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A REVIEW AND BIBLIOGRAPHY**

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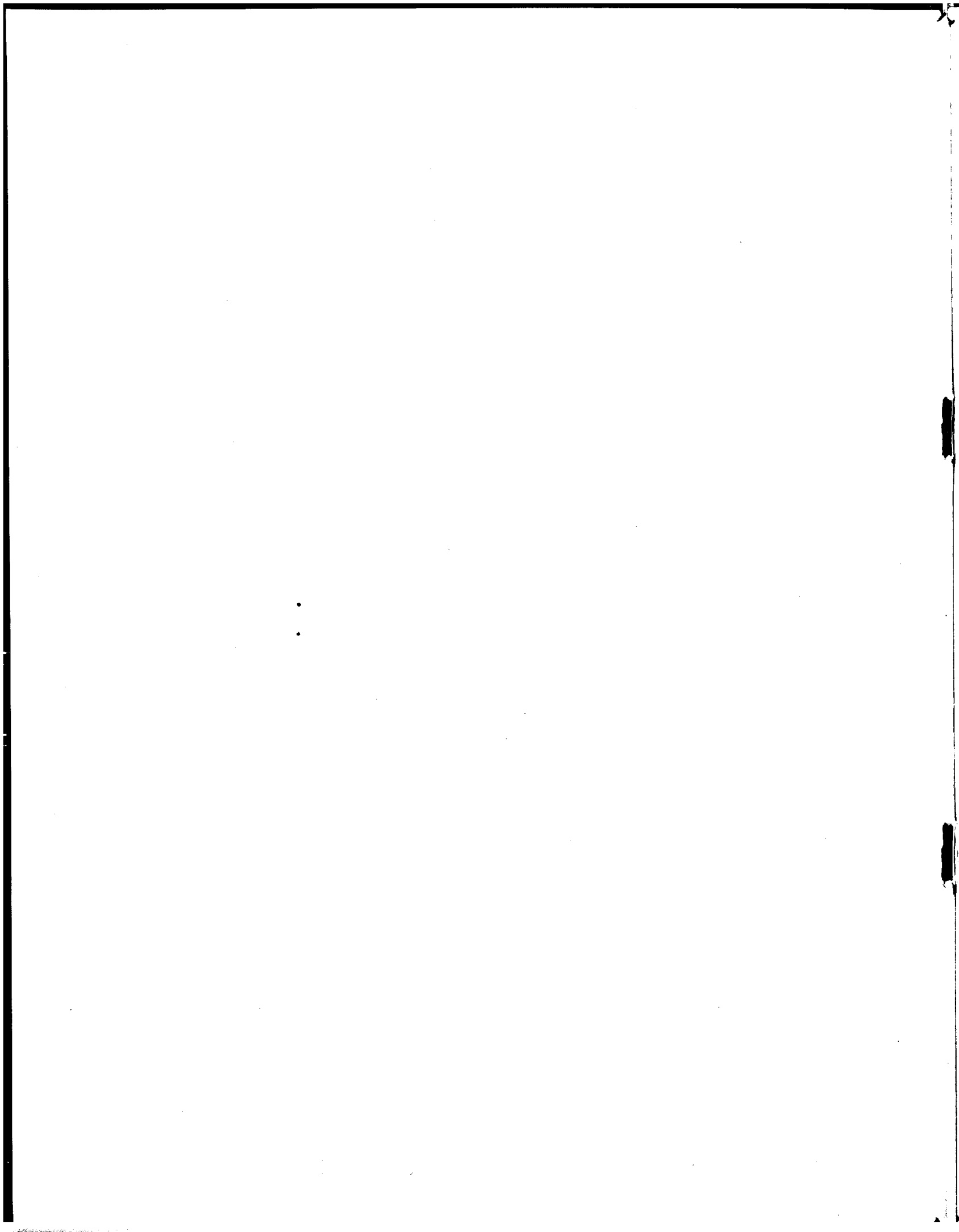
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THE AGRICULTURAL USE OF MARGINAL LANDS
A REVIEW AND BIBLIOGRAPHY

Kathleen G. Beattie, Wayne K. Bond
and Edward W. Manning

Lands Directorate
Environment Canada

Working Paper No. 13

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L'utilisation agricole des terres marginales:
une rétrospective et une bibliographie

ABSTRACT

The agricultural use of Canada's land varies greatly from region to region in its intensity, vitality and economic prospects. Over time, the agricultural frontier advances in some regions, retreats from others. This paper reviews the Canadian experience along the agricultural margins. A comprehensive review of the Canadian literature is undertaken. This review addresses the problem of definition of the margins, of marginal lands and of the "marginal" condition. The physical, economic and social factors which create retreating margins and advancing frontiers are reviewed, as are the conditions of the frontier and margins and their socio-economic consequences. The role of government programs as a further factor in the advance and retreat of the margin is discussed. Finally, an annotated bibliography of Canadian sources is provided.

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RÉSUMÉ

Au Canada, l'utilisation agricole des terres varie beaucoup d'une région à l'autre selon leur intensité, leur vitalité et les perspectives économiques qu'elles représentent. Avec le temps, la frontière agricole progresse dans certaines régions alors qu'elle recule dans d'autres. Ce document passe en revue l'expérience canadienne le long des terres agricoles marginales et donne une vue d'ensemble des études faites au Canada dans ce domaine. On y aborde le problème qui consiste à définir les limites des marges agricoles, les terres marginales elles mêmes et les conditions physiques, sociales et économiques qui expliquent la marginalité de ces terres. On y traite également du rôle provoquant la progression ou le recul des limites des terres marginales. Finalement, on présente une bibliographie commentée des études canadiennes sur le sujet.

