THE INFLUENCE OF THE CANADA LAND INVENTORY ON LAND USE IN THE PEMBINA HILLS, 1966-1996

by

Patricia Lynn Salzsauler

A thesis submitted to the Faculty of Graduate Studies in partial fulfillment of the requirements for the degree of

Master of Arts

Department of Geography
University of Manitoba
Winnnipeg, Manitoba

0-612-41771-9

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ABSTRACT

The Canada Land Inventory (1967) assessed the capability of agricultural land in Canada for various land uses. There is little evidence that any follow-up was done on the effectiveness of the Canada Land Inventory in promoting appropriate land use decisions. The purpose of this thesis is to determine the specific changes that occurred in land use in the Pembina Hills area of South-central Manitoba and to determine if land use in the area is according to the recommendations of the Canada Land Inventory. Agricultural census data were analyzed to determine land use trends in the study area. A more detailed analysis, using aerial photographs, assessed land use change in a portion of the study area where agricultural capability is very limited by relief. Finally, land use policies were reviewed to determine if the Canada Land Inventory played a role in their development and impact on land use decisions.

Changes representing a move toward land use as recommended by the Canada Land Inventory are apparent 10-15 years following its publication. This was a time of increased environmental awareness and widely available government assistance (educational and financial). The next 10 years showed a slight reverse of the trends in the wake of low grain prices, drought, and changes in the delivery of government assistance toward more technical/educational and less financial assistance. In recent years a slight trend toward permanent cover crops such as pasture and woodland is observed. The results of this study stop short of making the claim that the Canada Land Inventory was responsible for all land use change in the area. Movement toward appropriate land use for the study area is apparent in the study area. The trend is small and suggests that factors other than physical land capability must also be considered in land use planning. Changes in land use can be attributed to the changing economies of agricultural production, technological and management advances in farming, government policies, and changes in the natural environment.

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Chapter 1: Introduction

The purpose of this thesis is to determine the specific changes that occurred in land use in the Pembina Hills area of South-central Manitoba. This study establishes both the quantity and quality of the land involved in recent changes of use. The relationship between these changes and the publication of the Canada Land Inventory (CLI) in 1967 is investigated. Finally the effectiveness of the CLI in directing land use decisions is assessed.

The Canada Land Inventory was used in this study to determine if the current land use is in accordance with the original CLI recommendations. The results of this study show the cumulative impact of agricultural activities during a 30 year period of changing land use and determine the possible reasons for land use changes.

For land owners to maximize agricultural returns there is a need to use marginal lands and increase cropping intensity. The design and implementation of effective land and water management are required to protect the land for future use. To succeed it is necessary to economically transfer existing technology to the farmer's field.

Conservation of the land resource base often conflicts with Canadian Wheat Board (CWB) policies, land taxation, artificial drainage systems, and on-farm cost reduction practices. For example, the CWB quota system encourages farmers to cultivate marginal land to increase the amount of "quota-eligible acres" and, therefore, the amount of grain that is sold as permitted by the CWB. All agricultural land, regardless of its production capability, is assessed at the same rate for land taxes. Land owners are inclined to expect economic returns on taxable properties. Bringing marginal land into production increases the use of artificial drainage of farmland. The accelerated runoff from spring thaw and summer precipitation prevents moisture from infiltrating the soil and leaves it vulnerable to wind and water erosion. In addition, areas that would support waterfowl and other wildlife under more natural conditions are no longer available. Finally, on-farm cost-reduction practices such as burning crop residue after harvest leave the surface vulnerable to wind and water erosion. This action has serious consequences when marginal lands are cultivated. (Sawatzky: 1981)

To wisely manage land resources it is necessary to have reliable information about their intrinsic quality and extent. The Canada Land Inventory was designed to quantify land of different qualities and provide a baseline for measuring and assessing land use trends.

Preliminary reading reveals that further research is necessary to determine the effectiveness of the CLI in land use management. There is very little evidence that any follow-up was done on the effectiveness of the CLI and long term research needs to be undertaken to understand if land use change reflects a natural fluctuation or environmental degradation. These data are crucial and should be a priority in any management strategy. An important part of this study is the analysis of the nature and extent of land use change and the possible reasons for the change.

The focus of this study is the area within Manitoba's Agricultural Census Division 4. The agricultural practices of this Census Division are typical of those found throughout the Brandon Map Area (1:250 000 National Topographic System Map 62G). The study area has demonstrated land use problems because deforestation and agricultural practices have caused an increase in runoff and a decrease in the ability of the soil to resist erosion.

The proposed research method involves a bibliographic review, map analysis of land use changes in the study area since 1967, and a review of census data. Agricultural land use change is determined by analyzing the changes in the surface cover (cropping patterns) on sequential aerial photographs. These results are then compared to census reports for the same periods of time. Once the changes in land use have been determined, then the reasons for the changes are identified and analyzed. This study considers the role of the CLI in the evolution of land use planning.

Ultimately, this methodology will be useful for land managers in evaluating the effectiveness of land management based on the CLI and determining if current land use reflects the original CLI recommendations.

This study produces maps, tables, and charts showing the land use change in the study area since 1967. The evaluation of these products and comparison to the original objectives demonstrates the effectiveness of the CLI recommendations.

Chapter 2: Literature Review

Land use is defined as "man's activities on land that are directly related to the land". (Estes et al.: 1982 page 100). "Land use" incorporates the dimensions of land cover, activity, tenure or ownership, and resource quality.

The first step in monitoring land use change is to identify the types of land use and significant changes in use that have occurred in the study area. Changes may have significant implications for the economic and social structure of an area, for example industrial development in a rural area. (Bryant and Russworm: 1983)

The next step in monitoring land use change is to consider how to detect land use change. Land use change in rural areas tends to be slow and assessment of change is accomplished by analyzing areal data to detect how much land use change has taken place for each area over a period of about 10 years. (Bryant and Russworm: 1983) The relationship of land use change to land capability needs to be considered.

1. Overview of Research Methods in Land Use Studies:

Sequential analysis is the study of any period in the past for which an ordered and dated sequence is established. Using the most recent aerial photography the topography, drainage, vegetation, and land use is interpreted. If necessary, the information can be verified with field work (Sebastini et al.:1989). This information can be used as the foundation of a retrospective study. The study can be completed by supplementing with bibliographic review and personal interviews. Guidelines can be recommended for rational land use planning based on the study results.

A. Analysis of Aerial Photography

The use of sequential remote sensing data in land use studies allows a study of changes in land use over a time. Each image presents a "snapshot" of the land use of the area at a defined moment.

To analyze environmental and human factors contributing to gully development along the Manitoba Escarpment, Young (1975) studied historical aerial photographs to analyze past land uses and examine rates of gully growth. Analysis of the sequential photography of several gullies in the area clearly demonstrated the effect of inappropriate land use on gully development.

To investigate the effect of agricultural land use changes on a traditional walleye spawning habitat in the Valley River watershed, a series of aerial photographs, representing a period of over 30 years, was analyzed. An increase of cultivated acreage and a corresponding decrease of woodland and wetlands was clearly detected on the images. This evidence provided support for the hydrologic model demonstrating the effect of land use change on sediment production. (McGarry: 1987).

In a detailed report of cumulative land use impacts in Venezuela, Sebastini et al. (1989) used sequential aerial photography and field studies to update existing maps. Some of the aspects considered were changes in morphology such as artificial channels and changes in vegetation such as the expansion of cropped areas. This method allowed the gathering of detailed information on land use in the study area. This analysis recommended the use of sequential geographical analysis to set criteria for land use planning and defines the value of using sequential aerial photography to achieve this goal.

A method of using of historical aerial photographs to provide a physical history and preliminary mapping information for characterizing a waste burial site was described by Pope et al. (1996). In this analysis aerial photographs were digitized and imported to a geographic information system (GIS). The boundaries of features such as suspected trenches and waste burial sites were mapped. This preliminary analysis, used in conjunction with information gathered from other geophysical surveys, provided a basis for land use planning for a specific land use.

B. Analysis of Census Information

An agricultural census is a "snapshot" of agriculture at the time of each census (5 year intervals). An agricultural census reveals net changes in land use but will not document where agricultural land was gained or lost. For this reason, a study of agricultural census data should be supplemented by other methods of land use analysis, such as the study of aerial photographs.

A study by Maxwell (1966) made an evaluation of current land use in Renfrew County, Ontario using census records. The land use was compared to the original assessment of land capability in the late nineteenth century when agricultural settlement took place. This study was based on Geological Survey and Land Survey records. Maxwell recommends that a more comprehensive study covering an area larger than one township and an extensive literature review are necessary to gain full advantage of land use evaluation using agricultural census records.

In an attempt to relate the spatial variation in agricultural land use to factors of the physical environment, such as soils and climate, Dumanski et al. (1982) merges agricultural census data with soil and climate data. Analysis was done on individual soil map units from "Soils of Canada" (1989) and discussed in relation to the soil environment.

C. Land Use Studies

Existing land use policies relating directly or indirectly to the study area include federal, provincial, and local land use recommendations such as those recommended by the CLI, the Manitoba Soil Survey, and the conservation districts.

In an area of coastal Venezuela, that is at risk of environmental damage from tourism and recreation development, a cumulative impact study analyzing sequential aerial photography revealed land use changes and showed the results from the incremental impact of actions. Analysis was complemented with a review of existing land use plans and personal interviews to propose guidelines for future development. (Sebastini et al.:1989).

A soil capability scheme, similar to the CLI, was developed by Dumanski in 1979. This scheme based its classification system on climate, vegetation, soil, and landform elements. In a later study, Dumanski et al. (1987) compared soil survey data with land use. A significant correlation between land use and physical land factors was determined.

Soil survey reports can be used to interpret land use and to predict soil behavior under specific management regimes. (Michalyna: 1982). Smit, et al., (1984) demonstrated a link between bio-physical land information bases and the information requirements of land use planning in southern Ontario. The paper states that the importance of the available land units and their productivity is relative to the societal requirements for products and service of the land.

Sawatsky (1981) offers a perspective on the effectiveness of land resource management in Manitoba. He describes factors leading to "improving" land in spite of low crop production potential. These factors include the Canadian Wheat Board quota system that allows farmers to sell an amount of grain based on the amount of "improved" land they have rather than simply the amount of land that is under crops. Furthermore, land assessments place a taxable evaluation on "unimproved" land and wasteland. Farmers may attempt to produce a crop on unsuitable land because they are paying taxes on the land that may not be productive. Technology allows the chemical enhancement of these marginal lands using herbicides and fertilizers. Large agricultural equipment requires fields to be large, uniform in shape, and as flat as possible for optimal operation. To accommodate these requirements marginal areas within a larger field are brought into production simply for the convenience of cultivation.

2. Early Reports of Land Use in the Study Area

The study area was described by Alexander Henry during his expeditions (1800-1806) the rough topography, deep wooded valleys, and high barren hills. He noted that prairie fires occurred several times a year but that woods on the slopes and low areas tended to survive these fires and the grassland tended to regenerate. The woodland areas were sought out by both the indigenous people and fur traders for shelter, fuel, and game (McDowell: 1976).

The scientific expeditions of Captain John Palliser and Henry Youle Hind in the mid 1800s described the Manitoba escarpment as steep and scantily covered with small trees and the area above the escarpment almost treeless. Both explorers felt that whatever had once been forest had been destroyed by fire (McDowell: 1976).

When the Hudson Bay Company territory was transferred to Canada in 1869, surveyors were sent to subdivide the land in preparation for settlement. The Dominion Land Survey provided a very detailed picture of each township including surface cover, rivers and lakes, mineral deposits, pre-survey improvements, vegetation, type and class of soil, and all recognizable trails (Tyman: 1872).

Upham (1896) in a comprehensive report on Glacial Lake Aggasiz describes the topography and geology of the Pembina Hills and the Manitoba escarpment. J. Elson (1956) provides detailed descriptions of the Pleistocene history, surficial deposits, and landforms of the Tiger Hills area. E. C. Halstead (1959) describes the groundwater problems in the Brandon Map area. Included in his study are descriptions of bedrock and surficial geology and the influence of geology on groundwater flow.

3. Historical Land Use in the Study Area

Lands selected by pioneers are now often considered inappropriate for agriculture. Historically, all land has been considered as agricultural land and developed for agricultural purposes regardless of its capability to support agricultural production. (Dumanski et al. : 1981).

Agricultural settlement began in earnest in southern Manitoba in the 1870s. An extensive study of the agricultural settlement of the Brandon area was published by Tyman (1972). Physical conditions of the pre-settlement period are described in detail as well as the social and political events that preceded settlement. The settlement of the area, including the physical, social, and economic conditions that faced the settlers are also detailed.

The most severe modification of natural landscape has been caused by the cultivation of land for crop production, particularly during the first three decades of this century. The other great impact on landscape by agriculture has been through the grazing of domesticated animals, especially after 1920. A decrease in productivity of land has resulted from overgrazing and burning. (Coupland: 1977).

4. Land Use Proposals Relating to the Study Area

The goal of all agricultural land use planning policies is to protect agricultural resources from destruction or misuse. In Canada land use planning is usually carried out by provincial agencies that may, in turn, delegate the responsibility to the municipalities. (Richardson: 1989). Federal, provincial, and local strategies, policies, and plans influencing land use in the study area are described in the following section.

A. Dominion of Canada Topographical Surveys, 1871

A land survey divided the agricultural area of western Canada into square townships and sections. To assist settlers in choosing desirable farms, Dominion of Canada Topographical Surveys Branch began land classification surveys on all settled parts of the Prairie Provinces. The surveys included complete information on vegetation, soils, and the amount and type of land improvements. The Homestead Act of 1872 governed the dispersal of these surveyed crown lands to "homesteaders". (Tyman: 1972).

B. Prairie Farm Rehabilitation Act (PFRA), 1935

The Prairie Farm Rehabilitation Act was passed in 1935 as an emergency measure to attack economic depression and drought. The objectives were to rehabilitate areas of the prairies damaged by the drought and to prevent further damage by promoting land and water management practices. The PFRA continues to sponsor rehabilitation projects related to water resources, land use, and soil conservation. (Ellis: 1944)

C. Agricultural and Rural Development Act (ARDA), 1962

ARDA provided a fund of money for governments at all levels to assist in rural development. The objectives of the projects included improving farm productivity, increasing farm income, and raising the rural standard of living. ARDA funded projects included determining alternative and more lucrative land use, drainage and erosion-prevention projects, and rural education and research. All projects were undertaken and administered by provincial resource departments such as Natural Resources and Agriculture. (Ellis: 1971). The CLI was a product of this act.

D. CLI,1967

Will be discussed in a following section.

E. Land Rehabilitation Act, 1970

The act attempted to accommodate environmental concerns (e.g., emission of pollutants) while not interfering with local management. In an attempt to encourage local responsibility for land conservation, the Land Rehabilitation Act gave municipalities the authority to rehabilitate and develop any agricultural property within their jurisdiction. Municipal responsibilities include appropriate tillage practices, land use, water supply, and tree culture. To accommodate these responsibilities municipalities were permitted to pass by-laws that must be approved by the Minister of Agriculture and a vote of the rate-payers. (Bartott:1984). Conservation technologies continue, to the present time, to be implemented and delivered by local agencies (e.g., conservation districts) along with administrative assistance from Federal and Provincial agencies.

F. The Planning Act, January 1976

The Planning Act of Manitoba provided a land use planning framework for Manitoba's municipalities. Local planners were provided with such instruments as development plans, basic planning statements, zoning by-laws, and subdivision controls. The intent of this act was to decentralize as much of the land use decision making as possible. Local governments are encouraged to develop their land use policy within guidelines dictated by the Department of Municipal Affairs. Technical and administrative support is provided by the Province. (Orchard:1981). The Act provided for the protection of agricultural land designated as CLI classes 1, 2 and 3. The act also encouraged soil and water conservation by recommending the control and abatement of all forms of pollution. (Howden: 1975; Hildebrand: 1992).

G. Conservation Districts Act, 1976

The Conservation Districts Act provides for the establishment of conservation districts within Manitoba. The formation of a conservation district establishes a single authority having the responsibility of conserving and managing the water, soil, and related resources within the designated area. (Conservation Districts Boards of Manitoba Annual Report, 1977). The districts are administered by a board of appointed landowners and municipal officials. Conservation district boundaries are determined by either the area outlined by the drainage basin of the major river of the district or the boundaries of the municipalities forming the district. (Dickson: 1987). Programs initiated by Conservation Districts include the provision of forage seed, field shelterbelts, gully stabilization, and demonstration projects. Funding for Conservation Districts' Programs is provided by provincial and local sources. (Poole: 1986). Conservation Districts continue to play an important role in the provision of conservation technology and expertise at the local level

H. Provincial Land Use Policies, 1978.

The Provincial Land Use Policies were formulated shortly after the Planning Act was passed and was revised in 1980. The policies provided land use planners with directions for the management of provincial land resources. The policies relied directly on CLI recommendations for appropriate land use and a primary objective was to optimize land use and protect prime agricultural land (CLI classes 1, 2 and 3) (Manitoba Dept of Agriculture: 1978).

I. Federal Policy on Land Use, 1980

Recognizing the need for all of its departments to share information and coordinate activities, the Federal Policy on Land Use was established to provide a program of socioeconomic, scientific and technical research on physical characteristics (such as geology, soil, forests, and water) and land use. This program acknowledged the potential impacts of programs and policies of one federal department on another, particularly when land resources are involved. (Supply and Services: 1981). Reports on regional investigations of soil degradation (some of which were carried out under the ERDA agreements described below) were presented at a First Minister's meeting in 1986. Agricultural land protection and land use planning policies and legislation were implemented by this time in many provinces.

