million hectares.

Some of the 10 million hectares of class 1 to 3 land may never be accessible to agriculture if other rural activities do not surrender the area, or if the areas are too remote from markets to be used. At the same time, it can be argued that some hayland should be included with the cropland area because some of it, at least, does occur on class 1, 2 and 3 land. Also, some land in classes 1 to 3 that lies in urban fringe areas may well be irretrievably alienated from agriculture because it is too expensive and fragmented for agricultural use. Thus the 10 million hectares might well represent an optimistic estimate of unused class 1 to 3 land.[6] Nonetheless, if the caveats of this computation are accepted, an estimation of the time needed to reduce this margin to zero can be made.

The growth of cropland plus summer fallow is assumed to continue at the current net rate of about 1.5 percent a year (Figure 2, dotted line). The reduction of the area in classes 1 to 3 land through conversion to built-on land uses can be estimated if the area of such land at some future time is calculated. Table 4 provides three estimates of the total area of built-on land in the year 2001. The first is obtained by linear extrapolation from Figure 1. The next two are derived by multiplying the urban land provision in Table 1 (237 ha per 1000 population) by the highest and lowest of the population projections made by Statistics Canada [37]. The areal estimates provided by using the Statistics Canada figures give a minimum and a maximum value. The estimated loss of land in classes 1 to 3 is also given as a minimum and maximum estimate, and the effect of these on the potential cropland margin is indicated in Figure 2.

[6]On the other hand, the margin might be overly pessimistic, considering note 5 of Table 3. If smaller geographical units were employed in the analysis, many of them might show negative margins similar to that in Saskatchewan. Canada's potential cropland margin would then be comprised of the sum of all positive margins for each geographical unit. The incidence of negative margins at larger scales is expected to be limited, judging by results from the work of McCuaig and Manning [27].

The problem with including hayland is that the probability of having negative margins is raised when it is included in this anlaysis, simply because large areas of hayland are found on class 4, 5 or 6 land. The problem stems from a lack of sufficient detail in the information on the areal coincidence of land use and land quality.

Table 4

ESTIMATES OF THE TOTAL BUILT-ON AREA IN 2001, AND THE LOSS OF LAND IN CLASSES 1 TO 3 TO BUILT-ON LAND USES, 1981-2001

	Estimated area of built-on land in (1981-2001)	Estimated loss of classes 1-3 land, (1981-2001)
	(Millions of Hectares)	
Linear extrapolation (Figure 1)	7.5	1.05
Population 28.5 million*	6.7	0.6
Population 35.0 million	8.3	1.5

* Statistics Canada, Cat. No. 91-514 [37]. Though these projections are now somewhat out of date, they have not yet been modified by Statistics Canada. The population figure is multiplied by 0.237, the built-on land provision for Canada (Table 1) in ha per person. The figure 28.5 million is the lowest population estimate given by Statistics Canada, and 35 million is the highest.

The estimated time at which the area in crop use would equal the area capable of crop use (the sum of land in classes 1 to 3) occurs somewhere between the years 2015 and 2024.

Conclusion

This article has demonstrated how the Canada Land Inventory soil capability data can be used to estimate the size of the margin available for cropland expansion when it is combined with land use information. This information is important if the planning and development of land resources in Canada is to anticipate changes rather than merely react to them. The data could be refined further by undertaking surveys that combine land capability and land use information, such as those undertaken in the United States [39], but there do not appear to be sufficient fiscal resources available for gathering information by this method.

It is all too easy to view this computed limit to the area of land in classes 1 to 3 of the CLI as an insurmountable barrier to the expansion of agricultural production. In fact, it is not an ominous sign; but neither should it be taken complacently. It indicates that the next thirty to forty years will be a period of adjustment for the agricultural industry as the methods and forms of production are altered to meet the higher costs imposed by the impending limits to some qualities of agricultural land. Much of the shock from hearing of limits to land area in Canada stems from a history of more or less continual expansion, a history that has never seen phases of land scarcity such as those experienced in Europe

[6]. Recognizing a Malthusian limit to areal expansion is not, in itself, a cause for concern. It offers a challenge for which, in this case, there is ample opportunity to plan a response. The use of land resources can be adjusted so that the increasing cost of extending agricultural areas is at least partly compensated for by using existing agricultural land more intensively.

Malthusian limits to growth have been observed and surpassed many times throughout the history of agriculture. And it appears that there are at least thirty to forty years in which to plan for and adjust to the transformation in Canadian agriculture that will be necessary in order to realize a continual growth in output from a shrinking resource base.

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