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1. INTRODUCTION

In considering Canada's land resource as continuing base for agricultural use it must first be recognized that the quality of land is not uniform. Land is not a simple resource but rather a complex mosaic of resources. Like other land uses, agricultural production places specific requirements on the land and unless a specific area of land has these prerequisites it cannot be regarded as having capability for that use.

Whether land is used for agricultural production depends upon the nature of the climate and physical resource base, the demand for particular types of agricultural production, the technology available, and the demands in terms of remuneration that the individual user of the land requires. The balance of supply and demand, therefore, in the broadest sense, influences the location of the physical boundary of agriculture at any point in time. Land can be called marginal for agricultural production where it approaches this limit. It is clear, however that because of changes in markets, technology, management practice and in lifestyle concerns, the physical location of the actual agricultural frontier is dynamic. If the frontier moves to encompass additional land, we have the phenomenon of the advancing agricultural frontier. If, on the other hand, the economic frontier withdraws, leaving abandoned agricultural land or subsistence farming in its wake, we have the opposite situation of the receding agricultural margin.

The purpose of this paper is to present a general literature review on Canadian

experience with land on the margins of agriculture. This review attempts to indicate the extent of marginal agricultural lands in Canada and trends in its use; to document the physical as well as the socio-economic causes and consequences of these trends; and to relate the responses of various levels of government in adjustment of the marginal use of agricultural land. The emphasis is placed on a discussion of the retreating agricultural margins.

What are the problems associated with farming of the land in the advancing frontier and the retreating margin? What causes the margin to advance or to retreat? What is the response of an individual who is farming in a region where conditions become uneconomic? The various approaches taken to answering these questions are the substance of this review.

1.1 Marginal Lands - Approaches to Definition

Canada's broad regions of marginal agriculture are almost all located peripheral to or beyond the more densely settled core areas of the nation. Thus zones of marginal agriculture are found in the so-called "broken ecumene" (Troughton, 1977) along what Vanderhill describes as the "ragged edge" of northern settlement (References to B.G. Vanderhill's thesis on the advancing farming frontier of western Canada are provided by Ironside, et al. 1974b; Ehlers, 1974; and Proudfoot, 1974). Many different usages of the term "marginal" have been applied to describe physical, economic and social conditions of adversity. Usually the connotation is reflective of the particular approach taken in considering agricultural resources. For example, socio-economic marginality is primarily the concern of quantitative analysts of farm property

(Trant and Brinkman, 1979; Noble and Purvis, 1973; Dickinson, 1970; Wampach, 1968; and Szabo, 1965). Ecological and environmental studies which define absolute and relative limits to production and physical frontiers of crops focus primarily upon the physical marginality of agriculture (Rostad and Kozak, 1977; Harris and Carder, 1975; Proudfoot, 1974; Shannon, 1974; Williams, 1974; Harris, et al., 1972).

Attempts to elucidate ideas of agricultural marginality have been undertaken by several authors. Wonders (1975) explores the geographical concept of marginal settlement at the ecumene's edge along with the comparatively synonymous terms, "pioneer settlement" (new agricultural settlement at the margins), "frontier settlement" (agricultural settlement at the margins from an historical perspective), and "fringe settlement" (regions of discontinuous settlement at the margins of the ecumene). The redundancy of using similar terms and concepts interchangeably leads Wonders to conclude that "we must accept the fact that marginal settlement continues to serve as a convenient roof under which a considerable variety of lodgers are housed (1975: 15)." Troughton (1977) applies the term marginal to a zone of marginal rural settlement broadly described as lying between 45 and 55 degrees north latitude. This zone encompasses both the western areas of the "pioneer fringe" which are peripheral to core areas of settlement, and localities in eastern Canada within the settled ecumene.

Most exacting is Francis's 1970 discussion of marginality in the context of fringe settlement regions. His locational approach to conditions of physical, economic and

social marginality provides a focus for the identification and understanding of problems experienced within regions of discontinuous settlement, as well as within marginal areas considered effectively integrated into the national ecumene. Francis describes the physical marginality of those environmental and ecological parameters which determine both relative and absolute limits to production. Regional physical limits to agricultural cultivability are not necessarily fixed or static, but can be modified and extended through the technological innovations of man.

According to the analyses of the Canada Land Inventory (CLI), roughly 1½ to 2% of Canada's land area is physically "marginal" for agricultural production. However, these statistics are somewhat misleading since the term marginal is used here specifically to refer to lands of CLI class 6 soils which are only capable of producing perennial forage crops and rough grazing. Classes 4 and 5 soils can also be marginal for field crops if certain adverse physical and socio-economic conditions reduce the capability of land in a locality (Bureau of Municipal Research, 1977; Reeds, 1972; and Fortin, 1962). (Note the greatest part of Canada's vast land mass has no agricultural capability whatsoever, and is classified CLI Class 7).

Economically marginal conditions for agriculture are described by Francis (1970) as relating to factors of location, profit and capitalization. Not only are frontier areas disadvantaged in a spatial sense by their remoteness and distance from core regions but also in a more theoretical or perceptual sense of economic distance or

isolation. Such areas also may be disadvantaged with respect to infrastructure. Economic marginality also refers to the low levels of return on investment experienced by farms operating at or near subsistence. Capital deficiencies in fringe agricultural areas tend to sustain or accelerate economic marginality.