J. Economic and Regional Development Agreements (ERDA), 1984

Economic and Regional Development Agreements were signed in 1983 and the consequent Canada/Manitoba Agreement of Agri-Food Development was signed in 1984. The objectives of the EDRA were to facilitate the development, design, and on-farm adoption of improved soil and water management practices. The agreements used three methods of delivering soil conservation program activities: the delivery of field services to producers in conservation clubs or groups, regional investigations of soil degradation, and improved awareness of soil conservation. In Manitoba, the soil conservation program was jointly implemented by PFRA and Manitoba Agriculture. These agencies provided expertise and materials to assist farmers with soil conservation. In contrast to previous government conservation efforts, financial assistance to members of organized conservation groups was restricted (funding to these groups was provided through other agencies such as the PFRA). The ERDA agreements represented another step in the co-ordination of government agencies providing assistance for conservation projects. (Bircham and Bruneau: 1984)

K. National Agriculture Strategy, 1986

Reports on the regional investigations of soil degradation (carried out under the ERDA agreements) were presented at the First Minister's meeting in 1986. The National Agriculture Strategy was proposed as a response to the soil degradation issue. This strategy committed federal and provincial government agencies to co-ordinate soil and water conservation programs. (Agriculture and Agri-Food Canada: 1998).

L. National Soil Conservation Program (NSCP), 1987

The National Agriculture Strategy led to the initiation of the NSCP in 1987. Subsequently, federal-provincial Soil Conservation Agreements were completed with all provinces. These programs provide funding for research, education, and evaluation of soils and land use management. The program is equally funded by the federal and provincial governments and is administered by the PFRA in Manitoba. Activities ceased in 1993 under this plan and continue under the "Green Plan". Resources for land use monitoring in Manitoba were provided by the PFRA. (Agriculture and Agri-Food Canada: 1998; Acton: 1991).

M. Pembina Valley Conservation District, 1989

The Pembina Valley Conservation District was incorporated in October 1989. The district manages the resources of a 1340 square mile district including the municipalities of Pembina, Lorne, Louise, and Thompson. The primary objectives of the conservation district were soil and water management, wildlife and fisheries management, conservation education, tourism and recreation, and community and economic development. (Pembina Valley Conservation District: 1986).

N. Canada's Green Plan, 1990

Canada's Green Plan, administered by the Department of the Environment, was the federal government's first attempt to integrate environmental and economic considerations, using the idea of sustainable development. The goals of the Green Plan included clean air, water, and land; sustainable use of renewable resources; and protection of species and spaces. (Agriculture and Agri-Food Canada: 1998). The plan promoted agricultural practices that maintain productivity and environmental quality. The plan also recommended land use planning and management actions to protect farmland from urban encroachment and enhancing environmental protection. The plan recommended that existing Federal-Provincial Soil and Water Accords could serve as models to be broadened to embrace all aspects of environmentally sustainable agriculture. Recommendation for immediate and long term actions to be taken by all levels of government, educational institutions and industry included education, research, monitoring, and land use policy changes. (Agriculture and Agri-Food Canada: 1998).

In summary, the compilation and publication of the Canada Land Inventory successfully amalgamated the efforts of government agencies at all levels, universities, private companies, and individuals to achieve its goal of a land inventory and planning tool. However, subsequent efforts of land use planning and conservation have often been uncoordinated, overlapped, or overlooked by government agencies at various levels. In recent years conservation efforts in Manitoba have become more streamlined with funding and expertise provided by federal agencies, such as the PFRA, in co-operation with provincial agencies, such as Manitoba Agriculture, and delivered at the local level, through conservation districts whenever possible.

5. Canada Land Inventory

The Canada Land Inventory (CLI), a comprehensive survey of land capability and land uses, is specifically designed as a basis for land use and resource planning for agriculture, forestry, recreation and wildlife. The CLI agricultural classification groups land into seven categories depending on the productive potential determined by soil and climate characteristics.

A. Historical Development

In a period of intense technological and social change the Agricultural and Rural Development Act (ARDA) was established. The establishment of this agency responded to concern about emerging resource and land use conflicts in all provinces. The goal of ARDA was to maximize rural income and productivity. To pursue this goal the most efficient pattern of land use was determined. Then policies were implemented to encourage land use changes.

In 1963 the ARDA administration approved the CLI that was planned, implemented and funded as a joint federal/provincial project with involvement of universities, private companies, and individuals. The CLI provided the first consistent measure of the renewable resource wealth of Canada. The emphasis of the inventory was to compile all existing data to classify all land data according to the CLI classification systems. To accommodate this a computer mapping system was developed (CGIS) to collect, analyze, and store data, and to present data in useful format for planning.

B. Purpose and Objectives

The objective of the CLI was to assess and document the physical capability and land use within the settled areas of Canada and to determine the extent and location of each land use. The overall goal was to facilitate the orderly adjustment from inappropriate uses of land to more rational ones reflecting the transition of the national economy from a rural agricultural to an urban industrial base.

To accomplish these goals it was necessary to develop a land use classification system, a data processing system, and a user-friendly tool to ensure that the results of the study were accessible and usable by resource managers.

A standardized national classification system and methodology were developed to assess the capability of land for each resource sector. National capability class descriptions were modified for the different regions of Canada. The CLI created a national picture of actual and potential land use.

The CGIS was developed for processing the large amounts of data that were generated as a result of the inventory. Using a CGIS overlay of information from two or more CLI sectors, one could identify potential conflicts and determine where intervention was needed.

Capability maps were developed for planners and resource managers at the municipal, provincial, and federal levels. The CLI was never intended to be used for site specific planning as the scales are much too small for planning at the township and municipal level (Reeds:1965).

The CLI provided a simple inventory of resources and each capability map can be described as an independent, static representation of an assessment of the land resource for a single purpose at a particular time (Toews: 1988).

C. Method

Mapping data were compiled from soil surveys, maps, other published sources, aerial photographs, and field reconnaissance. Land was classified by land capability according to productivity, present use, and capability for different uses. Mapping was carried out at two scales.

Maps at a scale of 1:50 000 were used as base documents for planning. All other data were plotted on maps at a scale of 1:250 000.

D. Products

Maps of land capability were developed for four resources: agriculture, forestry, recreation, and wildlife. The capability classifications were based on the degree of limitations (biological, climatic, physical) of the resource base affecting productivity in the sector under consideration. These ranged from Class 1, which had no limitations to class 7 that exhibited severe limitations. The CLI found only 122 million hectares with any agricultural capabilities whatsoever and, therefore, called into question the idea of an unlimited Canadian land resource (McCuag and Manning 1982). The CLI was released as 1:250 000 maps, digital data, and technical reports.

6. Chapter Summary

A review of the literature indicates that sequential land use studies have proved to be an effective method of studying land use change and providing a basis for land use planning.

A substantial amount of literature has been published about the study area of south-central Manitoba describing physical conditions, agricultural land use, and land use planning. Over the last 40 years a number of land use and soil conservation policies have been developed by various levels of governments. The most notable of the government schemes is the Canada Land Inventory.

The CLI inventory addresses the following questions: how much and where are resources, how to make best use of resources, and how can CLI information be integrated with other resource and social factors. This inventory provided a 1967 baseline for measuring and assessing land use trend changes. This thesis will examine how effectively these questions have been addressed in the study area.

Chapter 3: The Study Area and Research Methods

The objective of the CLI was to promote wise land use. To assess the effectiveness of the CLI, it is necessary to assess the changes in land use since the introduction of the CLI and to attempt to determine the reasons for the changes. When evaluating land use changes over time the magnitude of change in each land use and the patterns of change in all land uses must be considered. Physical factors that affect the use of land, including the nature and composition of the soil, topographic position, drainage, and climate, must be assessed.

Methods used to assess actual land use changes include aerial photography analysis, agricultural census analysis, and reviews of existing land use studies. Land use policies published after the release of the CLI are reviewed to determine if actions and reactions of land use planners are a direct result of implementing recommendations of the CLI.

The study was limited to the Agricultural Census years from 1966 to 1996. Agricultural census districts were redefined in 1966 (coinciding with the publication of the CLI) and have been consistent since then, except for the 1972 Agricultural Census.

1. Study Area

The study area, located in the Pembina Hills Area of South-central Manitoba (Latitude 49°00-49°43/Longitude 98°00-100°00), represents Agricultural Census District 4 and partially represents the Brandon Map Area 1:50 000 NTS Map Sheet 62G (Townships 1-6 Ranges 8-14) (Figure 1). The area under review in this study encompasses the rural municipalities of Lorne, Louise, Pembina, Argyle, and Roblin.

The area is served by Provincial Highways 2 and 3. Main and branch lines of the CNR and CPR traverse the area.

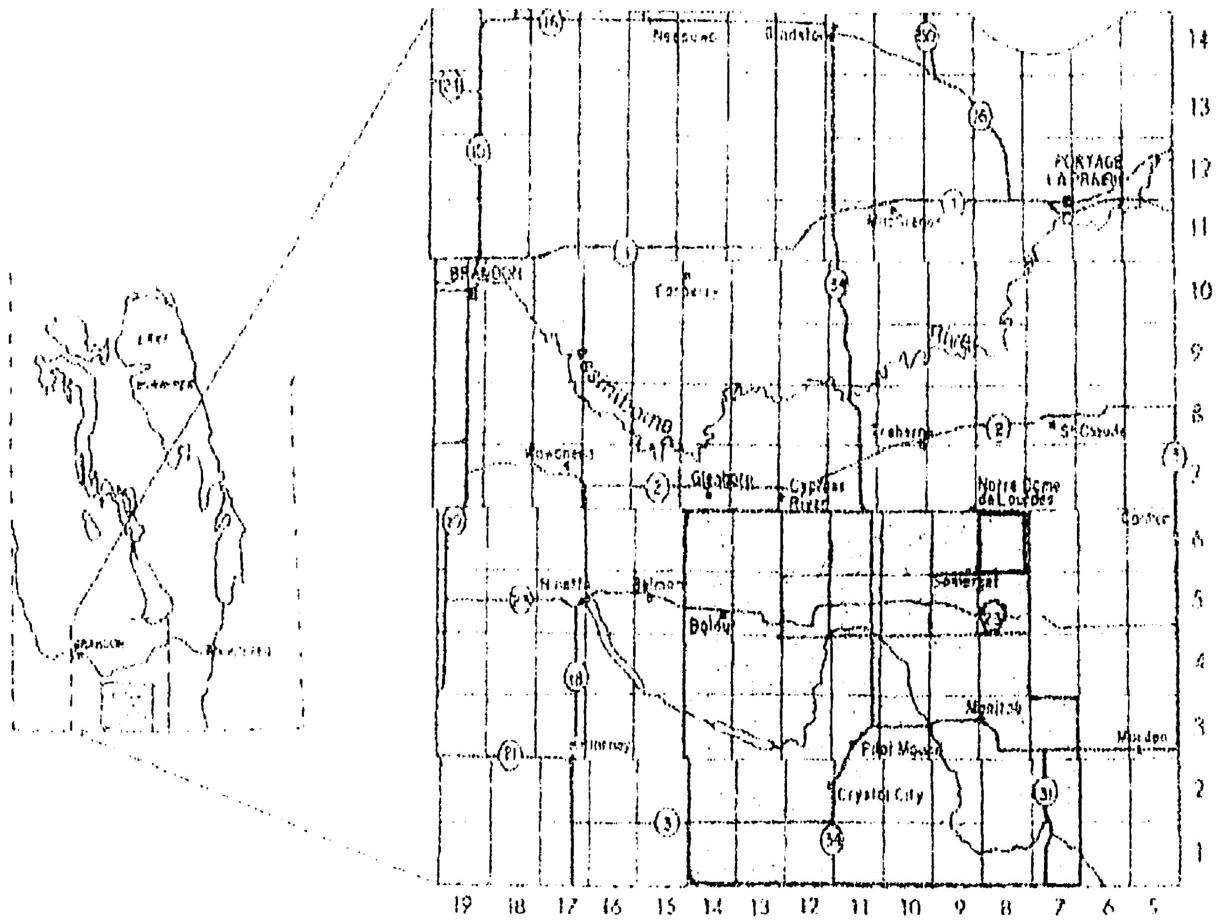
The main settlements include the towns of Manitou, Somerset, Notre Dame de Lourdes, La Riviere, Pilot Mound, Crystal City, and Baldur.

This area and the adjacent regions are separated into two broad physiographic regions by the Manitoba Escarpment. Above the escarpment the topography is irregular with good drainage. Below the escarpment the topography is nearly level and the soils are imperfectly drained. The study area is almost entirely above the escarpment.

A. Criteria for the Selection of the Study Area

The study area exhibits land use adjustment problems involving more than one CLI resource sector (agricultural land use is analyzed in this study) and has a range of physical capabilities for several different uses. The study area boundaries generally correspond with agricultural

• Figure 1: Map of Study Area



Source: Podolsky 1987

census areas (except for the 1972 census as noted above), municipalities and/or watersheds. CLI maps for all sectors are available.

The study area has demonstrated land use problems. Agricultural practices and deforestation on and above the escarpment have caused an increase in runoff and a decrease in the ability of the soil to resist erosion. An important part of this study will be the analysis of the nature and extent of land use change and the possible reasons for the change.

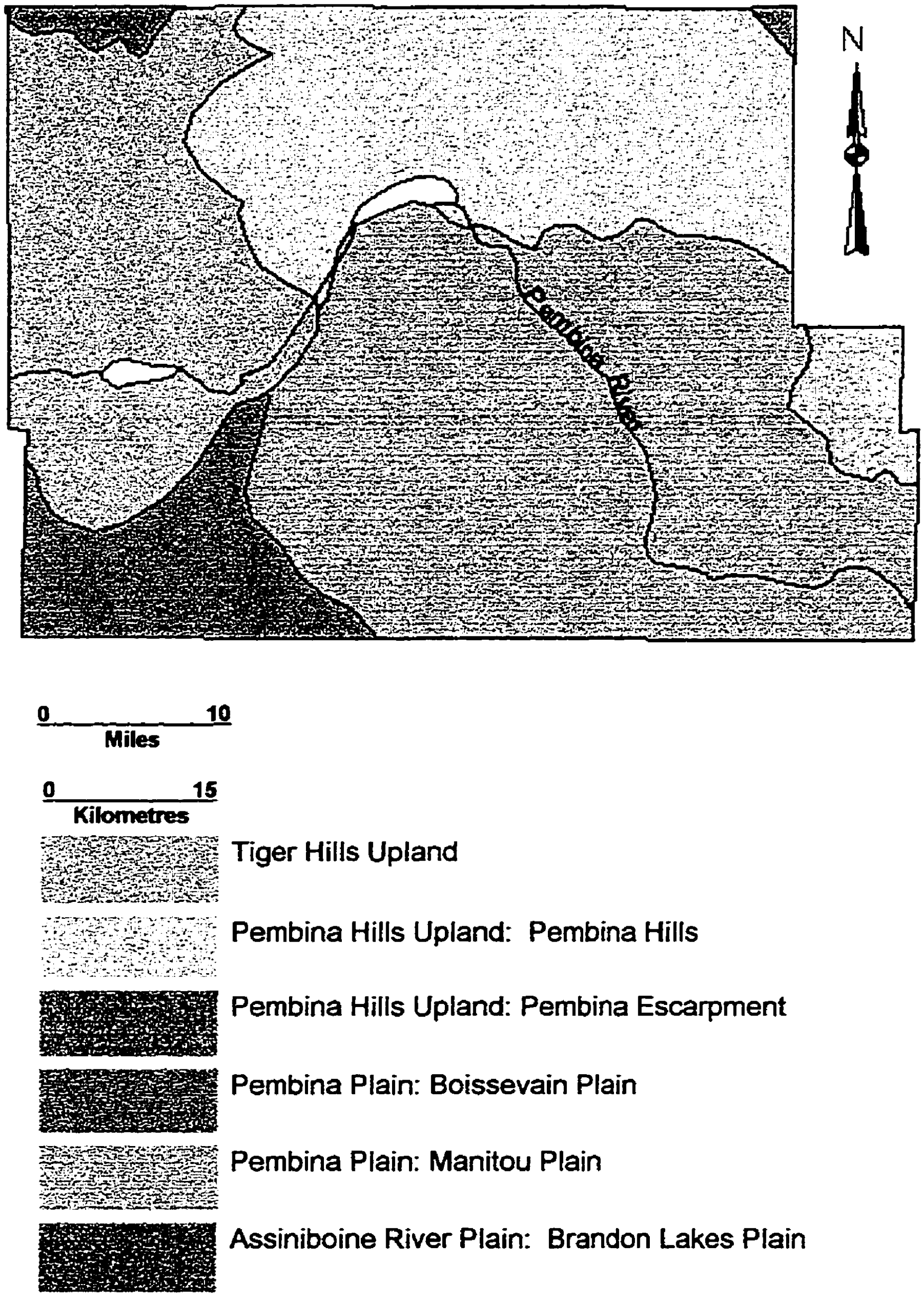
B. Description of Physical Features

The natural resources discussed in this section are of significance in both land use and land use planning. These factors include topography, geology, climate, soils, and vegetation.

i. Topography:

The major features of Manitoba's topography existed before glaciation (for example, the Manitoba Escarpment). However most landforms and surficial deposits in the study area are products of late-Pleistocene deglaciation. The study area is almost entirely located above the Manitoba Escarpment (a small section at the extreme north-east portion of the study area lies below the escarpment) (Figure 2). Most of the area lies within the watershed of the Pembina River; however a small section at the extreme north-west of the study area is within the Assiniboine River watershed.

• Figure 2: Physiographic Regions of the Study Area



Source: Podolsky: 1993

The *Manitoba Escarpment* is a transition zone of steep relief rising from approximately 250 metres above sea level (ASL) along the east side to an elevation more than 600 metres ASL in the study area (Figure 2). The Manitoba Escarpment trends north-west from the International Boundary near Morden and separates a lowland formerly occupied by glacial Lake Agassiz from an upland area or second prairie level on the west. To the east of the escarpment the slope is about 0.5% or less and to the west of the escarpment is a rolling landscape with considerable relief. (Klassen and Wilson 1992). The scarp is composed of the edges of the dipping beds of shale and the scarp face is marked by Glacial Lake Agassiz strandlines. (McDowell 1981; Halstead 1959).

The Pembina Hills are approximately 7 kilometers wide and rise about 90-150 meters above the lowland. End moraines contribute to the roughness of the *Pembina Hills*. Most of the area is gently undulating drift plain or glacially streamlined bedrock cored hills. (Elson: 1956; Halstead: 1959).

