PAPER

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LANDSCAPE CHANGES AT CANADA'S BIOSPHERE RESERVES: AN OVERVIEW OF LAND CHANGE STUDIES

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ABSTRACT: Results of landscape change studies at six of Canada's Biosphere Reserves show that resource development and human settlement are the major drivers of landscape changes at Biosphere Reserves since European settlement of Canada. Most of the major landscape changes occurred in the early days of European settlement of Canada, yet significant changes are occurring today. Resource development and human settlement is common across all the studies resulting in landscape changes including: the removal of forests, conversion of grasslands and draining of wetlands in order to convert land for agricultural purposes; and the building of houses, roads and other infrastructure to support an ever-increasing human population. Landscape changes at Biosphere Reserves have significantly fragmented wildlife habitats threatening wildlife species such as the grizzly bear (Waterton), caribou (Charlevoix) and scarlet tanager (Niagara Escarpment). These species are reflecting the impacts of land use change as indicators of overall wildlife habitat decline. The protected areas at Biosphere Reserves provide an opportunity to support wildlife species, but when species require more undisturbed area than the protected areas can provide, then certain wildlife become threatened. The paper demonstrates the significant insights about changes that humans have brought on the landscapes around Biosphere Reserves since European settlement of Canada that can be gathered from existing landscape data and information around protected areas.

Keywords: landscapes, land-use change, environment, biosphere reserves, wildlife, habitat, protected areas, sustainable development

1. Introduction

In October 1995, the Honourable John Fraser, Chair of Canada MAB, signed a Memorandum of Co-operation along with the MAB programs of the United States and Mexico that included the commitment for Canada to make available land cover maps from Canada's Biosphere Reserves (US National Committee for the Man and the Biosphere Program, 1995). Two years later, a partnership of the Ecological Monitoring and Assessment Network (EMAN) of Environment Canada, the Land Use Policy Branch of the Ontario Ministry of the Environment (MOE) and the Canadian Biosphere Reserve Association (CBRA) initiated the Biosphere Reserve Landscape Change Project - a project to conduct a landscape change analyses using original land survey records, air photos, satellite imagery or some combination of all three. The objective of the analyses was to provide an understanding to decision-makers and the Biosphere Reserve communities of the dramatic changes that humans have brought on the landscape since European settlement, and some understanding of the natural environment that surrounds them, or "sense of place".

The objectives of the analyses were:

- To test approaches to landscape change analysis within diverse landscapes and environments across Canada;
- To highlight the dramatic changes that humans have brought on the landscape since European settlement through landscape change data and information;
- To provide government agencies and others with landscape change data and information to better inform their decision making; and
- To provide Biosphere Reserve communities with some understanding of the natural environments that surround them (and how these environments have been changing) toward further developing each communities "sense of place". A community's "sense of place" is in part awareness of the local environment and a shared history of the area, but also involves something more in terms of individual values and feelings towards the land or values attributed to the elements of the land.

Each of the studies was undertaken with a different set of local objectives, available technologies, and available resources. Their results reflect these differences. This paper recognizes that each study has great value individually, yet this paper focuses on certain patterns that emerge across all the studies that can be used as valuable lessons for future landscape change studies.

2. Biosphere Reserves in Canada

Biosphere Reserves are areas of terrestrial or coastal ecosystems that are internationally recognized within UNESCO's Man and Biosphere Program for promoting and demonstrating a balanced relationship between people and nature. Presently there are 440 Biosphere Reserves in 97 countries (United Nations Educational, Scientific and Cultural Organization, 2004).

Each Biosphere Reserve is intended to fulfil three basic functions, which are complementary and mutually reinforcing.

- a conservation function - to ensure the conservation of landscapes, ecosystems, species and genetic variation.
- a development function - to promote, at the local level, economic development which is culturally, socially and ecologically sustainable.
- a logistics function - to provide support for research, monitoring, education and information exchange related to local, national and global issues of conservation and development.