The concept of social marginality relates to those social factors significant in causing disadvantage to agricultural regions. Aspects of social marginality include regional deficiencies in social services and amenities (e.g., education, medical, or transport services), as well as social characteristics of the farming population (e.g., aging population, low educational level, lack of farm managerial skill, and lack of mobility). These social deficiencies, of course, do not apply to the more enterprising who may well use their skills as tickets out of marginal agricultural regions, leaving behind the less skilled and less ambitious to eke out a living in an area of limited opportunity.

In short, interpretations of agricultural marginality have been at once vague as well as strict; narrow as well as comprehensive. Marginality, it appears, is like beauty, in the eye of the beholder (Francis, 1970: 22).

1.2 Operational Definitions for Agricultural Marginality

Because of the wide range of definitions shown in the previous paragraphs, it is essential for the clarity of this paper that an operational definition of marginality be derived. On the basis of the evidence in the literature, the following definitions are proposed:

A. The agricultural margin: The agricultural margin or frontier is defined as a line which at any point in time separates that area wherein agricultural production is economic from that part of the nation where it is not. The use of this economic definition of the margin subsumes many other factors which influence the location of the margin at any point in time. These include the physical capability of the land, climate, accessibility, technology, management capability, market demand, and expectations of what constitutes a reasonable return on investment and an "adequate" standard of living.

B. Marginal lands: Marginal agricultural lands are defined as those lands which at any point in time are at or near the economic margin for agriculture, as defined in definition A. As will be shown later in this paper, many social, economic and environmental phenomena are associated with being at or near the agricultural margin.

C. The advancing margin or advancing frontier: The concept of the advancing frontier is a dynamic one. Regions of the nation can be characterized as "advancing frontier" if, over a relatively short period of time, the agricultural margin has advanced to include a greater area within agricultural use or within potential for economic agriculture. Such areas can probably be best characterized as having had significant increases in the area in agriculture and in improved agricultural practice during any period of time. In Canada, advancing frontier is primarily concentrated in the Peace River Region of Alberta and British Columbia, although

smaller areas of the northern Prairies, Newfoundland and a few other parts of Canada can also be so characterized where new transportation access, new technology, or changes in markets have suddenly involved the opening up of new areas.

D. The retreating margin: Also a dynamic concept, the retreating margins can be defined as areas where the agricultural margin has withdrawn, leaving less land in economic agriculture. Because the response of individuals to the retreat of the economic margin is not rapid, many sub-marginal farms may remain in such regions. Typically, however, such regions are characterized by rapid losses of area in agriculture and of area in improved agricultural land. Most retreating margins also experience substantial losses in numbers of farms. The Gaspé Region of Quebec and Northern New Brunswick are the most extreme examples in Canada (McCuaig and Manning, forthcoming).

These operational definitions of advancing frontier and retreating margin have been applied by McCuaig and Manning (forthcoming) by use of data from the last four agricultural censuses - 1961, 1966, 1971 and 1976-adjusted to constant boundaries and definitions. In operational terms, the advancing frontier encompassed all regions which experienced an increase in agricultural land of 25% or more from 1961 to 1976, as well as a gain in improved farmland of 20% or more over the same time period. Conversely, the retreating margins comprised all regions which suffered a loss of 25% or greater in agricultural land from 1961 to 1976 and also experienced a reduction of 15% or greater in improved land

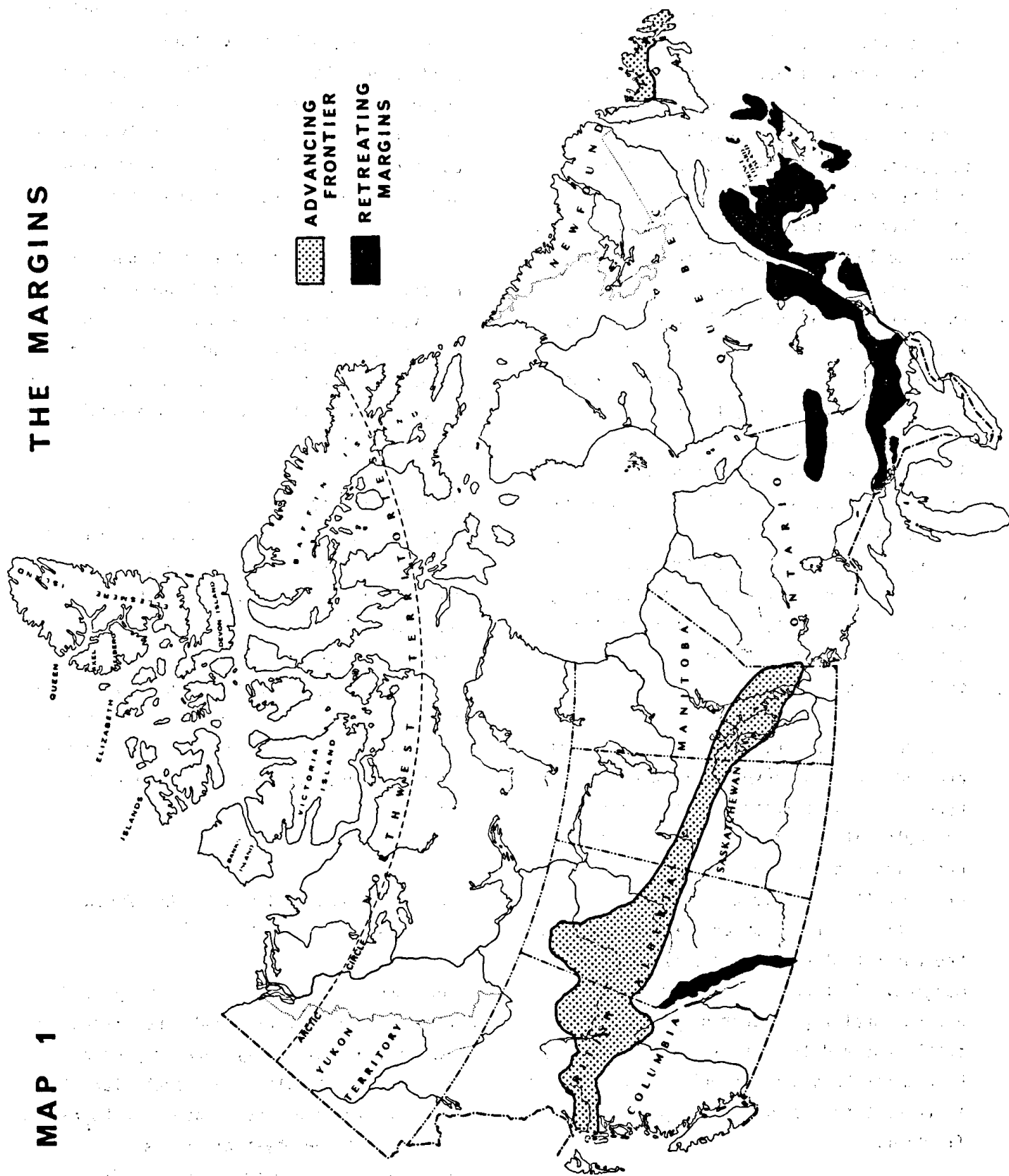
during the same time span.