The *Pembina Plain* is located west of the Pembina Hills. The surface of the plateau is flat, except near the north-east and northern margins, where glacier ice pushed the shale of the scarp edge into low moraine ridges and drumlins. Bedrock is rarely far below the plateau surface and at several places it forms low whaleback ridges, such as Pilot Mound. (Bird: 1972)

The *Tiger Hills* occur in a belt of end moraine 8-15 kilometers wide. The hills consist of a series of hills and closed depressions (some hold water throughout the year). The general elevation is 400-425 meters but a few of the highest have elevations of 500 meters above sea-level. (Halstead: 1959)

The main stream in the study area is the Pembina River. This small stream was once a large river that carried meltwater from Glacial Lake Souris. The underfit stream now flows in a valley averaging about 1.5 kilometers in width. The Pembina River ultimately joins the Red River.

While the main water courses carry the water through the area and facilitate the runoff of spring thaw and heavy rainfall, much of the surface drainage is local. The runoff accumulates in depressions and removal of water from these local catchments is mainly through evaporation and seepage. The large, flat upland with its gently sloping surface, has prevented the development of well-defined drainage channels. (Manitoba Escarpment Headwater Study: 1988)

ii. Bedrock Geology

The bedrock geology of Manitoba can be divided into two distinctive age units: the sedimentary zone of post-Precambrian age (west of longitude 96°25') and the Precambrian zone that underlies sedimentary rocks and appears at the surface (east of 96°25') (Figure 3). The formations that form the study area range from Jurassic to Upper Cretaceous in age. The sediments are mainly soft shales with more competent siliceous shales, massive calcareous shale and siltstones with minor amounts of sand and sandstone (Table 1). (Elson: 1956).

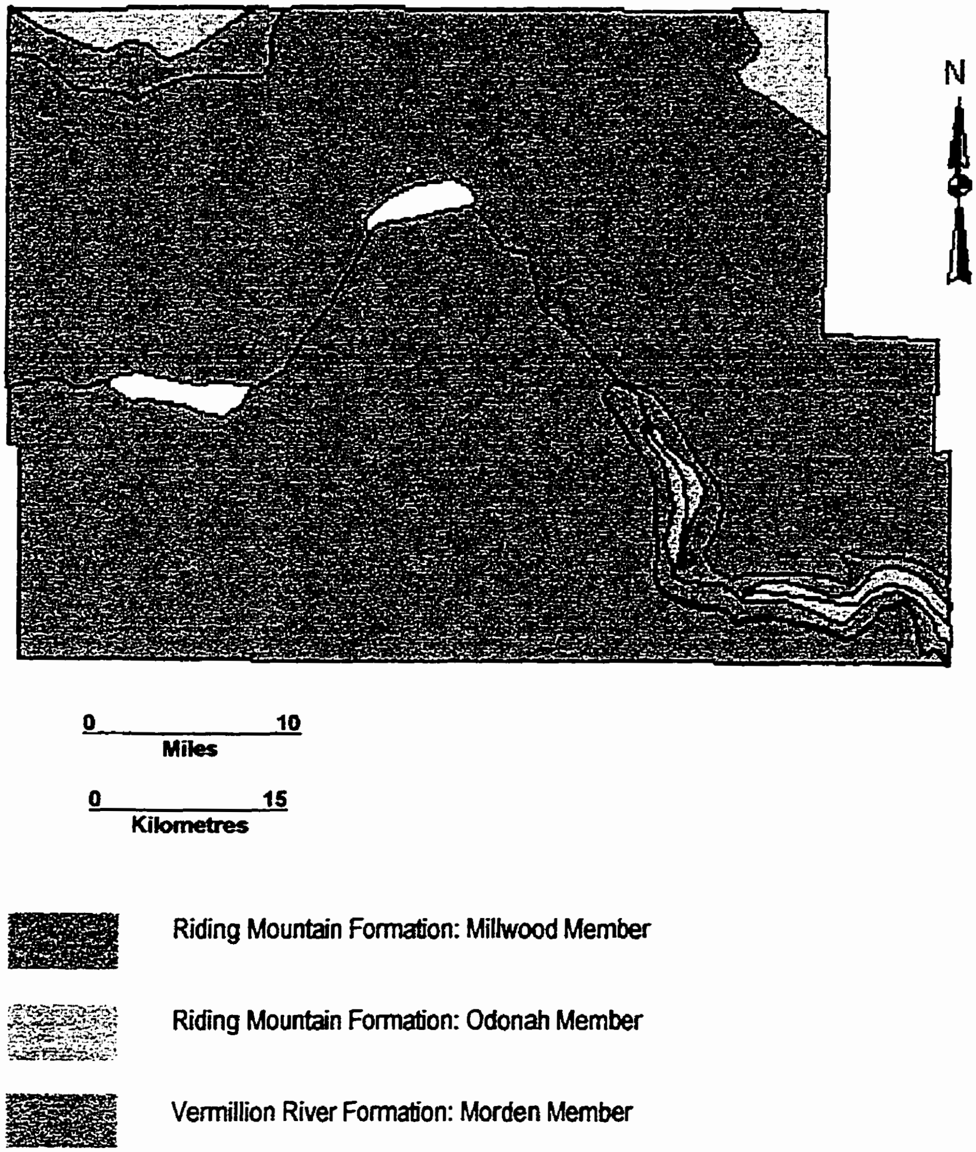
In the study area the *Riding Mountain Formation* underlies the upland west of the Manitoba escarpment and consists of greenish-grey clay beds (*Millwood* Phase) and hard siliceous grey shale (*Odanah* Phase). This formation is approximately 120 meters thick in the study area. Soft bentonitic and thin beds of pure bentonite also occur near the base of the Odanah beds. (Elson: 1956; Halstead: 1959).

• **Table 1: Bedrock Formations of Southern Manitoba**

Era	Period or Epoch	Formation	Lithology
Mesozoic	**Upper Cretaceous**	***Riding Mountain***	
		• Odanah Phase	Hard siliceous grey massive shale breaking fissile; ironstone concretions
		• Millwood Phase	Soft waxy greenish-grey shale of variable thickness
		Vermillion River	
		• Pembina Member	Soft black shale with large amounts of bentonite near the base
		• Boyne Member	Buff-weathering, calcareous, silty, white speckled, grey shale with iron-stained bentonite beds
		• Morden Member	Dark grey, soft, non-calcareous shale with septarion concretions
		Favel	Grey shale with heavy calcareous specks and soft grey buff-weathering limestone
	Upper and Lower Cretaceous	***Ashville***	Dark grey, non-calcareous shale, minor silt, sand, limestone, and bentonite
	Lower Cretaceous	***Swan River***	Sand, sandstone, grey, non-calcareous shale
	Jurassic	***Jurassic***	Grey shale, calcareous shale, variegated shale

Source: Elson:1956; Teller and Bluemle: 1983

•Figure 3: Bedrock Formation in Study Area



Source: Manitoba Soil Survey, 1976

iii. Surficial Geology

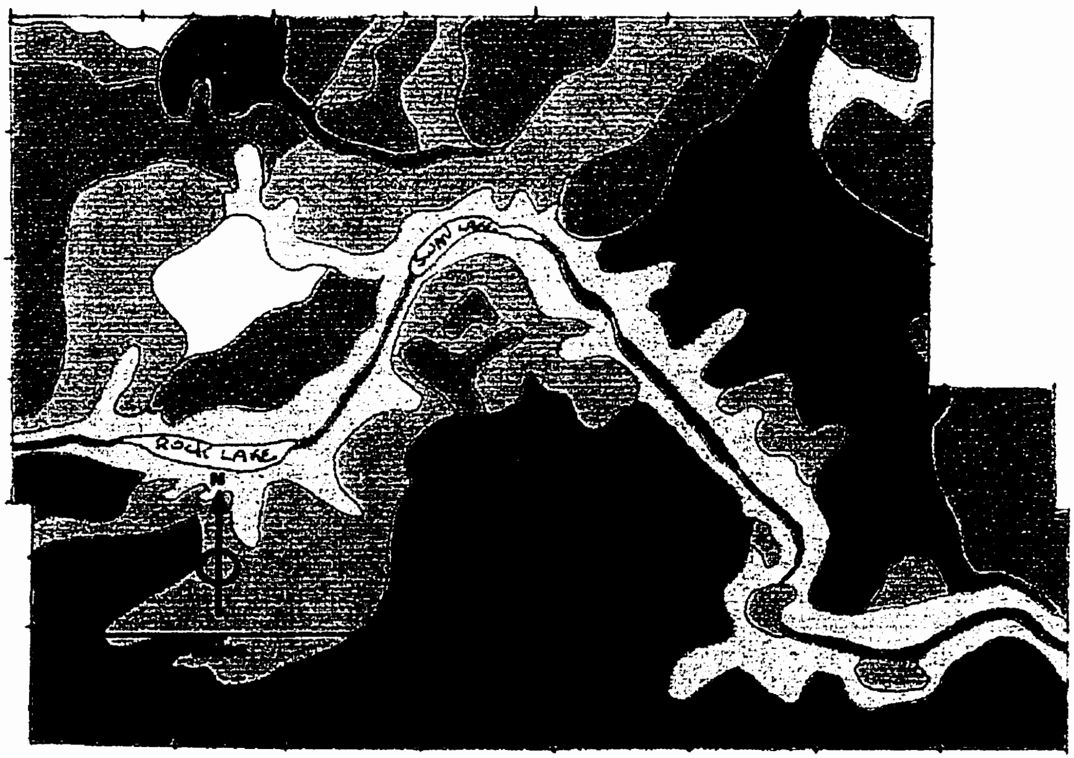
The surface deposits observed in the study area represent a complex sequence of strata deposited during the Pleistocene (Figure 4). Texturally the strata include a wide range of materials: glacial till, glacio-fluvial deposits, and lacustrine deposits. The prominent surface material in the study area is clay-rich till. (Manitoba Escarpment Study: 1986)

Preglacial Topography and Pleistocene History

The preglacial topography in south-western Manitoba was modified relatively little by glacial erosion. Larger landforms, such as the Manitoba Escarpment, were eroded very little except for a smoothing effect. (Halstead: 1959) The lowland areas of the present topography are typically underlain by preglacial valleys filled with glacial and glacio-fluvial sediments. These sediments completely obscure the preglacial valley form. For example, one preglacial valley trends south-south-east through townships 1 to 4, ranges 14-17 and in places is covered by more than 90 meters of drift. Similar preglacial valleys drain townships 1 to 9, ranges 10 to 14, northward into the ancestral Assinboine River. (Halstead: 1959)

The last Pleistocene ice-sheet that covered the area flowed south-eastward. As it thinned and retreated it divided into two lobes that coalesced along the Manitoba escarpment north of Pembina Mountain. (Halstead: 1959)

Figure 4: Surficial Geology of the Study Area



- Colluvial slumps slope wash and some ice push deposits
- Alluvial silt, sand, and clay
- Offshore silt locally interbedded with sand or clay
- Littoral and nearshore gravel sand and silt
- Lacustrine silt and clay
- Glaciofluvial and outwash sand and gravel
- Grey calcarious silty till
- Brown clay till

Source: Manitoba Soil Survey 1976

During the retreat of the ice west of the Manitoba escarpment, meltwater flowed southward across the Tiger Hills through several channels. Numerous small eskers were deposited in ranges 8 to 14. During retreat of the western lobe, the lobe east of the Manitoba escarpment remained stationary along Pembina Mountain and the Tiger Hills. Meltwater from the wasting of this lobe flowed southward across the Tiger Hills into the Souris-Pembina Valley. (Halstead: 1959).

Glacial Deposits

Glacial deposits form the surface material of the Brandon map-area at altitudes higher than 400 meters, whereas glacial lake deposits cover the surface below that altitude. (Halstead: 1959). "Till is a direct glacial deposit in which water activity plays a minimal role." (Elson:1956 p.51). Till is a heterogeneous mixture of boulders, stones, gravel, sand, silt, and clay.

Ground moraine is the most extensive till deposit in the study area. It is poorly drained and characterized by low knolls and numerous sloughs. In the eastern part of the map-area (township 1, ranges 6 and 7) a series of discontinuous parallel ridges 1-10 meters high and 150 meters to 2.5 kilometers long were formed parallel to the retreating glacier margin. These parallel ridges are composed of sandy till with numerous inclusions of silt and sand. Streamlined ridges, such as Pilot Mound, consist of bedrock overlain by a thin mantle of ground moraine. (Halstead: 1959)

Relief distinguishes end moraine from ground moraine. End moraine is generally rough, comprising a narrow range of hills that were deposited at the terminus of the glacier when its retreat began (for example, the Darlingford-Tiger Hills end moraine). Knobs and undrained depressions characterize end moraine. For example, Pembina Mountain has a "knob and kettle" belt that forms a crest near its west boundary and slopes steeply to the east and north along the Manitoba Escarpment. Irregular bodies of silt, sand, and gravel are common in end moraine in townships 6 to 9, ranges 18 and 19. (Elson: 1956; Halstead: 1959)

Glaciofluvial Deposits

Ice-contact Stratified Drift occurs as kames, and eskers. Kames are irregular bodies of poorly sorted sand and gravel that accumulated as outwash cones or small deltas on the ice. After the ice melted these deposits remained as mounds. Kames are found in townships 3 and 7, ranges 10 to 13. Eskers are deposits formed in subglacial tunnels and are deposited over ground moraine. Eskers typically extend downward into the ground moraine, 1.5 meters or more. Eskers in the study area are comparatively small and form ridges 1-10 meters high, 30-150 meters wide and from a few hundred meters to several kilometers. (Halstead: 1959)

Outwash is composed of gravel, sand, and silt washed out of the debris at the glacier's margin by meltwater. It may be as thick as 4.5

meters. In the study area outwash occurs as broad plains overlying ground moraine and as a thin mantle on terraces in Pembina Valley. (Halstead: 1959)

Lacustrine Deposits

Glacial Lake Agassiz beach deposits are composed of well-sorted sand and gravel in ridges that range in thickness from .5 to 5 meters, 30 to 150 meters wide and from a few hundred meters to many kilometers long. Glacial Lake Agassiz beach deposits are found at the extreme north-east corner of the study area (township 6, Range 8). (Elson: 1956; Halstead: 1959)

Medium- to coarse-grained lake bottom deposits, which were typically deposited in water less than 30 meters deep, occur in the extreme north-east corner of the study area. (Halstead: 1959)

Alluvium

The alluvium in Pembina Valley consists of several beds of gravel and silt each about 15 centimeters thick. These beds accumulate to a thickness of 15 to 20 meters near the International Boundary and form paired terraces 6 to 25 meters above the valley floor. (Halstead: 1959)

Alluvial Fans are predominantly clay with lenses of sand and gravel near their apex. Most of the fans are thin, less than 2 meters thick, and several cover escarpment strandlines. (Halstead: 1959) (Elson: 1956).

iv. Climate

The study area climate is typically sub-humid continental with large seasonal temperature ranges and moderate precipitation. Climate is influenced by three major air masses: cold air from continental polar regions, cool moist air from the Pacific, and, on occasion, warm moist air from the Gulf of Mexico. Winters are long and cold and summers are short and cool. (Klassen and Wilson: 1992).

The weather recording station at Somerset records an average mean daily temperature of 2.0°C. Climate data for the Manitou and Pilot Mound recording stations is shown in Table 2. Frost free days vary from 100-120. The shorter growing season limits the success of cereal crops in the study area. (Langman: 1986).

Annual precipitation, including snow, is approximately 50 cm. (Appendix C). About 70% of annual precipitation occurs as rainfall from May to October. Spring and fall precipitation tends to be uniformly distributed as a result of low pressure systems passing through the area. Local showers and thunderstorms are more frequent in the summer. (Klassen and Wilson: 1992).

The plateau and eastern slopes of the escarpment are subject to enhanced precipitation due to the orographic effect of the hills. It is estimated that the plateau receives at least 25% more precipitation than the base of the escarpment. (Manitoba Escarpment Headwater Study: 1988).

• Table 2. Climate Data from Stations at Manitou and Pilot Mound.

	MANITOU	PILOT MOUND
Mean Annual Temperature	1.4°C	1.9°C
Frost Free Days (Days O°C)	122 days	119 days
Last Frost (Spring)	May 18	May 20
First Frost (Fall)	Sept. 18	Sept. 17
Degree Days (above 5°C)	1636	1670
Total Precipitation	540 mm	517 mm
Mean Annual Rainfall	407 mm	388 mm
Mean Annual Snowfall	138 cm	130 cm

Source: Environment Canada, Atmospheric Environment Service Canadian Climatic Normals, 1951 – 1980.

v. Vegetation:

The vegetation of the study area is predominately aspen-oak parkland with forest on the high ground and steep slopes of the Tiger Hills and Pembina Hills. At the time of settlement the vegetation of the study area was predominantly parkland. Broadleaf forests grew along the escarpment and mixed grass grew in the extreme south-west section (Windsor and Carlyle: 1986). Since that time most of the area has been cleared for cultivation.

In the north-east section (Pembina Hills and Tiger Hills) of the study area are dense oak and poplar woods, with some maple and associated herbs and scrubs. In the south and west sections are woods interspersed with prairie grasses (Boissevain Till Plain). Poplar, maple, elm, oak, and ash with shrubs and associated herbs and ferns are found along the Manitoba Escarpment and ravine slopes. In the lacustrine deposits at the escarpment base tall prairie and meadow prairie grasses and herbs are found.

Most of the study area is under cultivation and natural vegetation is restricted to steeply sloping, dissected areas, knoll positions and in poorly drained depressions.