Since 1978, eleven areas in Canada have been recognized internationally as World Biosphere Reserves (see Figure 1): Mont St. Hilaire (Quebec, 1978); Waterton (Alberta, 1979); Long Point (Ontario, 1986), Riding Mountain (Manitoba, 1986); Charlevoix (Quebec, 1989); Niagara Escarpment (Ontario, 1990); Clayoquot Sound (British Columbia, 2000); Redberry Lake (Saskatchewan, 2000); Lac St. Pierre (Quebec, 2000); Mount Arrowsmith (British Columbia, 2000); South West Nova (Nova Scotia, 2001); and Thousand Islands – Frontenac Arch (Ontario, 2002).

FIGURE 1
Map of Canada's Biosphere Reserves.
Source: Canadian Biosphere Reserve Association, 2004.

3. Methods

The Project started with a workshop co-sponsored and co-organized by the Ontario Ministry of the Environment and Environment Canada. The workshop brought together a youth hired under the Environment Canada's *Science Horizons Youth Employment Strategy* from each Biosphere Reserve to: explore and develop common landscape change protocols for Canadian Biosphere Reserves; train Science Horizon youth in the protocols through demonstrations involving experts in historical records, air photo interpretation and earth observation; undertake assessments of each Biosphere Reserve in terms of their needs with respect to landscape change information (what has been done, what is needed); address what is feasible for each Biosphere Reserve given technological, temporal and financial constraints; and set out a strategy to deliver the project.

Each Science Horizon youth undertook their component of the Project using the training provided at the workshop and local resources. Each of the studies was undertaken with a different set of local objectives, locally-available technologies, and locally-available resources. Therefore, each study was significantly different, yet followed the same steps to completion.

Each Biosphere Reserve conducted the study by:

1. determining whether work had been completed on land survey records, air photo or satellite interpretation and, if so, acquired the work;
2. seeking land survey records, air photos and satellite imagery as far back in time as possible;
3. evaluating the expertise of their Science Horizon youth and partners assisting the Biosphere Reserve, e.g. National Parks, Universities and Colleges;
4. selecting a study area appropriate for the information sources; where applicable, mapped and classified land survey records, digitized and classified air photos, digitized and classified satellite imagery;
5. analyzing landscape changes based on the mapping;
6. drafting reports on causes and implications of landscape changes; and
7. submitting a final report to the Canadian Biosphere Reserve Association and Environment Canada.

TABLE 1

Summary of Geographical Area and Time Periods for Landscape Change Studies at Canada's Biosphere Reserves

Biosphere Reserve	Total Area Studied	Time Changes Examined	Main Approach
Waterton	795 km^2 in southwestern Alberta	Logging since 1950s Roads 1951-1997	aerial photos satellite imagery road/trail digital data clearcut digital data
Niagara Escarpment	corridor stretching 725 km in southwestern Ontario	regional 1976-1995 area study 1974-1994	aerial photos satellite imagery baseline digital data
Long Point	270 km^2 on shore of Lake Erie in southern Ontario	presettlement 1985-1990	land survey digital base maps
Charlevoix	148.52 km^2 located east of Quebec City, Quebec	1970-1990	ecological forestry maps
Riding Mountain	144 km^2 in Manitoba	1873, 1948, 1993	land survey aerial photos topographic maps satellite imagery
Mont St. Hilaire	~ 150 km^2 in southwestern Quebec	1761, 1815, 1839, 1867, 1932, 1963, 1993	topographical maps (recent ones drawn from aerial photos)

4. General Results

4.1 Landscape Changes at Biosphere Reserves

Since European human settlement of Canada in the 1700s and 1800s, resource development and growing human populations are the major drivers of landscape change at Biosphere Reserves (see Table 2). Many of the major landscape changes took place in the early days of European settlement, yet significant changes are still occurring today. Landscape changes include: removal of forests; conversion of grasslands and draining of wetlands in order to convert land for agricultural purposes; and building of houses, roads and other infrastructure to support the material well-being of human populations.

Conversion of landscapes for agriculture happened primarily during the early days of European settlement while development of human infrastructure has occurred more recently. Most of the ongoing landscape changes today are the result of forest fragmentation due to tree harvesting, house construction for an expanding human population at Biosphere Reserves, and the regeneration of abandoned agricultural lands to forests.