The spatial extent of the advancing frontier and retreating agricultural margins, delimited on the basis of these operational definitions, is shown in Map 1. The agricultural frontier is advancing most notably in the Peace River country of Alberta and B.C. as well as in northern Saskatchewan and Manitoba. Minor advances were also reported in parts of Newfoundland. Retreat is occurring in the Maritime Provinces, especially New Brunswick, and throughout Quebec, particularly in the Gaspé, the Beauce and the north shore of the St. Lawrence River. The margins are also retreating in the Muskoka-Haliburton area and throughout most of the clay belt in northern Ontario and western Quebec. Only limited areas of significant agricultural land loss occur in the west, associated with the creation of parks and wilderness areas on the margins of the Rocky Mountains.

While marginal agricultural areas are often readily identifiable in terms of their present physical characteristics, geographic location, land use pattern and settlement at any point in time; they are best characterized by the processes going on within them (e.g., the approach undertaken for the operational definition). Central to the identification of the processes creating advancing and retreating margins are the works by Gunnar Myrdal. In particular, his 1957 work, Rich Lands And Poor: The Road to Rural Prosperity, focussed on the process of circular and cumulative causation which causes poorer regions to be caught in a "vicious circle" of poverty and economic disadvantage. Myrdal's further works - An American Dilemma, and Asian Drama, which

THE MARGINS

MAP 1



examined this phenomenon on a national and international scale, show the reinforcement of positive and negative factors once regions have initial advantages or disadvantages. Thus, the retreating margins exhibit the characteristics of becoming progressively poorer in many respects. Factors such as declining markets or out-migration may in turn stimulate abandonment of agricultural land. Once the level of agriculture in a region gets below a certain threshold, infrastructure ceases to be economically viable and may leave. This in turn stimulates further out-migration, further loss of infrastructure, further agricultural abandonment and so on. Similarly, an advancing region benefits from the process of circular and cumulative causation in a positive sense. The perception of greater opportunities may cause new investments which in turn bring greater productivity which in turn attracts settlers, capital, and infrastructure and so the process continues.

At a regional scale, agricultural margins are made up of different agricultural types. Depressed regions of marginal agricultural characterized by declining economies and out-migration are what Friedman (1972) would call downward transitional areas, which are comparable to the concept of retreating agricultural margins. Another type of marginal agricultural region characterized by new settlement and land cultivation is found in Friedman's "resource frontiers", comparable in concept to the advancing agricultural frontier.

The remainder of this paper focuses on the

study of Canadian marginal lands. It examines the physical resources involved - the physical base which influences whether or not land can be agriculturally productive. It examines the socio-economic resources necessary for agricultural production and reviews Canadian literature as it deals with the variations of these and their influences upon marginality.

The paper goes on to attempt to develop a classification for marginal agriculture derived from the literature and to examine the policy implications as studied in the Canadian literature for various governments concerned with the advancing and retreating margins.

A brief description of some of Canada's major regions of marginal agricultural use is also included. In addition, an indication of the nature and extent of agricultural marginality in Canada are provided by several measures of land capability, agricultural land loss and the socio-economic characteristics of farming for selected areas which are representative of the advancing frontier and retreating margins.

2. APPROACHES TO THE STUDY OF MARGINAL LANDS

Four broad approaches to the study of marginal agricultural lands are evident in the literature. Early work adopted a regional or locational approach, largely descriptive in nature. Later, cartographic analyses of the physical limits of agriculture gained prominence as did descriptive investigations of the evolution

of settlement in marginal areas. Most recently, quantitative studies have been conducted concerning the socio-economic characteristics and trends in marginal agricultural regions. Each of these four approaches is outlined below.

2.1 Regional Approach

By far the most common approach to the study of marginal agriculture and marginal farmlands is the regional approach. From the early days of Canadian settlement, when propagandist literature encouraged pioneer settlement of farming frontiers, to the present day, ideas of marginality have been most widely discussed in a locational context.