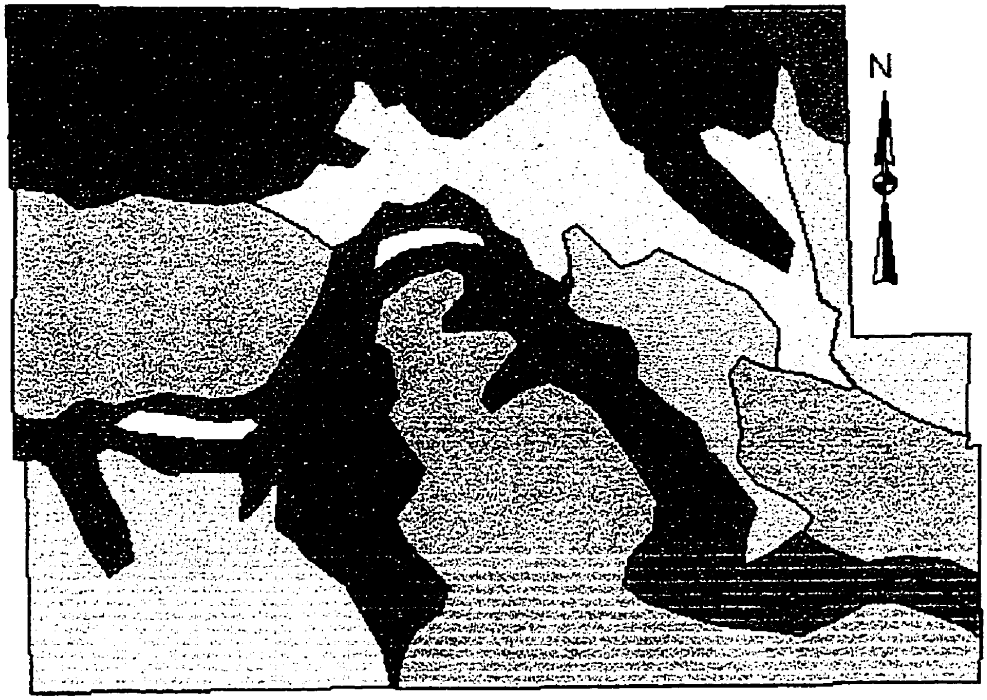
vi. Soils:

In the study area soils have developed on recent glacial deposits. The glacial deposits are primarily clay till near the surface to the West of the escarpment and underlying lake basin deposits east of the escarpment. Coarse-grained deposits associated with glacial sediments are also common (Klassen and Wilson 1992).

The soils of the study area range from Chernozemic to Luvisolic, with Gleysols occupying depression areas and Regosols occurring on the tops of some hills.

The soils of the study area (Figure 5) are predominately Chernozemic Black. These soils, developed under grassland vegetation, reflect cool temperatures, long winters, and relatively low rainfall. Orthic Dark Grey Chernozemic soils have developed in areas of rolling to hilly topography with a more continuous forest cover than Black Chernozemic soils. The parent material is typically calcareous till but these soils may develop on any type of parent material. Climate,

• Figure 5: Soils of the Study Area



0 10
Miles

0 15
Kilometres

	Soil Development	Soil Texture	Parent Material	Surface Form	Slope (%)
	Black Chernozemic	Clay Loam	Lacustrine	Level	1-3%
	Black Chernozemic	Clay Loam	Lacustrine	Dissected	4-9%
	Black Chernozemic	Clay Loam	Morainal	Undulating	1-3%
	Black Chernozemic	Loam	Morainal	Hummocky	4-9%
	Black Chernozemic	Loam	Morainal	Knob and Kettle	4-9%
	Black Chernozemic	Sand	Lacustrine	Level	1-3%
	Dark Grey Chernozemic	Clay Loam	Morainal	Hummocky	4-9%
	Dark Grey Chernozemic	Clay Loam	Morainal	Hummocky	10-15%

not parent material, is the controlling factor in the development of Chernozemic soils. Soil texture is typically clay or clay loam. These soils are not strongly weathered. (Langman: 1986). Chernozemic soils have a high agricultural value for growing cereal crops (CLI classes 2 and 3) but may be limited by topography. (Podolsky: 1998)

Gleysols soils are found in association with imperfectly to poorly drained areas such as depressions. These soils can develop in most types of finely textured (clay/clay-loam) parent materials. Gleysols in the study area have moderate restrictions for crop use (CLI classes 2 and 3) and are typically limited by topography, excess moisture, or salinity. (Podolsky: 1998)

Regosols are immature soils that are found in the study area on recent alluvial deposits (for example, along the terraces of the Pembina River). These soils have little or no profile development. Regosols in the study area have moderate restrictions for crop use (CLI classes 2 and 3) and are typically limited by topography or occasional inundation by floodwater. (Podolsky: 1998)

C. Land Use in the Study Area

A major factor in achieving better land use is obtaining current information about existing land uses and changes in land use over time. Factors influencing changes in land use include: an increased demand for land resources, changing economics of agricultural production and a changing labor supply; technological and management advances such as machinery, seed varieties, and chemicals; and government programs and regulations. (Dumanski et al.: 1982)

i. Settlement History

The landscape at the time of agricultural settlement was similar to what might it have been a thousand, or even several thousand years earlier. Homestead land was available, virtually free of charge, to all the early settlers. The first settlers in the Pembina Mountain arrived in the early 1870s and by 1926 all lands in the study area that were capable of supporting agriculture were in use with a high percentage in grain production. (Windsor and Carlyle: 1986).

A striking change has occurred in the evaluation of the land between the period of first settlement and the present day. Lands selected by the pioneers are now often considered unsuitable for agriculture (Maxwell 1966). Most settlers claimed the most convenient land. Well-drained beach ridges were important dry-point sites for farmsteads. Clumps of trees for shelter and building were desirable Running water was not necessary since good spring water was easily obtained. Little consideration was given to the quality of the land if it appeared adequate for farming. (The original surveyors' reports, while intended to assist in agricultural settlement proved to be inconsistent in reporting soil quality) (Richtik et al.1987, Warkintin: 1966).

Once a homestead had been established, several factors affected the settler's success. Ample wood for building and heating was needed. Soils and topography suitable for cultivation were needed.

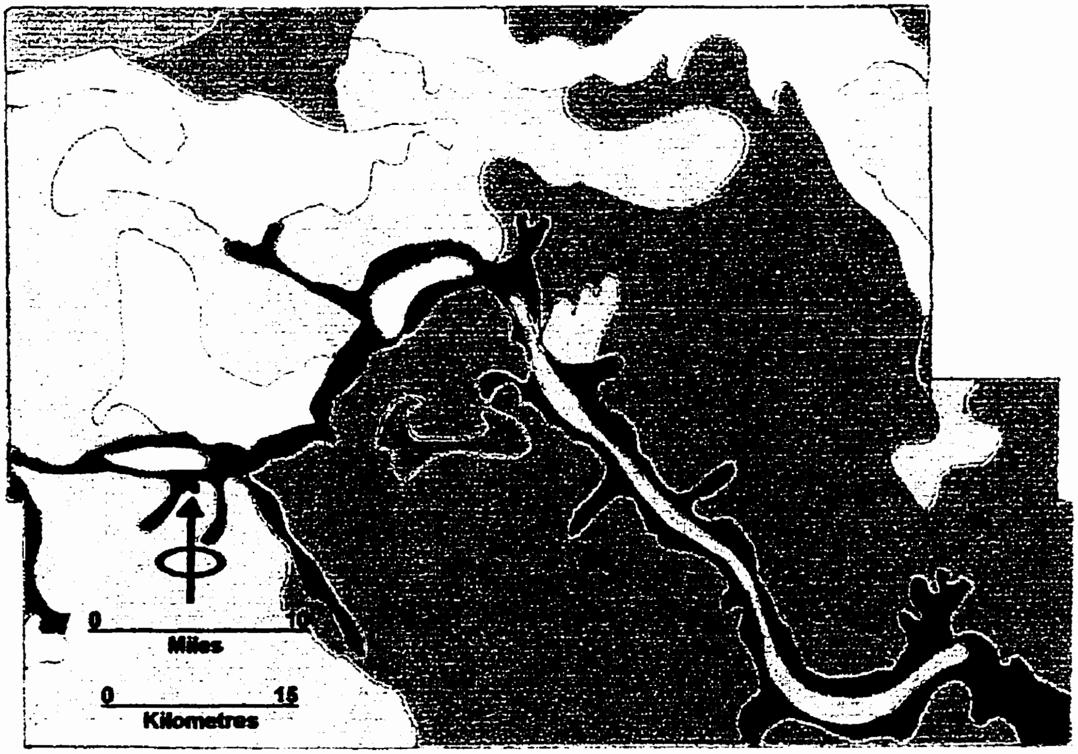
The support of closely related families or small groups of friends helped the settlers establish new homes and communities. (Windsor and Carlyle: 1986).

ii Agricultural Land Use In the Study Area

Agriculture is the dominant land use in the study area. In 1992 more than 74% of the area was identified as being in agricultural usage. Cereal grain and oil seed production, including wheat, barley, flax, and canola, are the dominant land use above the escarpment. Mixed farming occurs in the steeper topography. (Klassen and Wilson: 1992).

Most of the agricultural land in the study area is rated as CLI classes 1-3 (i.e., capable of sustained production of common field crops). The areas of the Pembina Valley, Manitoba Escarpment, and Darlingford Moraine are typically rated CLI Class 4 (i.e., physically marginal for sustained production). (Figure 6). CLI agricultural capability classes and subclasses are described in Appendix A. Table 3 describes land use and CLI classifications in the study area.

•Figure 6: CLI Agricultural Capability for the Study Area



CLI Class 1	Soils have no significant limitation in use for crops
CLI Class 2	Soils have moderate limitations that restrict the range of crops or require conservation practices
CLI Class 3	Soils have moderately severe limitations that restrict the range of crops or require special conservation practices
CLI Class 4	Soils have very severe limitations that restrict the range of crops or require special conservation practices
CLI Class 5	Soils have very severe limitations that restrict their capability to producing forage crops
CLI Class 6	Soils are capable only of producing perennial forage crops
CLI Class 7	Soils in this class have no capability for arable agriculture or permanent pasture

Source: Canada Land Inventory 1967

Table 3: Land Use and CLI Classifications for Municipalities in the Study Area

Municipality	Land Use	CLI Classification of Agricultural Land
Argyle	• Agriculture: grain, beef, dairy, hog, poultry	• 60 % classes 2&3 • 40% classes 4&5 • topography and drainage are the major limiting factors • over 25% of the municipality is considered to be severe/high risk Haluschuk et al.: 1997
Lorne	• Agriculture: grain, beef, dairy, hog, poultry • rural and urban residential, wildlife, wooded areas, and aggregate quarries	• predominantly CLI classes 3&4 • topography and drainage are the major limiting factors • water erosion is wide-spread and causes significant limitations to land use Langman: 1986
Louise	• Agriculture: grain, beef, dairy, hog, poultry • rural and urban residential, wildlife, wooded areas, and aggregate quarries	• 25 % class 1 • 60% classes 2&3 • topography and drainage are the major limiting factors Podolsky: 1998
Pembina	• Agriculture: grain, beef, dairy, hog, poultry • rural and urban residential, wildlife, wooded areas	• 12 % class 1 • 66% classes 2&3 • 20 % classes 5&6 • topography and drainage are the major limiting factors Podolsky: 1992
Roblin	• Agriculture: grain, beef, dairy, hog, poultry • rural and urban residential, wildlife, wooded areas, and recreation areas	• predominantly CLI classes 3-5 • topography and drainage are the major limiting factors Podolsky: 1983

A primary land use problem involves the control of and protection from surface waters because the escarpment area is subject to flash floods and most of the study area is subject to severe water erosion. The clay and clay loam soils in the study area cannot overcome the influence of topography and are very susceptible to severe water erosion. This risk is increased considerably if the land is summerfallowed. Evidence of this is provided by the presence of large gullies such as the Moreau gully located south-east of Notre Dame de Lourdes.

Generally speaking the land in the Pembina Hills/Tiger Hills area is physically marginal for sustained agricultural production with a typical CLI capability of Class 4 and the land on the Boissevain and Manitou Plains is well suited to cereal crops with typical CLI ratings of class 1-2. Besides agriculture, there are also small areas of forest, recreational areas, and urban settlements. Small deposits of gravel are excavated from this area for the aggregate industry (Langman: 1986).

2. Method

A. Data Sources and Data Required

i. Aerial Photography

Images used for three selected sites in the study area were taken in the years 1970, 1980, and 1990. An attempt was made to select images collected in the years close to the years that the agricultural census was taken.

ii. Socio-economic data on users' land demands and economic factors

Statistics Canada agricultural census data for years 1966, 1976, 1982, 1986, 1992, 1996 were used for the study. Data from the 1972 census was not used because the census divisions did not match those used in the previous or the subsequent census. Census data for agricultural land use is compared to the land use change assessed from the aerial photography.

iii. National Land Use Data

The CLI lists land use capability at the time of publication (1966) and provides a baseline for analyzing land use changes. The CLI data is available in digital form and 1:50 000 and 1: 250 000 maps. The base map for this study is prepared from this data.

iv. Physical Data

Much of the data was taken from four maps: topography, geology, vegetation, and land use. The topographical map follows the NTS 1:50 000 quadrangle series and serves as a base map. The surficial geological map indicates the distribution of distinct surficial deposits. (Elson: 1956). A generalized land cover (vegetation) map was developed using NTS 1:50 000 topographic maps and aerial photographs for 1970, 1980, 1990, and 1995.

B. Rationale for Mapping Scale

"Comparison of land use maps with those of land capability will assist in the location of areas where changes in land use are desirable." (Reeds: 1965 page 207)

The original CLI maps were published using a scale of 1:250 000. The working scale used for the preparation of the final CLI maps was 1:50 000.

To reliably correlate the physical features of the landscape and to adequately represent the land uses and land use changes, it was considered important for this study that a scale of 1:25 000 be used to create the final maps.

3. Data Collection, Analysis, and Interpretation of Research

Land use studies require areal data on specific land uses. Knowledge of both land use and land cover is important for land planning and management. Land cover is a type of feature present on the surface of the Earth (e.g., vegetation and artificial constructions). Land use is the human activity associated with a specific piece of land (i.e., human activities on and about the land but not directly visible form photographs). By observing land cover one can infer land use. (Estes et al: 1984)

In this study land covers are initially mapped from aerial photographs. Results are then compared to agricultural census data for the same period.

A. Photointerpretation

Remote sensing affords a cost effective method of providing large amounts of data on land cover, soils, and landforms. Baseline conditions can be established and current land use maps can be created. Trends can be established by applying the same technique to historical aerial photography. To accomplish this, it is necessary to manually interpret categories of land cover on multidate photographs and then compare the categories at different dates to detect change. (Johannsen and Saunders: 1984)

The principal steps in the process of interpreting aerial photography in sequential land use studies are:

1) Assemble aerial photography of the study area for each period to be analyzed. (Images must correspond in scale and areal extent.)

2) Review collateral materials related to the study area, such as NTS maps, soil surveys, CLI maps, and land use policies (past and present).

3) Select classification scheme. The classification units used in this study are crops, summerfallow, improved pasture, unimproved land. (Table 4). The CLI land use classification system is described in Appendix C.

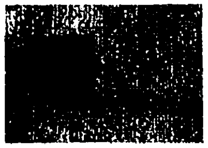
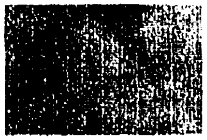
4) Manually interpret the land covers and determine boundaries between sections of differing land cover on each photograph for each period. When necessary, refer to topographic maps, existing land use maps, and reports to confirm interpretation.

5) Map each land cover for each date. Areas where changes have occurred are determined by superimposing the maps. The breakdown of actual acreage for each land use category (e.g., %/ha) can be calculated with emphasis on cultivated, woodland, summerfallow, and conservation practices.

6) These changes are then recorded on a final map that will display the extent, location, and type of change(s) that have occurred.

Land cover classification and area inventory calculated through the interpretation of aerial photography are based on the premise that specific land covers can be identified by their spectral response and photo texture. The interpretation of remotely sensed image data is dependant on a number of factors including the interpreter's understanding of fundamental aspects of image formation and image generation and the interpreter's ability to detect, delineate, and classify data, recognize patterns, identify landscape and surface characteristics as expressed on imagery. For example, differences in vegetation cover often indicate differences in terrain conditions. Table 4 lists some of the factors that should be considered when interpreting aerial photography.

• Table 4: Identification of Agricultural Land Use Types on Aerial Photography

Symbol	Name	Definition	Ground Features	Image Appearance	Example
A	Cropland	Land used for annual field crops, i.e., grain, oil seeds, sugar beets, field vegetables, summerfallow, land being cleared for field crops.	Cultivated farmland; land planted in crops	• Fields frequently have straight or even sides • Fine even texture • Photo tone usually light for crops and dark for summerfallow.	
P	Improved Pasture/ Forage Crops	Land used for improved pasture or for the production of hay or other cultivated fodder crops. Includes land being cleared for these purposes	Some evidence of cultivation; evidence of use by livestock; open grassland with isolated shrubs and trees	• Smooth texture • May have mottled patterns caused by bushes or weed invasions	
K	Rough Grazing And Rangeland (Unimproved Pasture)	Land used for extensive grazing that cannot be improved (limited by stoniness, soil fertility, drainage, or drought).Natural grassland; abandoned farmland, grassy open woodland	Evidence of use by livestock; scattered patches of weeds, stumps, or shrubs.	• May have mottled patterns caused by bushes or weed invasions • Brush and trees cover up to 25% of the area • Rough topography	
T	Productive Woodland	Land covered with tree, scrub, or bush growth	Land bearing commercial forest (potential for sawlogs, pulpwood, or fuel)	• Crown density exceeds 25% • Trees over approximately 20 feet in height	
U	Unproductive Woodland	Land covered with tree, scrub, or bush growth	Land covered with tees and scrub that has no potential commercial value	• Crown density exceeds 25% • Trees less than approximately 20 feet in height (but not less than 4 feet in height	

Source: McClellan, et al: 1968

Table 5: Factors Influencing the Interpretation of Aerial Photography

Date of Photography	Vegetation cover can be more accurately defined and changes in crop characteristics during the growing season can be more readily detected if photography from several dates during the growing cycle is used.
Photo Tone and Texture	Color and color infrared images provide better spectral information and more detailed interpretation than black and white images.
Stereoscopic Coverage	Stereoscopic image interpretation enables the interpreter to use the dimension of height in determining land cover (i.e., plant height).

Source: Lillesand and Kiefer: 1987

There are several advantages of using aerial photography in land use studies. Abundant pictorial detail provides consistency and reliability of data. Information can be extracted from historical photographs revealing the nature and extent of changes by precise geographic location. Aerial photography provides a more accurate estimate of the extent of land use classes than is typically available through satellite imagery. The coarse spatial resolution of historical satellite imagery can lead to significant error in the representation of land cover. This may lead to inaccuracies of class extent.

B. Analysis of Census Data

Land information is most useful when it is compatible with other data collected at the same time and same level of spatial detail (e.g., aerial photography and the agricultural census).

The Census of Agriculture is the basic inventory of Canadian agriculture taken every fifth year. This provides a "snapshot" of agriculture at the time of each census. Questions are asked on a variety of topics including farm land use, crops, and land management practices.

To determine the present agricultural land use in south-central Manitoba it is necessary to select a composite area to coincide with the unit areas for which the agricultural census data are available. The composite selected is made up of Census Division number 4 that includes the municipalities of Lorne, Louise, Argyle, Pembina, and Roblin.

The principal steps in the process of analysis of agricultural census data in sequential land use studies are:

1) Assemble agricultural census data for the study area for each period to be analyzed.

2) Export land use data to a spreadsheet. Enter data for total area of farms, land in crops, summerfallow, improved pasture, and unimproved land (including natural pasture and woodlots) for each census year.

3) Create a chart displaying the amount of agricultural land (in ha) in the census district that represents each land use type for each census year.

4) Create a chart displaying the amount of each land use type (in ha) as a percentage of the total area of farms in the census district for each census year.

5) Record in a table the amount of change (in ha) of each land use type in the census district, gains and losses, for the study period.

6) These changes are then recorded on a final map that will display the extent, location, and type of change(s) that have occurred.

The advantages of using agricultural census data in land use studies include the availability of survey data on every farm in a census district, inventory of crops and livestock in the census district, and the regular updates of the information at five year intervals.

C. Comparison of Data From Aerial Photographs and Agricultural Census

By comparing the data from the analysis of the sequential aerial photography to the data from the analysis of the agricultural census the amount and timing of land use changes in the study area can be confirmed. The results (total number of ha for each land use and percentage of total in each land use) are calculated and demonstrated in Figure 11.

4. Chapter Summary

To understand land use and land use change in the study area it is necessary to understand the physical and cultural features of the area. Lacustrine and glacial material deposited during the Pleistocene left a legacy of soils well suited for cultivation though occasionally limited by topography through most of the study area. The area was settled rapidly in the wake of the Dominion Land Surveys, The Homestead Act, and the development of transportation routes. Occasionally, in the haste of agricultural settlement, land that was not well suited for agriculture was cultivated for cereal crops. Present land use in the study area is primarily agricultural with much of the land rated as CLI Classes 1-3.

Land use changes over time can be determined by detecting and comparing land cover changes on sequential aerial photographs. The results can be compared to Agricultural Census data for the same periods of time to confirm findings. Finally the results are compared to the original CLI recommendations for land use to determine if current land use is in accordance with CLI recommendations.

Chapter 4: Results And Discussions-Analysis Of Land Use Change

This study determines how much land use change has occurred in the study area from 1966-1996 and suggests reasons for that change. The study results demonstrate the total area of each type of land use and the location of areas where change has occurred is determined. The relationship of land use change to land capabilities as recommended in the CLI is described.

1. Data Acquired and Processed

Data acquired in the analysis of land use change in the study area are presented: in tables to document the breakdown of percentages of land use change per hectare; in charts to demonstrate the changes for selected study years; and in maps to display land use changes occurring since the publication of the Canada Land Inventory in 1967.

A. Aerial Photography

Aerial photography provided the main source of data for this study. Images from the years 1970, 1980, 1990, and 1995 provided the closest temporal representation of the land use documented in the agricultural census years.

A sub-area (Twp 6, R8W) of Agricultural Census Division 4 was selected for the analysis of aerial photography. The sub-area represents the worst of the land use problems found in the census division. Agricultural capability in the study sub-area is severely limited by topography and is at high risk for water erosion and flash flooding. In spite of limitations most of the land is planted in cereal crops, occasionally with devastating results. For example, growth of the Moreau Gully (located at NE 17.6.8) is clearly observed on sequential aerial photography. The land immediately surrounding the gully is used for crops in every image captured since 1946. Although climate, topography, and soil type played an important role in the gully's development, its growth could have been inhibited with appropriate land use in the immediate vicinity. (Klassen and Wilson: 1992).

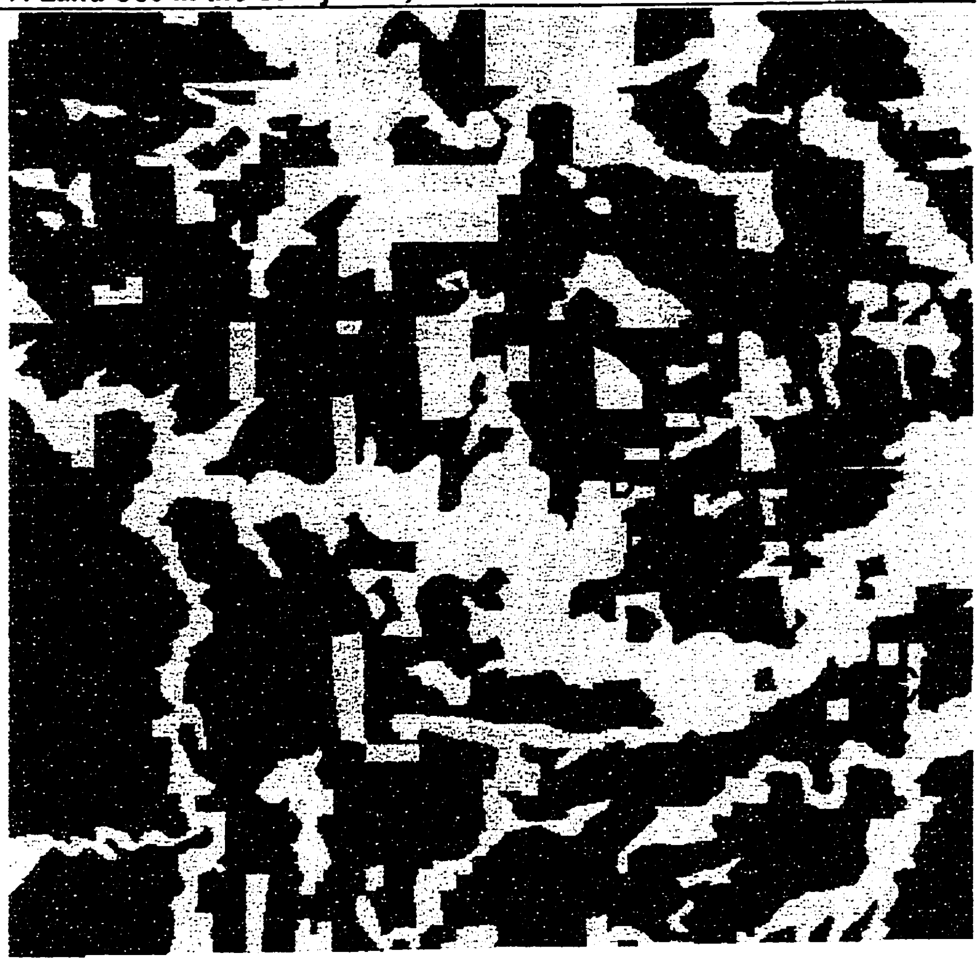
The land cover classes were identified through interpretation of stereo pairs using the parameters defined in Appendix B for crops, improved pasture, rough grazing, productive woodland, and unproductive woodland. Summerfallow is included in the "crops" category. In the 1970, 1980, and 1996 images, summerfallow is easily recognized. However, the 1990 images were collected in early May and summerfallow is not readily recognized. Land cover for the study years is depicted in Figures 7–10.

A clear relationship is visible between land use and the physical features (i.e., topography, soil, water, and vegetation) of the study area. An increase in the amount of cleared land since 1970 is also visible. A corresponding increase in gully development is evident. On close examination it was determined that newly cleared land was typically used for crops and, occasionally, improved pasture.

While changes in land use/land cover could be observed in the maps that were created from the aerial photography, to provide a quantitative assessment of the changes the maps were analyzed using a simple GIS application. (Figure 11).

The land use maps that were manually created from the analysis of the aerial photography were digitized and processed with ArcView GIS. The total area of each land use type was calculated for each image studied. The results are shown in Tables 6 and 7. Trends in land use change for the study area are displayed in Figures 12 and 13.

• Figure 7: Land Use in the Study Area, 1970



0 10
Miles
0 15
Kilometres

Cropland

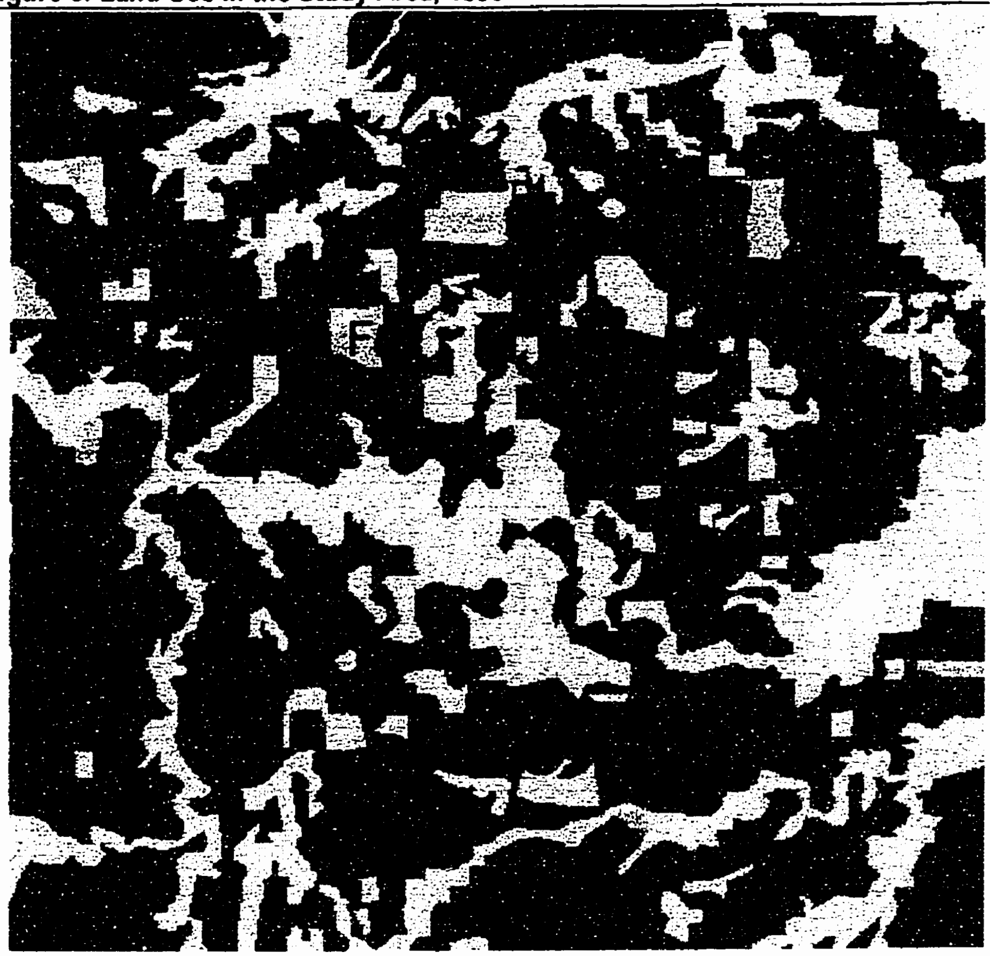
Unimproved
Pasture

Improved
Pasture

Woodland

C Unimproved Pasture was converted to Cropland by 1995
D Woodland was converted to Cropland by 1995
E Woodland was converted to Cropland by 1995

• Figure 8: Land Use in the Study Area, 1980



0 10
Miles
0 15
Kilometres

Cropland

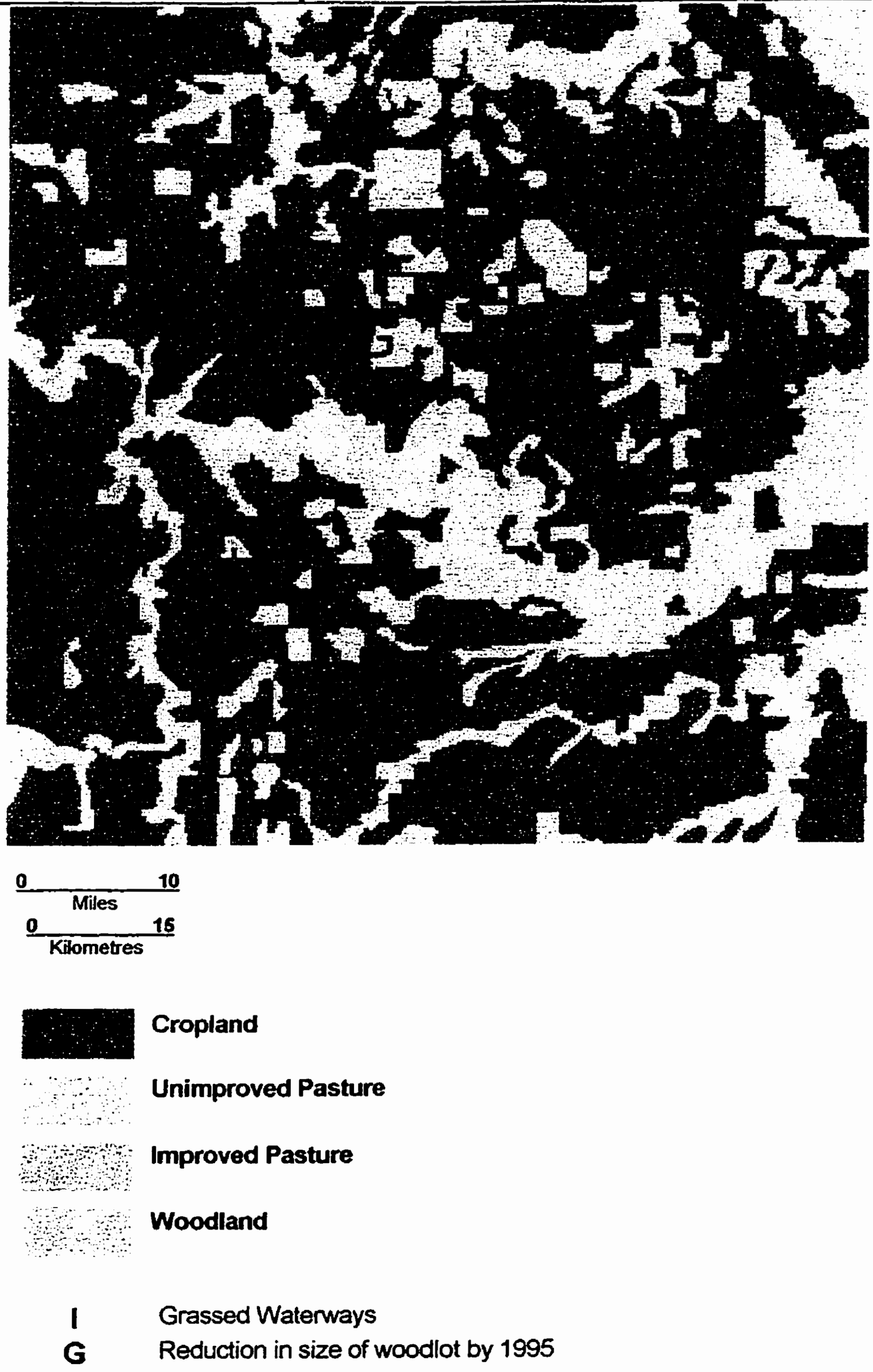
Unimproved Pasture

Improved Pasture

Woodland

F Cropland was converted to Pasture by 1995
H Woodland was converted to Pasture by 1995

• **Figure 9: Land Use in the Study Area, 1990**



• Figure 10: Land Use in the Study Area, 1995

0 10
Miles
0 15
Kilometres

Cropland

Unimproved Pasture

Improved Pasture

Woodland

A Expansion of Cropland on land suitable only for Pasture (CLI Class 4)
B Expansion of Cropland on land suitable only for Pasture (CLI Class 4)
J Matured Shelterbelts