Regional studies have traditionally focused upon the physical margins and the physical limits of agriculture (Francis, 1970). Almost all of the propagandist literature of the period extending from the mid-nineteenth century to the 1930's sought to describe and promote the development of Canada's frontiers of agriculture. It was during this period, too, that maps showing the supposed northern limits to cultivation were first published. A review of these early works is provided by Proudfoot (1974), in his paper, "The Northern Limit of Agriculture in Western Canada", and to a lesser extent by Stone (1972), in his brief article, "Rural Settlement Regions at the Ecumene's Edge: Europe and North America".

The same kind of literature that encouraged settlers to venture into areas marginal for agriculture in western Canada also gave publicity to the marginal clay belt and

southern Shield regions of northern Quebec and Ontario (Parson, 1975; 1977). However, by the 1930's, persistent agricultural failures in these regions brought such optimistic reports to a halt.

Thereafter, more scholarly, realistic studies of frontier settlement and land use began to appear. This was especially the case by the 1950's when the unprecedented growth of Canada's agricultural core, or heartland, accentuated the relative disadvantages and decline of marginal areas. Rural poverty now became the subject of public documentation and social science research (Troughton, 1977). Since that time a great number of investigations for research and policy purposes have been undertaken. (Those issued by provincial and federal governments are reviewed in a later section.)

2.2 Cartographic Approach - Physical Limits

The mapping of ecological and environmental limits to cultivation has continued from its early origins to this day. One of the more recent interpretations is Chapman and Brown's (1966) study, The Climates of Canada for Agriculture. This Canada Land Inventory (CLI) report includes a map of the 2,000 degree-days isoline delimiting the growing seasons significant to agriculture. Similarly, Laut (1973c) uses an agro-climatic approach in his interpretation of limitations to cultivation in the northern Prairie Provinces, Yukon, and Northwest Territories.

Another cartographic approach that is effective in identifying zones of marginal agriculture is the mapping of soil-geomorphic-climatic limits to the production of certain crops (Williams,

1974). This method involves graphic overlays of the four physical limits to agriculture: temperature, moisture, soils, and topography. Perhaps the most useful agro-climatic method of delineating agricultural areas is the Agroclimatic Resource Index (A.C.R.I.) devised by Williams in 1975. This index is based on the length of the frost-free season, modified downward to reflect deficiencies in moisture or the lack of sufficient summer heat. A comprehensive description and review of Williams' A.C.R.I. methodology is provided by Simpson-Lewis et al. (1979) in Canada's Special Resource Lands.

2.3 Settlement Processes - Descriptive Approach

The other traditional approach which has continued to be developed and applied by geographers and other scientists pertains to the process of agricultural settlement of marginal and frontier regions (Wonders, 1975; Francis, 1970). The study of marginal agricultural settlements has proceeded at both micro- and macro-scales: the former approach typified by national overviews of land use and zones of agriculture; and the latter approach providing more detailed local settlement case studies and specific regionally oriented, land utilization reports. In view of the relatively large number of reports with regional emphasis, relevant examples and specific references shall be provided throughout the remainder of this paper. However, the extent and importance of regionally oriented research on marginal settlements can be appreciated by acknowledgement of the following papers presented at the International Geography Union Symposium on "Frontier Settlement on the Forest-Grassland Fringe", held at

Edmonton and Saskatoon in 1972: Ironside, et al., 1974a; 1974b; 1974c; Ehlers, 1974; Williams, 1974; Lamont and Proudfoot, 1974; Fairbairn and Ironside, 1974; and Shannon, 1974.

2.4 Quantitative Approach - Socio-Economic Analyses

Up until the mid-1960's, the main thrust of regional studies had been descriptive and land-use oriented, centering on concepts of physical marginality (Ironside, 1970). Documentation of the economic and social marginality of regions have been largely neglected because of the lack of data and statistics for rural areas. By 1965, however, quantitative analysis was gaining popularity among agricultural economists, geographers, and other investigators of rural poverty and marginal settlement. The use of statistics and computer techniques greatly facilitated socio-economic analyses. In 1965, Szabo published one of the first statistical analyses of socio-economic variables related to small-scale marginal farms, with his paper, "Depopulation of Farms in Relation to the Economic Conditions of Agriculture on the Canadian Prairies". A somewhat parallel study of the abandonment of Ontario's marginal farmland came out the following year (Ontario Economic Council, 1966). Other socio-economic works highlighting this period include: Biays, 1964; Schmitz, 1965; Booth and Retson, 1966; Gartner, 1968; Wampach, 1968; Crabb, 1969; Dickinson, 1970; Fuller, 1970; Heighton, 1970; Gruber, 1971; Pich and Proudfoot, 1971; and Noble and Purvis, 1973. The bulk of this literature comprises either governmental studies, or geographical research.

Statistical analyses have gained momentum throughout the 1970's. Current research into agricultural economics and agro-climatology is built upon the growing data base of agricultural statistics. Strictly regional approaches to the study of marginal lands have given way to quantitative analyses such as provided by Bollman (1979), and Shaw (1979), with their Census Analytical Studies, Off Farm Work by Farmers, and Canada's Farm Population: Analysis of Income and Related Characteristics, respectively. Both of these works are based on recently available data derived from the 1971 Census Agriculture-Population Linkage (Ag-Pop) Project. Troughton's (1979) work on the International Geographical Union Commission on Agricultural Typology further exemplifies the importance of new statistical methodologies in national and international agricultural research.