Figure 11: Land Use Change in the Study Area, 1970-1995

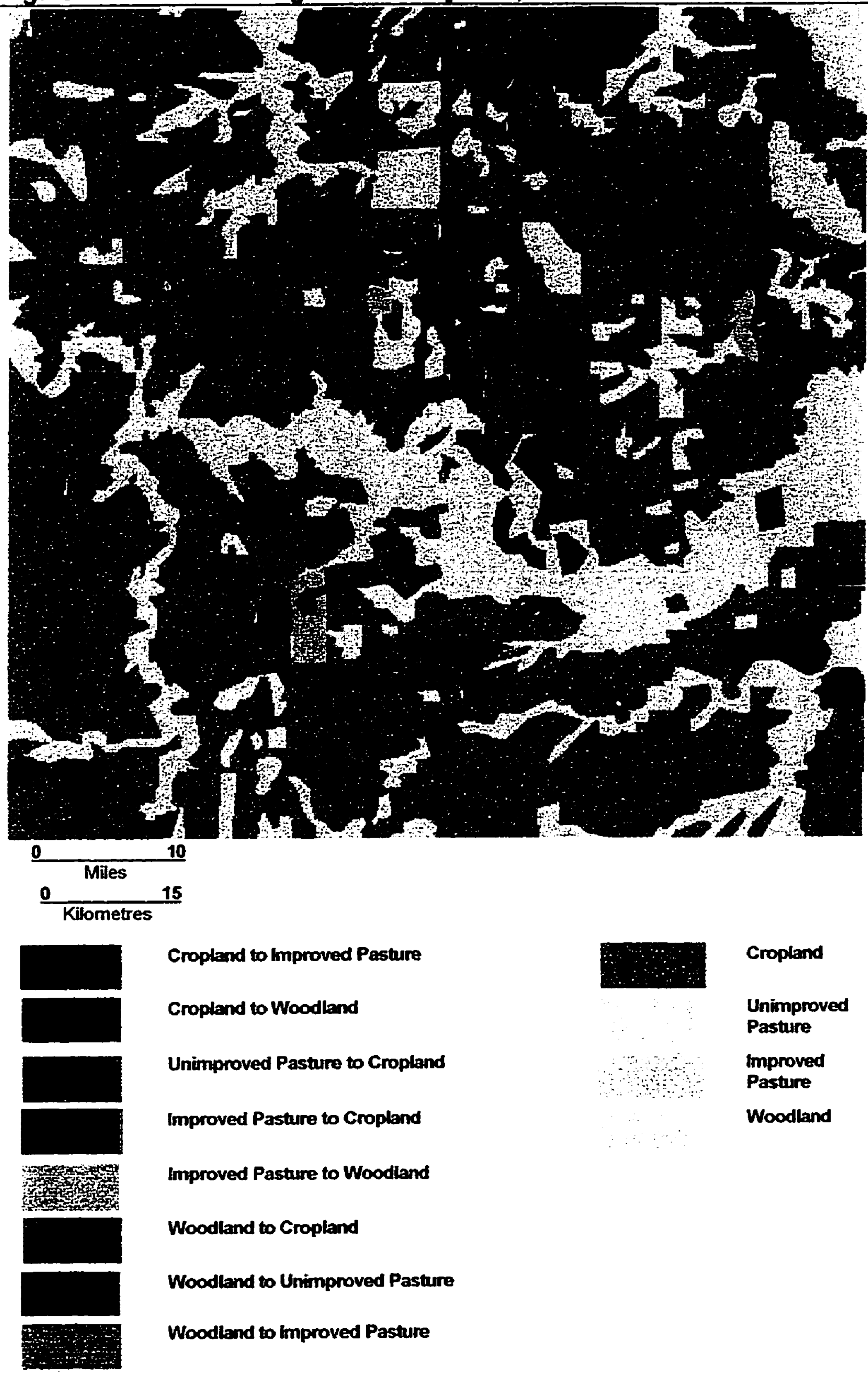
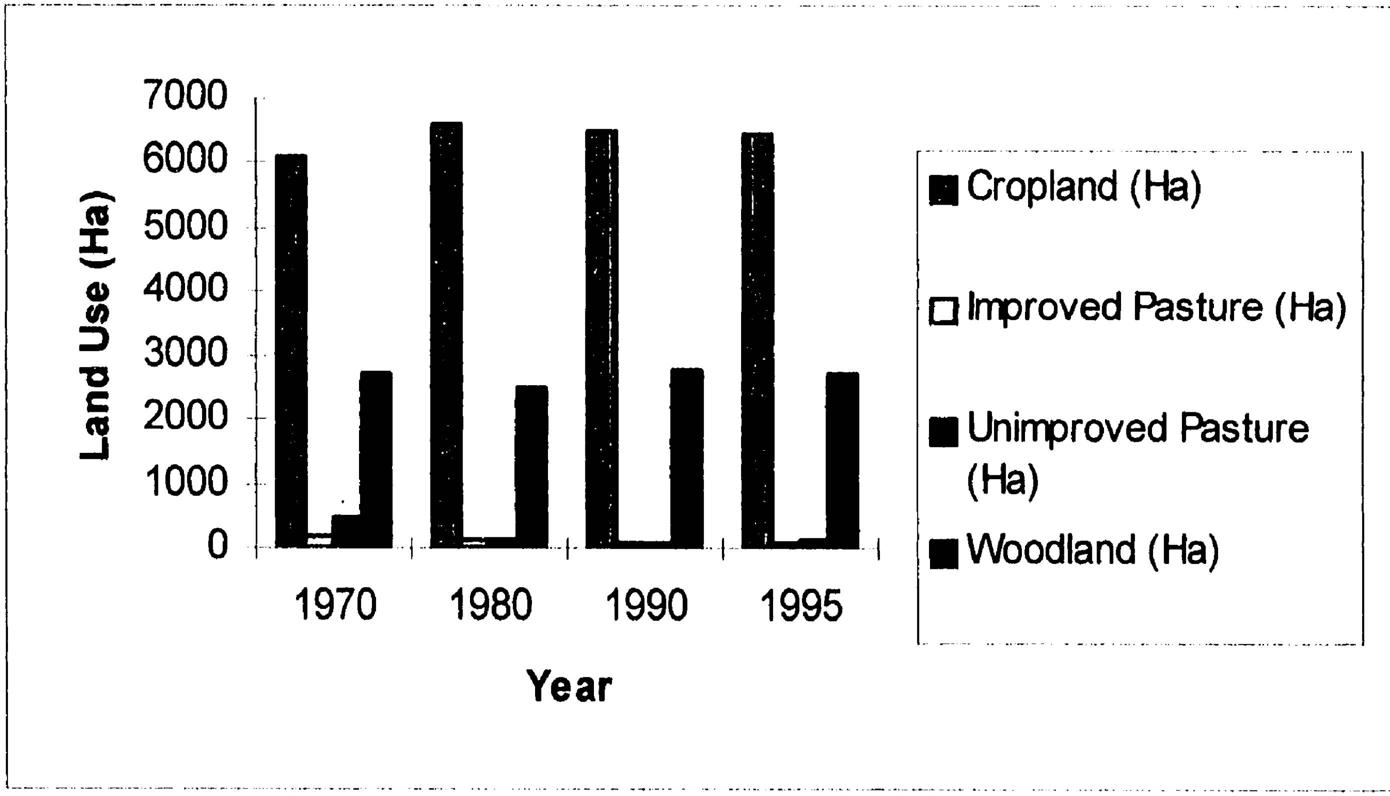


Table 6: Land Use (Ha) in Study Sub-area, 1970-1995

Year	Cropland (Ha)	Improved Pasture (Ha)	Unimproved Pasture (Ha)	Woodland (Ha)
1970	6057.98	145.80	466.98	2669.27
1980	6614.36	98.63	130.97	2495.45
1990	6504.14	79.39	28.98	2727.42
1995	6447.16	83.13	135.42	2673.95

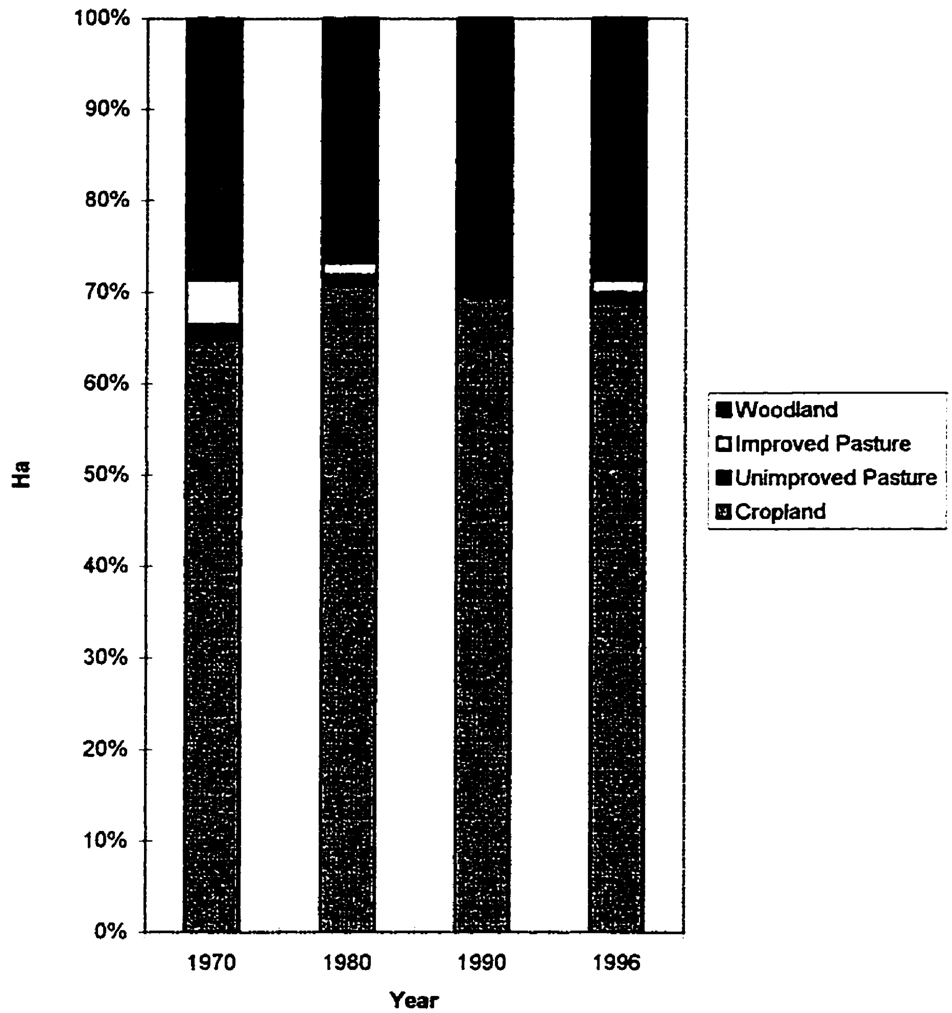
• **Figure 12: Land Use Changes in the Study Area (Ha), 1970-1995**



• Table 7: Percentage of Total Land Use (Ha) in Study Sub-area, 1970-1995

Year	Cropland % of Total Area	Improved Pasture % of Total Area	Unimproved Pasture % of Total Area	Woodland % of Total Area
1970	64.86%	1.56%	5.00%	28.58%
1980	70.83%	1.06%	1.40%	26.72%
1990	69.64%	.85%	.31%	29.21%
1995	69.03%	.89%	1.45%	28.63%

• Figure 13: Percentage of Total Land Use in Ha, 1970-1995



B. Agricultural Census

The Agricultural Census provided a comprehensive set of numbers at 5 year intervals of all land holdings in Canada defined as agricultural use. The census provides a snapshot of agriculture for each census year. Net changes in agricultural land area, land use, and improvements, can be calculated from these data. The principal advantages of the agricultural census are its periodicity and its cost (free to researchers). The 1976 census districts, which exactly correspond to the municipalities of Lorne, Louise, Roblin, Argyle, and Pembina, are used as standards in this study.

Classes of land use recognized by the agricultural census and used in this study are crops (including summerfallow), improved pasture, unimproved pasture, and woodland (including improved and unimproved woodland). Percentages of each land use were calculated as compared to the total area of farms.

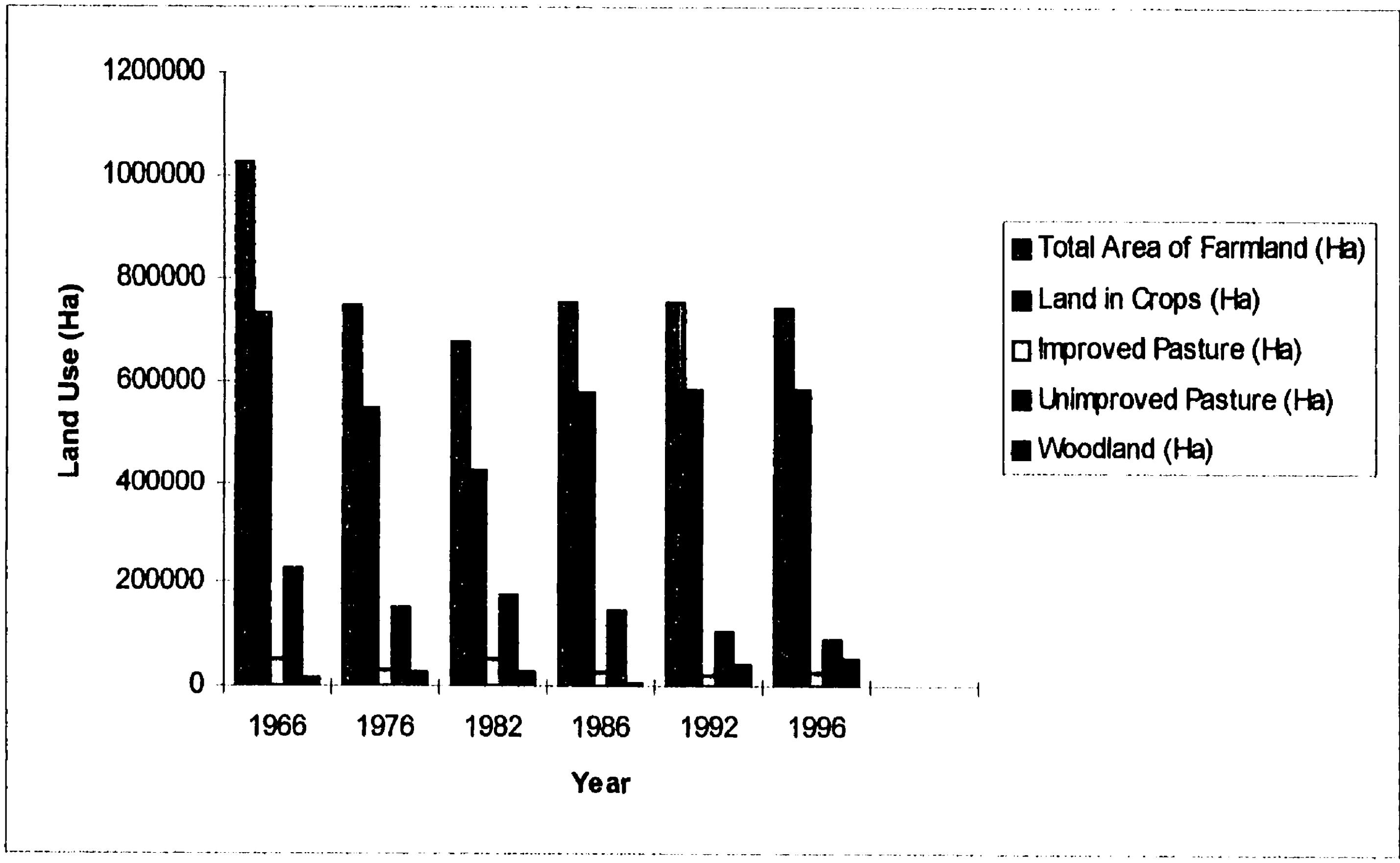
The largest class of land use for all years was crops. Blocks of pasture and other unimproved land were scattered throughout the study area with a clear correlation to relief.

• Table 8: Land Use in Ha for Agricultural Census District 4, 1966-1996

Year	Total Area of Farmland (Ha)	Land in Crops (Ha)	Improved Pasture (Ha)	Unimproved Pasture (Ha)	Woodland (Ha)
1966	1,024,550	735,311	49,514	225,574	14,151
1976	751,448	546,255	30,668	150,159	24,366
1982	675,782	426,557	50,689	173,762	24,774
1986	753,921	580,232	25,107	142,277	6,305
1992	753,634	583,824	22,230	105,883	41,697
1996	746,461	583,463	23,717	89,995	49,286

Source: Statistics Canada

• **Figure 14: Land Use in Ha for Agricultural Census District 4, 1966-1996**



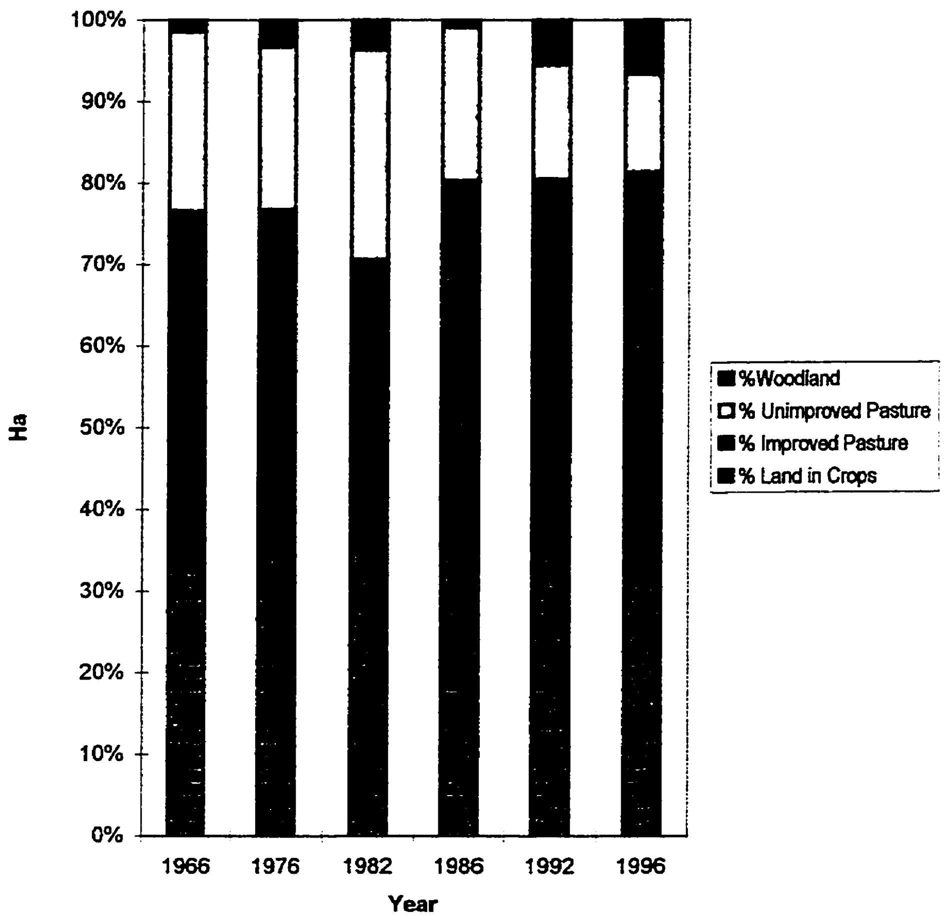
Source: Statistics Canada

Table 9: Percentage of Total Land Use in Ha in Agricultural Census District 4, 1966-1996

Year	% Land in Crops	% Improved Pasture	% Unimproved Pasture	%Woodland
1966	71.77%	4.83%	22.02%	1.38%
1976	72.69%	4.08%	19.98%	3.24%
1982	63.12%	7.50%	25.71%	3.67%
1986	76.96%	3.33%	18.87%	84.00%
1992	77.42%	2.95%	14.05%	5.53%
1996	78.16%	3.18%	12.06%	6.60%

Source: Statistics Canada

• **Figure 15: Percentage of Total Land Use in Ha for Agricultural Census District 4, 1966-1996**



Source: Statistics Canada

2. Interpretation of Results:

In the thirty years represented by this study, woodland and unimproved pasture have been converted to cropland, frequently in areas where the land is unsuitable for supporting any type of crop. There are few examples of land previously used for crops being converted to pasture or woodland, even though these would be more appropriate uses of land for most of the sub-area.

A. Aerial Photography

i. Cropland

The continued cropping of land deemed unsuitable for crops or, in some cases, expansion of cropped area is evident. An example of this can be seen in sections 28 and 29. (Points A and B on Figure 10, page 64). Rough grazing land in section 13 (Point C on Figure 7, page 61) and productive woodland in sections 15 and 22 (Points D and E on Figure 7, page 61) were converted to cropland. A noticeable increase in cropland resulting from the cultivation of basins is seen in the 1990 and 1995 images following the drought of the 1980's. Once cultivated, these basins are often drained to maintain yields. A decrease in the overall amount of land used for summerfallow is noted throughout the study period.

ii. Improved Pasture

The return of some land deemed unsuitable for crops to pasture was noted in some areas. An example of this can be seen in section 29. (Point F on Figure 8, page 62). A slight increase in pasture land is noted on the 1995 images that could be attributed to the Permanent Covers Program.

iii. Unimproved Pasture

The return of some land deemed unsuitable for crops to unimproved pasture was noted in some areas but, overall, a decrease in the overall amount of land used for rough grazing is noted.

iv. Woodland

A decrease in the amount woodland occurred during the1980s and can be viewed in the 1990 image. An example of this can be seen in section 21. (Point G on Figure 9, page 63). A slight increase in woodland is noted on the 1995 images that could be attributed to the Permanent Covers Program.

In some areas unproductive woodland was cleared and used, frequently, for crops and , occasionally for pasture. An example of this can be seen in section 36. (Point H on Figure 8, page 62)

v. Other Changes

Conservation efforts such as grassed waterways (seen in section 29) were in evidence in the 1980 images but not visible in the 1990 or 1995 images. (Point I on Figure 9, page 63). Not all areas show improvement in land use decisions. The Moreau Gully (section 17) continues to grow in size. In each image used in this study the land immediately surrounding the gully was used for crops. Shelterbelts on some farms have matured and can be detected on aerial photography. An example can be seen in section 26 (Point J on Figure 10, page 64).

In summary, there is an obvious efforts to employ conservation methods and move to appropriate land use in the 1980 images. In some areas a return to inappropriate land use is observed in the 1990 and 1995 images.

B. Agricultural Census

The analysis of agricultural census data confirms the trends observed in the interpretation of aerial photography.

i. Cropland

Lands in crops remains approximately the same. Although summerfallow was not considered as a separate category it is important to note that since the 1982 census there has been a steady decrease in summerfallow. This trend can be confirmed by the analysis of aerial photography.

ii. Improved Pasture

A trend toward increased land in pasture and decreased land used for crops and summerfallow is apparent in the early 1980s. A slight reversal of this trend is noted in subsequent years. These results are comparable to the findings of the air photo analysis.

iii. Unimproved Pasture

A slight increase in unimproved pasture was noted in the 1982 results. The amount of unimproved pasture has slightly decreased in subsequent census years. The results are similar to those of the air photo analysis.

iv. Woodland

The amount of woodland declined steadily until the 1982 census and then showed a slight increase. Only the 1995 aerial photography demonstrated a slight increase in woodland.

3. Discussion and Recommendations

The objective of the CLI was to promote the wise use of land resources. Land use decisions are governed by a number of factors including: government policies, environment, economic conditions, technological advances, and human factors.

A. Factors Influencing Land Use Change

i. Land Use Changes in Response to Government Programs

In the 1960s and 1970s many conservation efforts were attempted at all levels of government, often seemingly without much co-ordination among agencies. Financial incentives were frequently offered as part of the assistance packages. During this time the ground work was established for future efforts, including the Land Rehabilitation Act, The Planning Act, and The Conservation Districts Act. Conservation efforts are evident in the 1980 aerial photography.

In the 1980s a movement toward inter-agency cooperation (focusing on soil conservation) in the wake of the Federal Policy on Land Use (1980) led to sharing of information, coordination of financial assistance, and shift in focus toward education and technical assistance rather than financial incentives.

A reduction in conservation efforts is visible on the 1990 images. This may be attributed to drought conditions existing through most of the 1980's. Because of the drought, former wetlands were cultivated, perhaps to address a need to bring as much land as possible into production to maintain income. By 1990 many of the conservation efforts (such as grassed waterways) noted on the 1980 image were no longer evident on aerial photography.

Canada's "Green Plan" (1987) included an effort to expand environmental sustainability in agriculture. By the 1990s resources were being allotted for demonstration and technical assistance rather than direct financial assistance. The Permanent Cover Program (a component of the National Soil Conservation Program, 1989) provided a payment to land owners to permanently convert eligible land from annual crop to permanent forage or trees. Land with CLI classifications 4, 5, and 6 were eligible for this program. A slight increase in woodland and pasture land is noted on the 1995 images that could be attributed to this program.

In the mid-1990s changes were made to several government programs. The Western Grain Transportation Act was eliminated. In time the increased costs of bringing crops to market may encourage owners of marginal land to convert cropland to permanent cover. Other policy changes that may reduce the incentive to grow crops on marginal land include changes of the Canadian Wheat Board quota system, discontinuing of the Guaranteed Revenue Insurance Program (GRIP) and a review of Crop Insurance. Land use changes resulting from these policy changes were not yet evident on the 1995 aerial photography.

ii Environmental Factors

Environmental awareness increased overall in the 1970s. This awareness was evident in the adoption of conservation efforts such as grassed waterways on the 1980 images. Prolonged periods of drought, such as those experienced in the 1980s (Appendix C), expose dry basins where wetlands previously existed and encourage the conversion of wetlands to agriculture by exposing areas that are potentially arable. While this was a period of increased government focus on soil conservation and sustainability, at the farm level conservation efforts seemed to have been abandoned. In the 1990s precipitation returned to normal levels and the need to convert marginal land to permanent status seemed less urgent. No obvious attempt was made to reestablish conservation efforts (such as grassed waterways), as is visible on the 1990 or 1995 images.

iii Economic Factors

Changing economies of agricultural production are often reflected in land use decisions (e.g., noticeable decrease in summerfallow around

1976). The change in government policies reducing the amount of financial incentives for conservation seems to have coincided with the reduction of conservation efforts and the increase in cropland beginning in the 1980s.

The main reason for the cultivation of Class 4, 5, and 6 land during the study period has been linked to the world price of grain (Appendix D) (Vaisey, et al.: 1996). The cultivation of marginal land in the study area seems constant in spite of the fluctuation of grain prices.

On-farm costs resulting from conservation practices often outweigh on-farm benefits. In view of the reduction of available financial assistance from governments, occurrences of droughts, and depressed world grain prices, it is possible that farming, like any other business, is forced to focus on the "bottom line".

iv Technological Factors

Technological and management advances (machinery, seed varieties, chemicals) have made it possible to farm land once considered unsuitable for crop production. In spite of this wealth of technology to improve short-term production many farmers lack site-specific knowledge of their land's degradation and of modern conservation practices. The best economic return is possible when land use is suited to land capability, i.e., the chemical and technical investment needed to produce crops on Class 4 land may exceed (or at least greatly limit) financial return (Hiley and Richards: 1995). For example, change in field size and shape (necessary to accommodate larger machinery) is evident on the sequence of air photo images, even though this change is inappropriate for the topography of the area.

During the last 30 years there have been many improvements in the communication of scientific and technical information through the media, including the Internet. The potential for rapid dispersement of new technologies to the land owner should become increasingly evident in agriculture. Great possibilities exist with the Internet. The decreasing cost of computers and Internet service it possible for most land owners to have access to this technology. The Internet provides a means to access the information on government policies and the latest research from government, industry, and universities. The sharing of information with peers is possible through newsgroups, e-mail, and personal web pages.

v. Human Factors

Humanly induced elements considered in studies on land use change (such as land occupancy, land cover, and tenure) must be reviewed in conjunction with socio-economic change such as population, income, and education.

Land owners are generally better educated than they were even a generation ago. This provides a better understanding of changing trends in land use and contributes to informed decision making.

Like any other business, the focus in farming is on achieving a profit. Land owners frequently assess the suitability of the land by comparing the value of the goods produced to the cost of production.

Farm population has been steadily declining since its peak during agricultural settlement. Advances in technology (machinery, chemicals, and seed varieties) have reduced the need for human labor in farming. Conversely, a family farm no longer achieves the level of profit to support more than a few adults.

vi. Summary

Some basic ideas must be considered when monitoring land use problems. Exact knowledge about the actual state of the problems (causes and impacts) is necessary. Government agencies must continue to build and share a base of knowledge about land capability and suitable land uses. Competing government policies are the major challenge for conservation adoption (e.g., policies that favor the production of cereal crops such as grain quotas based on amount of land as opposed to the capability of the land). Land use proposals developed by various levels of government need to be realistic for the area. These proposals must consider factors such as cost, available labor, skills of the workforce, and involvement from other levels of government.

Farmers who recognize the need to analyze, and possibly change, land use on their property may apply for assistance in developing and applying a conservation plan from Manitoba Agriculture or PFRA. This assistance includes planning and financial assistance.

In the 30 years of land use and conservation efforts reviewed for this study there has been a movement from treating the symptoms to treating the cause of inappropriate land use. Earlier efforts focused on reducing the effects of inappropriate land use. For example, grassed waterways and shelterbelts slowed the effects of wind and water erosion on cropland but often did not address the underlying problem (i.e., because of the high risk of erosion, these lands were not considered capable of supporting crops). Recent efforts, such as the Permanent Covers Program promoted through the National Soil Conservation Program, address the cause of land degradation by permanently removing from production land considered to be incapable of supporting crops.

B. Effectiveness of the Research Method

Analysis of aerial photography provided evidence of land use trends. Trends could often be related, directly or indirectly, to the establishment of government policies, environmental factors, changing economies, and human influences. This research offers the advantages of low-cost, easily acquired data. Interpretation of land uses on aerial photography can be accomplished with a minimum of equipment (simple analysis can be completed with a hand-held stereoscope). If further analysis is necessary, data can be processed with a GIS.

Analysis of agricultural census data may have some value in demonstrating trends in a census division, but their value is questionable in a study of land use at the township level. Information provided by land owners is quite generalized and since anonymity of census participants is protected specific problem areas cannot be pinpointed. More appropriate methods of confirming trends in land use would be regularly scheduled field verifications and personal interviews with land owners.

While analysis of aerial photography and agricultural census data provides evidence of trends, it does not provide evidence of the driving forces behind the trends. Studies of land use change are greatly enhanced if physical evidence and government policy reviews were accompanied by personal information provided by land owners (ideally by personal interview or questionnaire).

C. Effectiveness of the Canada Land Inventory

When published in 1967, the Canada Land inventory provided baseline ratings for agricultural capability. Most of the parameters used to rate agricultural capabilities are unlikely to change in the future (e.g., topography, soil texture, and stoniness). Some parameters will vary slightly over a short term (i.e., soil moisture may be reduced during a drought and soil fertility can be altered with fertilizers). The CLI provided a simple structure for land management decisions to be based on land capability. Many government policies involving land use and soil conservation have been based directly or indirectly on the CLI (for example: The Planning Act, 1976, and the National Soil Conservation Program, 1987).

The CLI neglects factors, other than the physical attributes of the land, which influence land use decisions, for example, fluctuations in the natural environment (e.g., droughts) and technological advances (e.g., improved fertilizers, machinery, and seed varieties). While the physical capability of the land is the primary concern in land use decisions, social and economic factors must also be considered. Because these factors will change much more rapidly than the physical factors, land use plans should be routinely reevaluated with full consideration given to all elements.

While the CLI provided a valuable baseline for land use planning for the past 30 years improvements in the quantity and quality of soil survey data may make this a preferred source of agricultural land use planning information. Soil surveys in recent years have been broadened to include ratings of land quality and soil suitability for various uses (including those for land uses other than agriculture, such as recreation and wildlife).

4. Potential Sources of Error

Three potential sources of errors may occur in land use studies: errors in the original data, inconsistencies in the transfer of the information, or misinterpretations or omissions of information in the final report. (Reeds: 1965).

A. Aerial Photography

Aerial photography provides a "snapshot" of land use at specific points in time. The quality of the data extracted from an aerial image can be affected by the actual flight path and atmospheric conditions. The skill of the photographer also affects the quality of the images (e.g., camera angle, resolution, and film processing). The images used in this study provided complete coverage of the study sub-area and no evidence of adverse atmospheric conditions is apparent. Some of the images were captured at a small scale (approximately 1: 70 000) and it was necessary to enlarge the images for interpretation. No loss of information occurred as a result of the enlargement.

The classification scheme is the most important factor in analyzing land use patterns on aerial photography and the level accuracy of the maps produced is closely related to this scheme. The classification scheme used in this study was developed for the original Canada Land Inventory (McClellan: 1968). The scheme is simple and easy to use but tends to be very generalized. The high relief of the study area (end moraines dissected by a valley) created some difficulty in classifying land use and placing boundaries between land use types, particularly on the steep slopes. Generalizations within land use units and along boundaries between land use units create the potential for errors in the results. This potential error could be reduced by using a larger scale. Digitizing these maps for processing in a GIS results in some further generalization of the data and may also contribute to some inaccuracies of the results.

The degree of accuracy achieved in the interpretation of aerial photography ultimately depends on the skill of the interpreter.

B. Agricultural Census

One limitation of the agricultural census is the inconsistency of definitions for many variables. (i.e., census district boundaries may change or land use classifications may vary between census years).

Errors may occur in the original data because the survey relies on information provided by land owners who may misunderstand the survey or incorrectly evaluate the land use on their property.

Errors in the transfer of data may occur by the miscalculation or misrepresentation of information by the land owners. The census indicates that rural change is occurring, but it does not document where new agricultural land came from or where "lost" agricultural went (i.e., agricultural census is most valuable for indicating land use trends rather than amounts and locations of specific land uses).

When interpreting an agricultural census report, some data are subject to interpretation and some built-in inaccuracies impair objectivity. Therefore census data cannot be used to reliably measure the intensity of land use or the nature of land use change. However this data is valuable in indicating trends. (Smit et.al: 1984)

C. Comparison of Agricultural Census Data to Aerial Photography Results

Along with the compilation of errors in the original data, the comparison of results obtained from agricultural census and aerial photography will manifest further errors. For example, agricultural census data are not site specific. The census data gives a general overview for the entire census district and can provide verification for conclusions reached by interpreting aerial photographs for the same area (i.e., define trends but not specific problem areas).

Aerial photography surveys may not have been conducted in census years. In this study images were used from the years 1970, 1980, 1990, and 1995 and the agricultural census was taken in 1966, 1976, 1982, 1986, 1992, and 1996 (the agricultural census at 1972 was not used in this study because the census district boundaries did not coincide with the other study years).

The aerial photographs are a representation of actual conditions that existed at a specific time. The agricultural census represents farmer-estimated values of land use a specific crop year. Hiley and Richards (1995) state that, while very similar estimates of land use are found between remotely sensed images and agricultural census inventories, census estimates are higher for cultivated and lower for uncultivated areas as compared to remotely sensed images. This is attributed to the uncertainty of the land owner when classifying non-productive land such as farmsteads when completing the census questionnaire.

In this study the agricultural census represents the land use of an entire census division. The aerial photographs represent a portion of the census division where land of low capability is often managed inappropriately. While similar trends can be observed in both sets of data, neither source offers a precise account of land use and neither source can accurately validate the results of the other analysis.

5. Chapter Summary

The interpretation of the aerial photography and the analysis of the agricultural census data of the study area indicates that agricultural land use is progressing toward more appropriate land use since the publication of the CLI.

Aerial photography is an inexpensive source of land cover/land use information. However the completeness and accuracy of the interpretation ultimately depend on the skill of the interpreter. Interpretation of a series of images of the study sub-area that were captured between the years 1970 and 1995 indicates that land use in some sections of the study area has become more appropriate to its agricultural capability. Some problem areas still exist, most notably the Moreau Gully. Large tracts of land continue to be cropped in spite of the Class 4 capability.

Analysis of agricultural census data reveals net changes in the agricultural census district but does not document the dynamics of these changes. The census data is valuable in verifying the conclusions resulting from the interpretation of aerial photography. Analysis of the agricultural census data for the study area obtained for the years 1966 to 1992 indicates a trend toward less cropland (especially a reduction in the amount of land in summerfallow) and more natural and improved pasture.

This also indicates a movement to more appropriate land use according to the CLI recommendations.

In the study sub-area some farms showed a definite move to more appropriate land uses while others tended to use poorly suited land for crops and summerfallow.

The results of this study will stop short of making the claim that the CLI was solely responsible for land use change in the study area. It is possible that land use changes were made for other reasons such as climate variation, land owner education, increase in chemical agriculture, improved mechanical agriculture, and improved communication. Most government policies directing agricultural land use decisions reflect the recommendations of the CLI. Education, technical, and financial assistance is directed toward the maintenance and improvement of agricultural land quality including the adaptation of appropriate land use.

Chapter 5: Summary and Conclusions

Land use patterns change over time in response to economic, social, and environmental forces. The study of land use changes allows the identification of long-term trends and the formulation of policy in anticipation of the problems that accompany changes in land use.

The purpose of this study was to determine the specific changes that occurred in land use in the Pembina Hills area of south-central Manitoba since the publication of the Canada Land Inventory in 1967. The most important factor affecting land use in the study area is the irregular topography that contributes to the serious problem of soil erosion by water.

Land use changes were assessed by analyzing and comparing aerial photographs of the study sub-area (TWP 6, R8W) for the years 1970, 1980, 1990, and 1995. Agricultural census data were analyzed to confirm the land use trends observed in the aerial photography. This indicated a trend for the years 1966-1982 throughout Agricultural Census Division 4 of slightly decreasing amounts of farmland used for cereal crops (including summerfallow) and a corresponding increase in land used for improved and unimproved pasture. The trend reversed for the years 1986-1992.