2.5 Gaps in Research

In spite of these advances, large gaps remain in the kinds of information needed to assist rural planning and development in areas of marginal agriculture, particularly regions experiencing a circular and cumulative process of economic decline. Marginal agricultural lands, in a strict sense, received scant attention by Canadian researchers during the last decade. The kind of research that was undertaken looked at regions of marginal farmland as a side issue in studies of part-time farming practices (Fuller and Mage, eds., 1976; Benson, 1976; Bollman, 1979), and frontier settlement (Ironside, et al., 1974a). Some aspects of government research into marginal agriculture have also been curtailed. The number of experimental stations in Canada's

north-western marginal areas have been significantly reduced with the contraction of the federal Department of Agriculture's northern research program (Laut, 1973c). Also, the development and expansion of experimental northern Prairie community pastures, under the auspices of the Prairie Farm Rehabilitation Act (P.F.R.A.), have occurred at a slower pace (Laut, 1973a; 1973b). It would seem that research on marginal farmlands has been eclipsed by the not unrelated analyses of low-income farmers in general, the loss of prime agricultural lands to urban uses, and the growing phenomena of part-time farming.

A decade has gone by since Ironside (1970) called for statistical and analytical research into the impact of distance, scale, and location on rural poverty in physically and economically marginal areas. At the same time he suggested that other basic statistics be gathered for areas smaller than the census division so that rural planning needs could be met, and decisions concerning public investment in marginal areas soundly based. Ten years later these needs have not been fulfilled to any great extent.

On the other hand, a renewed interest in the livelihood of marginal agricultural regions has recently appeared as more and more people and government agencies acknowledge the value of preserving all potential farmlands, and as it is recognized that marginal lands may soon be enlisted to replace farmlands absorbed by urban interests (Canada, Parliament, Standing Senate Committee on Agriculture, 1976; Akhurst, 1978a; 1978b; Troughton, 1977; Wight, 1978; Agricultural Institute of Canada, 1979). There are those, too, who, fearful of a world food crisis, look to

Canada's marginal areas for new expansion of agricultural frontiers (Beacom, 1974; Wight, 1978).

3. THE PHYSICAL RESOURCE BASE

Man's ability to alter the environment has time and time again shown that, to some extent, the physical limits to agriculture are not fixed or unchanging.

Technological innovation has pushed world agricultural frontiers outwards through time. Most notable has been the expansion of agricultural areas in response to the 'green revolution' of recent decades. On the other hand, the improvement of technology has in many instances caused agricultural retreat from marginal lands (Francis, 1970). This has largely been the case in Canada, where once farmed northern areas have been abandoned as modern innovations lend greater comparative economic advantage to the larger scale, commercial operations located on land with higher capability for agriculture.

Nevertheless, whatever the effect of man on his environment might be, practical limits of cultivability do exist. No matter how astounding future advances are in agricultural science and technology, the physical limits to agriculture will ultimately dictate where farming cannot succeed at a given time. The physical suitability of any region for various crops will primarily depend upon parameters of climate (sunlight, temperature and moisture), soils, and topography, the so-called "physical frontiers of agriculture" (Williams, 1974).

3.1 Climate

Much of the land in marginal areas of agriculture is lower in quality by reason of less favourable climates. The importance of climate to agriculture is due to the susceptibility of crop production to climatic variations, and it is for this reason that agro-climatic research focuses on climatic variation.

The factors of climate which influence land productivity operate at different scales, the most commonly documented being the regional scale, for which climatic zones are identified (Williams, 1974). Usually, it is at this macro-scale of agroclimatic analysis that the marginality of agricultural districts is judged. Significantly less documented in agroclimatic analyses are micro-climatic factors (Proudfoot, 1974). Climatic variations of this scale are dependent on local soil and relief differences such as elevation, aspect, exposure, and type of forest cover (Laut, 1973c). The effect of micro-climates, can either be that of reducing opportunities for agriculture, or enhancing local opportunities for agriculture in an otherwise marginal area. Due to the lack of data, micro-climatic methods are seldom employed to identify marginal agricultural areas.

A highly generalized form of climatic analysis is the classification of regional climates into zones based on the aggregate data of average seasonal weather conditions. The classification of continental or sub-continental climatic regions will show major variations in climate related to general farming regions, or common field crops. However, since these agroclimatic

schemes are based on climatic measures for common field crops, which are not generally suited for production in marginal areas, they can only serve to identify very broadly defined zones of marginal agriculture (Proudfoot, 1974). Chapman and Brown thus point to the deficiency of their CLI climatic regions in relation to special crops, and further advise that, "for field crops they are admittedly inadequate in the northern fringe areas of agriculture" (1966: 13).

Moreover, general climatic zones are not intended to neatly correspond with any districts of agriculture other than very large generic regions. Laut (1974) found this to be the case when attempting to compare the distributions of climatic measures with the results of his socio-economic classification of Canadian Prairie agriculture. The high degree of detail and specialization apparent in Laut's land classes and agricultural districts makes such a comparison unfeasible. Clearly, the assigning of climatic parameters to agricultural marginality is not a simple task. If agricultural interpretations of climatic limits are to be meaningful, then climatic normals must be considered objectively for specific types of crops. Also, micro-climatic variations must be taken into account.