The results of the analysis of agricultural census data are comparable with the interpretation of aerial photography in the sub-area of the study area. A decrease in cropland (especially summerfallow) and a corresponding increase in pasture is noted in the 1970 and 1980 images (Figures 7-10). For some areas the trend was reversed in 1990 image. Some problem areas remain. For example, the Moreau Gully continues to be surrounded by cropland and continues to grow in length and complexity. Aerial photography from 1980 displays visible improvement in land management. For example, many of the gullies in the area are contoured into grassed waterways. In the 1990 images many of these gullies were, again, under cultivation.

The Canada Land Inventory classified most of the farmland in the study area between Class 1 and Class 3 (suitable for cereal crops). Within the study area numerous smaller areas of land poorly suited or unsuitable for agriculture (Classes 4 to 6). In most situations topography and/or high soil moisture content were responsible for the low ratings. In the study sub-area much of the land is rated Class 4 or lower. In spite of the low rating, most of the area continues to be planted in cereal crops. Often the decisions appear to be farm-specific and examples of neighboring farms practicing very good and very poor conservation methods can be observed.

Overall, this study concluded that some changes in land use have occurred in the study area and that the changes represent a move toward the type of land use that is recommended by the CLI for the area.

The results of this study stop short of making the claim that the CLI was responsible for all land use change in the area. Changes in land use can be attributed to the changing economies of agricultural production, technological and management advances in farming, a changing labor supply, government policies, and changes in the natural environment (i.e., minor climate fluctuations).

There must be a public understanding of the planning process. Coordination of land use decisions with all levels of government needs to be a high priority. A significant involvement by all sectors will ensure that the maximum benefit for the minimum cost from all land-use related policies. Conservation efforts should continue to be initiated at the local (farm) level with technical and financial assistance from government agencies and an increased awareness of soil conservation benefits and land degradation costs by all levels of society.

To accomplish appropriate land use, technical assistance needs to be provided to farmers for diagnosis of their problems, for the development of practical solutions, and for the implementation of those solutions. Financial and material incentives should be made available to farmers to undertake conservation practices that appear to have short-term economic penalties. Research on a number of land degradation and soil conservation problems should include a more precise survey of the status of land degradation and continuous monitoring of the situation. In Manitoba, agriculture conservation and planning assistance programs have evolved and are now well established, especially in high-risk areas such as the Manitoba Escarpment.

Wettlaufer and Brand (1992) state that "competing government policies are perhaps the major challenge for conservation adoption." Policies that encourage monoculture and favor the production and transport of cereal grains over other crops, provide almost overwhelming support to the status quo. Similarly, policies that manage product deliveries based on the amount of land (Ha) owned and/or cultivated encourage the cultivation of marginal land. Finally, programs that reduce the price of fuel to farmers encourage unnecessary tillage. While a movement has been made to coordinate agricultural planning and conservation efforts at all government levels, there is a need to encompass other government departments when making decisions regarding grain quotas, transportation, and farm subsidies.

In conclusion, the CLI provides useful information for regional planning but must be supplemented with economic and social information to ensure complete representation of the agricultural industry in the planning process.

Land is not a renewable resource on a human time-scale. Natural processes act to both destroy and create land and to increase and decrease its quality. However, these are slow processes compared with human activities that may quickly degrade land. Good planning of land use restricts activities that degrade the land and encourages those agricultural and recreational uses that can preserve or enhance land quality.

If land use planning is to be used effectively to support sustainable development, there must be a clear and coherent structure of communication and responsibilities, from policy direction to day-to-day management and decision-making, in every land related public program.

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Appendix A: The Agricultural Land Classification System (Canada Land Inventory)

In the CLI classification system of land capability for agriculture, mineral soils are grouped into seven classes according to their potential and limitations for agricultural use.

Class I

Soils of this class have no significant limitations for crop use. They are generally level, or have very gentle slopes, deep, well-to-imperfectly drained, and have good waterholding capacity.

Class 2

Soils of this class have moderate limitations that restrict the range of crops or require moderate conservation practices. Class 2 soils are deep and have good water-holding capacity. The limitations of the soils in this class may be, for example, adverse regional climate, moderate erosion, poor soil structure, or low fertility that is readily correctable.

Class 3

Soils of this class have moderately severe limitations that restrict the range of crops or require special conservation practices. Although these soils have more severe limitations than those in Class 2, they are still fair to moderately high in productivity for a fairly wide range of field crops adapted to the region. Limitations may be a combination of those described under Class 2, or are of the following moderate climatic limitations, moderately severe erosion, intractable soil mass or very slow permeability, correctable low fertility, moderate to steep slopes, frequent runoff accompanied by crop damage, or stoniness necessitating some clearing.

Classes I to 3 are considered to be capable of sustained annual production of common cultivated crops.

Class 4

Soils in Class 4 have such limitations that they are suitable for only a few crops, the yield for a range of crops is *low*, or crop failure is high. These soils are low to medium in productivity for a narrow range of crops but may have higher productivity for a specially adapted crop. Limitations may include steep slopes, severe past erosion, frequent surface runoff with severe effects on crops, severe salinity, extreme stoniness, or severe aridity.

Class 5

Class 5 soils have such serious physical, climatic or other limitations that they are not capable of use for sustained production of annual field crops. Class 5 soils are amenable, however, to improvement and, with intensive management practices, may be used for permanent pasture. The limitations described in Classes 2 to 4 may be present for Class 5 areas. Cultivated field crops may be grown in Class 5 areas where adverse climate is the main limitation but crop failures will occur under adverse conditions.

Soils of Classes 4 and 5 are considered suitable for most varieties of forage crops.

Class 6

Soils of this class are capable only of producing perennial forages and improvement practices are not feasible. Class 6 soils have some natural, sustained grazing capacity for fan-n animals, but they have such serious climatic or other physical limitations that the application of improvement practices is impractical.

Class 6 soils are marginal for any agricultural use but they can often support periodic rough grazing.

Class 7

Soils of this class have no capability for arable culture or permanent pasture. Combinations of severe climatic and physical limitations preclude economic use of the land for agriculture.

All classified areas, except organic soils, and sods not designated as Classes I to 6, are placed in Class 7.

Subclasses

The CLI has a detailed sub-classification system for agricultural land that defines the limitations inherent in a land area. Each area is classified according to its capability and additional symbols indicate limiting factor.

C	adverse climate
D	undesirable soil structure and/or low permeability
E	erosion
F	low fertility correctable by careful management and fertilizer use
I	inundation by streams or lakes
M	moisture limitation (usually due to low water-holding capacity)
N	salinity
P	stoniness
R	consolidated bedrock near surface
S	adverse soil characteristics in general
T	topography
W	excess water
X	cumulative minor adverse characteristics

Source: Environment Canada, 1970. Canada Land Inventory: Land Capability for Agriculture Preliminary Report. Ottawa: Environment Canada-Lands Directorate.

Appendix B: Summary Of Classification For Canada Land Inventory Present Land Use

1) **URBAN**. Land used for urban and associated non-agricultural purposes.

- *Built-up Area*. (Parks and other green spaces within built-up areas are included.)
- *Mines, Quarries, Sand and Gravel Pits*. (Land used for the removal of earth materials.)
- *Outdoor Recreation*. (Golf courses, parks, beaches, summer cottage areas, game preserves, and Historical sites.)

2) **AGRICULTURAL LANDS**.

- *Horticulture, Poultry, and Fur Operations*. Land used for intensive cultivation of vegetable and s al fruits including market gardens, nurseries, flower and bulb farms, and sod farms. Large scale commercial fur and poultry farms are also included because of their specialized agricultural nature.
- *Orchards and Vineyards*. Land used for the production of tree fruits, hops, and grapes.
- *Cropland*. Land used for annual field crops: grain oilseeds, sugar beets, tobacco, potatoes, field vegetables, associated fallow, and land being cleared for field crops.
- *Improved Pasture and Forage Crops*. Land used for improved pasture or for the production of hay and other cultivated fodder crops including land being cleared for these purposes.
- *Rough Grazing and Rangeland*.
    - Areas of natural grasslands, sedges, herbaceous plants, and abandoned farmland whether used for grazing or not. Bushes and trees may cover up to 25 per cent of the area. If in use, intermittently-wet, hay lands (sloughs or meadows) are included.
    - Woodland grazing: If the area is actively grazed and no other use dominates, in some grassy, open woodlands, bushes and trees may somewhat exceed 25 per cent cover.

3) **WOODLAND**. Land covered with tree, scrub, or bush growth, including:

- *Productive Woodland.* Wooded land with trees having over 25 per cent canopy cover and over approximately 20 feet in height. Plantations and artificially reforested areas are included regardless of age.

- *Non-Productive Woodland.* Land with trees or bushes exceeding 25 per cent crown cove-r, and shorter than approximately 20 feet in height. Much cut-over and burned-over land is included.

4) **WETLAND**.

- Swamp, Marsh or Bog. Open wetlands, except those which frequently dry up, and show evidence of grazing or hay cutting.

5) **UNPRODUCTIVE LAND**. Land which does not, and will not, support vegetation, e.g., eroded soil or rock and active depositional features.

- *Sand.* (Sand bars, sand flats, dunes, beaches.)

- *Rock and Other Unvegetated Surface.* (Rock barrens, badlands, sand flats, gravel bars, eroded river banks, mine dumps.)

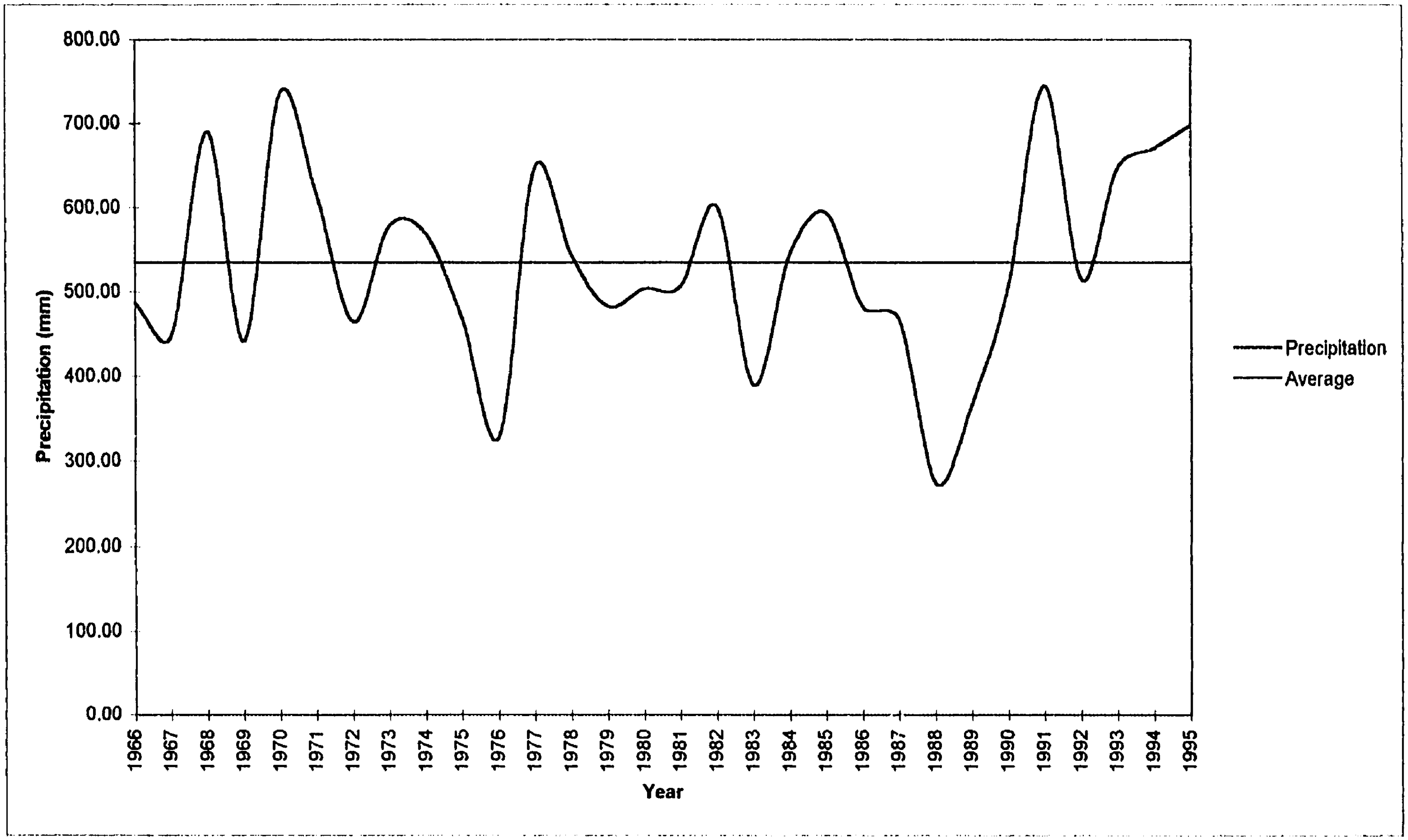
6) **WATER**.

Source: Scace, R. C. 1981. Land Use Classification: An Overview. Lands Directorate Working Paper No. 14. Ottawa: Environment Canada-Lands Directorate.

Appendix C: Annual Precipitation Records for Morden, 1966-1995

Year	Precipitation
1966	485.84
1967	447.72
1968	689.58
1969	441.37
1970	736.21
1971	616.45
1972	463.22
1973	576.55
1974	568.16
1975	466.78
1976	328.55
1977	646.30
1978	542.70
1979	482.50
1980	502.80
1981	505.80
1982	600.10
1983	388.80
1984	544.10
1985	593.10
1986	481.00
1987	466.50
1988	273.60
1989	367.20
1990	506.80
1991	745.00
1992	514.00
1993	646.00
1994	670.00
1995	697.00
Average	**533.12**

- **Annual Precipitation at Morden, 1966-1995**

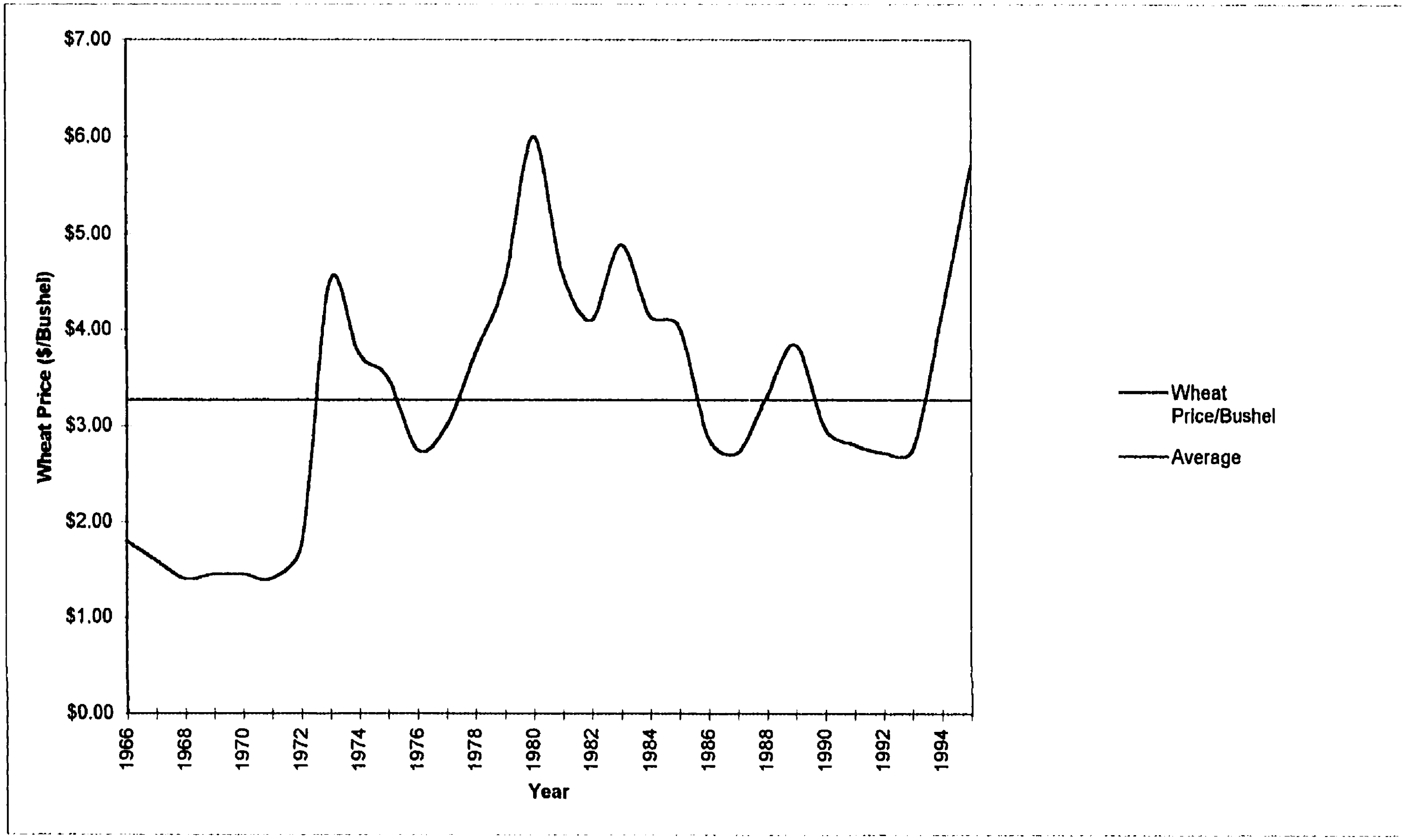


Source Manitoba Agriculture Yearbook

Appendix D: Price of Wheat ($/ Bushel), 1966-1995

Year	Wheat Price
1966	1.80
1967	1.60
1968	1.40
1969	1.45
1970	1.45
1971	1.40
1972	1.75
1973	4.50
1974	3.75
1975	3.50
1976	2.75
1977	3.00
1978	3.75
1979	4.50
1980	6.00
1981	4.59
1982	4.10
1983	4.89
1984	4.14
1985	4.03
1986	2.86
1987	2.72
1988	3.31
1989	3.84
1990	2.97
1991	2.80
1992	2.72
1993	2.75
1994	4.15
1995	5.70
Average	3.27

• **Price of Wheat ($/Bushel), 1966-1995**



Source Manitoba Agriculture Yearbook