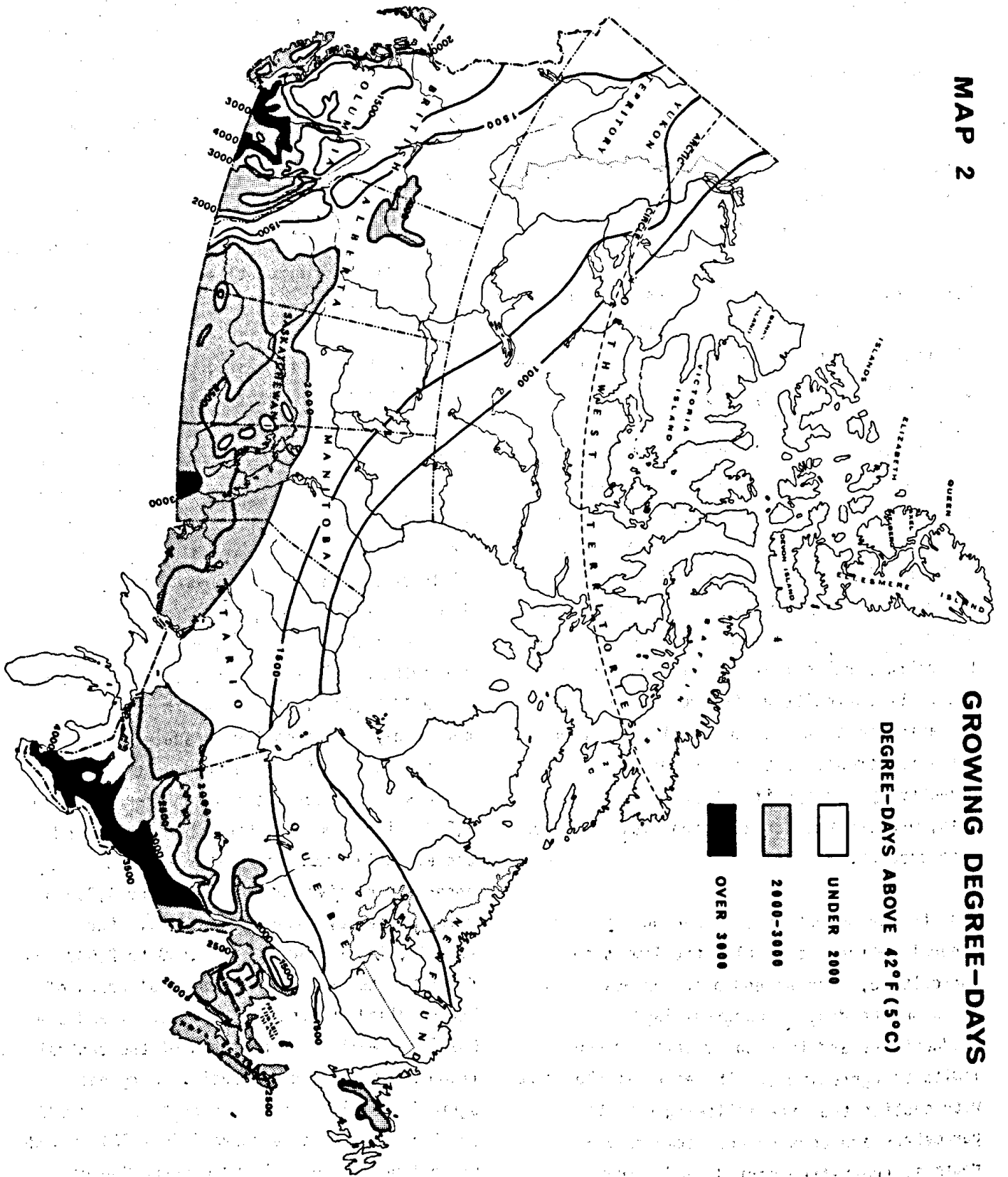
Despite the uncertainty of making any generalizations about climatic limits to agriculture, such an endeavor can assist in the understanding of marginal land productivity and in broadly defining the limits to agriculture. Therefore it should be with caution that the following climatic parameters are considered: temperature regimes, frost-free period, and bright sunshine. Each is discussed below.

1. Temperature Regimes, Growing Degree Days

Temperature regimes are useful indicators of the climatic suitability of marginal areas for agricultural production. The range between maximum and minimum temperatures within a year, month, or day is of importance to agriculture since crop production is limited by specific ranges of air temperature (Simpson-Lewis, et al., 1979). Accumulated values of temperature are commonly measured in degree-days and cumulative heat units (Chapman and Brown, 1966; Williams, 1974). Degree-days represent the cumulative or total amount of heat available for plant growth, and are calculated by combining the length of the growing period with mean daily temperatures above 42°F (5°C). The system of cumulative heat units makes use of maximum and minimum daily temperatures, but only for the warmer areas of Canada and in relation to common field crops (Chapman and Brown, 1966; Simpson-Lewis, et al., 1979).

The accepted minimum requirement for any agricultural production is 1,000 degree-days above 42°F (5°C). Map 2, which shows degree-day isotherms for Canada, reveals that marginal areas of agriculture generally have indices of degree-days ranging from 2,000 to 2,500, with some exceptions both below and above, while prime agricultural areas generally receive between 3,000 and 4,000 or more degree-days above 42°F (5°C). For example, index readings of 1,500 to 2,000 are found in the marginal agricultural areas of Newfoundland, northern New Brunswick and the Gaspé, as well as in portions of the central Yukon and the Mackenzie Basin. Marginal agricultural lands registering between 2,000 and 2,500 degree-days above 42°F (5°C) include those found in central and western Quebec along the southern margins of the Shield, and

MAP 2



the clay belt farming region of northern Ontario, as well as those marginal lands along the agricultural frontier of the Prairie Provinces, into the Peace River district of northern Alberta and British Columbia. Areas of marginal agriculture with fairly high degree-day levels of 2,500 to 3,000 are found in the Muskoka-Haliburton and Renfrew areas of central and eastern Ontario. In contrast, high degree-day levels approximating 4,000 are found in the prime agricultural areas of southern Ontario, and in the southern Okanagan Valley of British Columbia. Wheat-growing areas with degree-day readings of 2,500 to 3,000 and over are found in the southern Prairies (Chapman and Brown, 1966; Simpson-Lewis et al., 1979). (Table 1).

The growing season, simply stated, is the period which favours plant growth. The dates in spring and fall, corresponding to a mean daily temperature of 5°C are often used as the start and end of the growing season (Chapman and Brown, 1966). A growing season of 112 days is accepted as the minimum requirement for the production of hardy, early maturing crops such as barley and silage.

The growing season is not identical to another major climatic limit, the frost-free period. Typically, the growing season begins three to five weeks earlier and ends three to six weeks later than the average frost-free period, discussed next.

2. Frost-Free Period

The mean number of days between last occurrence of frost in spring and the first occurrence of frost in fall is defined as the frost-free period. A minimum of 80 frost-free days is required for the successful production

of hardy crops (Laut, 1974). However, frost limitations to agricultural production are not uniformly restrictive over a wide area. Factors such as local topography, land use and close proximity to water bodies can cause marked contrast in the length of the frost-free season over short distances. Also, compensating farm management practices can extend the frost-free period to some degree.

Because unfavourable climatic conditions seem to combine and compound within regions of marginal agriculture, these areas are characteristically susceptible to frost hazards. The disparity between the longer frost-free period of prime agricultural areas and the short period of marginal areas is very similar to the distribution of growing degree-days between these regions. Whereas the best agricultural lands of British Columbia and Ontario have frost-free periods upwards of 160 days, the broad zone of marginal agriculture in Canada averages between 80 and 125 frost-free days (Simpson-Lewis et al., 1979).

3. Bright Sunshine

The duration of direct sunlight or photoperiod is another important factor related to the time/energy requirements for crop production, especially in northern marginal areas where the daily amount of sunlight received controls, to a certain extent, the rate of crop maturation (Williams, 1974). Since the mean period of summer daylight is generally longer in the northern latitudes, the extra hours of daylight compensate for low degree-day averages by allowing certain hardy crops capable of continuous growth through the long summer day to mature early enough to escape the killing frosts (Simpson-Lewis et

TABLE 1

Selected Climatic Characteristics in Contrasting Agricultural Areas

County/Region	Agroclimatic* Resource Index	Growing Degree-Days (Degree-Days Above 42°F)
<u>Retreating Margins</u>		
<u>North-East New Brunswick</u>		
Gloucester	1.6	1,500-2,500
Kent	1.7	2,000-2,500
Northumberland	1.5	1,500-2,500
<u>Gaspé-Québec</u>		
Bonaventure	1.5	1,500-2,000
Matane/Matapédia	1.2	1,500-2,000
<u>North Clay Belt-Ontario & Quebec</u>		
Abitibi	1.5	1,500-2,000
Cochrane	1.7	1,500-2,000
<u>Advancing Frontier</u>		
Fraser-Fort George, B.C.	1.0	1,500-2,000
Peace-Alberta	1.3	2,000-2,500
Peace River-Liard, B.C.	1.1	1,500-2,000
<u>Prime Lands</u>		
Essex County, Ontario	3.0	4,000 and over
Kent County, Ontario	3.0	4,000 and over

* In most marginal regions, agricultural uses only comprise a small portion of the region which often is the most climatically favoured part, whereas the index value is an average for the entire region or county.

al., 1979).

Photoperiods depend on both the macro-climatic variations of continental climates and micro-climate changes that give rise to orographic precipitation, coastal fog etc. As a result, the distribution of mean photoperiods across Canada varies significantly from place to place, and is in no way distinctively related to agricultural regions. However, where photoperiods are particularly short, like along the fog-bound coasts of Newfoundland, agriculture is limited owing to the compounded climatic risks of short photoperiods, low degree-day levels, and a minimal frost-free period.

4. Moisture

Marginal agricultural areas often have problems with being either excessively wet or arid. Moisture differences between locations are the result of both climatic variations and factors of soil and topography. The average amount and distribution of rainfall throughout the year and the growing season are important determinants of the moisture available for crop production.

Chapman and Brown (1966) define nine moisture classes for the agricultural areas of Canada. Marginal regions of drier, water deficient classes occur in the interior valleys of British Columbia, and in the Yukon. On the other hand, wetness is a problem in the marginal agricultural areas of the Atlantic provinces, and in the poorly drained clay belt region of northern Quebec and Ontario. The Peace River district on the advancing agricultural frontier has a favourable moisture class, as does the Rainy River district of northwestern Ontario. These

latter two regions, however, must face other physical and socio-economic constraints to agriculture.

5. Summary - Climate

Troughton defines an all-encompassing marginal zone of Canadian agriculture for which he describes a climate, "marked by a long, cold winter (4-5 months, mean daily temperature below 0°C), a correspondingly short, cool summer (less than 2,600 growing degree-days), and a short frost-free period" (1977: 98). These climatic conditions, in addition to the problems of excessive moisture in the eastern part of the marginal zone, contribute to below average productivity throughout the zone and impose critical limits for agriculture in some parts of the zone.

The inherent climatic risk in farming on the margins coupled with generally much lower crop yields than in Canada's prime agricultural areas is graphically illustrated by two summary measures: the Agroclimatic Resource Index (ACRI) and the ripening limit associated with a 1°C cooling of the climate. The ACRI, which is based on the length of the frost-free season and modified downward for moisture limitations or insufficient summer heat, has been shown to directly reflect the potential crop yield (Williams, 1975). On this basis, it can be suggested that the prime farming areas of southern Ontario which register an ACRI of 2.5 or more have the potential, from an agroclimatic standpoint, to be twice as productive as Canada's agricultural margins which generally have an ACRI of 1.0 to 1.5 (Simpson-Lewis et al., 1979: 17). (Table 1). The vulnerability of farms at the margin is emphasized by the