Regeneration of forested lands is occurring in areas where agricultural production is being abandoned. In many cases, the soils of these lands are not sufficient (and perhaps never were sufficient) for successful agricultural production. Observations from the Charlevoix Biosphere Reserve study indicate that years of agricultural production have depleted the soil quality even further, thus constraining regeneration of native forests.

4.2 Habitat Fragmentation, Loss and Degradation at Canada's Biosphere Reserves

Resource development and human settlement at Biosphere Reserves have significantly fragmented wildlife habitats, thus threatening wildlife populations at Canada's Biosphere Reserves (see Table 2) such as: the grizzly bear (Waterton Biosphere Reserve), caribou (Charlevoix Biosphere Reserve) and the scarlet tanager (Niagara Escarpment Biosphere Reserve). These species reflect the impacts of landscape change as indicators of overall wildlife habitat decline. Carolinian tree species are also under threat in the Long Point Biosphere Reserve.

Protected areas provide an opportunity to support wildlife populations, but when particular species require more undisturbed area than the protected areas can provide, then certain wildlife become threatened. For example, parts of the Niagara Escarpment Biosphere Reserve, although not experiencing overall forest area decline, are experiencing more forest fragmentation resulting in smaller forest patch sizes. The smaller fragments and increased forest edge (due to changing shapes) threaten the scarlet tanager, a bird species requiring large, undisturbed forests.

TABLE 2

Summary of Key Pressures Driving Landscape Changes at Canada's Biosphere Reserves

Biosphere Reserve	Key Pressure Driving Landscape Change	Impacts	Specific Findings
Waterton	Road development associated with industrial activity (seismic activity/ gas wells/pipelines/ logging)	Wildlife species more vulnerable to legal and illegal hunting; disturbed ranges.	Grizzly bear Elk

TABLE 2 cont.

Summary of Key Pressures Driving Landscape Changes at Canada's Biosphere Reserves

Biosphere Reserve	Key Pressure Driving Landscape Change	Impacts	Specific Findings
	Off-road vehicle use	Habitat degradation (soil compaction, reduced cover, disturbed ranging patterns)	Grizzly bear Elk
	Logging	Habitat degradation (loss and/or fragmentation)	Grizzly bear Elk
Niagara Escarpment	Mineral extraction (above Escarpment) and Clearing for agricultural activity (below Escarpment); urban development	Forest fragmentation with declining forest interior and increasing nest predation and parasitism.	Scarlet tanager Wood thrush
	Clearing for agricultural activity; urban development	Forest fragmentation leading to the spread of invasive plants.	European buckhorn
Long Point	House or cottage development	Forest fragmentation with declining forest interior.	Neotropical migrants
Charlevoix	Abandoned agricultural areas	Forests re-establishing to create different habitats at a slow rate due to soil degradation in fallow.	change in species
	House or cottage development	Altering natural landscape	change in greenspace patterns
Riding Mountain	Clearing for agricultural activity	Habitat loss and fragmentation, increased conflicts between wildlife and adjacent land owners resulting in wildlife decline and genetic isolation.	Wolves Moose Elk

TABLE 2 cont.

Summary of Key Pressures Driving Landscape Changes at Canada's Biosphere Reserves

Biosphere Reserve	Key Pressure Driving Landscape Change	Impacts	Specific Findings
Mont St. Hilaire	Clearing and drainage of swampy land for agricultural activity	Forest fragmentation	change in greenspace patterns
	Reforestation of unsuitable agricultural land	Forest regrowth	change in greenspace patterns
	House or cottage development; road and railway development	Forest fragmentation, pollution and barrier to ecological processes	change in greenspace patterns

4.3 The Need for Environmental Planning and Management

Additional resource development and human settlement at Biosphere Reserves require thoughtful planning and environmental management to define the appropriate uses of the land.

Specific human activities that continue to threaten the natural environment can be curtailed without disturbing main economic drivers of the community. For example, at the Waterton Biosphere Reserve, the threat to the grizzly bear results from the ongoing use of recreational off-road vehicles on forestry roads - not necessarily the forest harvesting activities themselves.

Planners and environmental managers associated with the Niagara Escarpment Biosphere Reserve have come to understand the importance of monitoring at various scales: the regional level (greater than 1:250,000), the area level (1:50,000 - 1:15,000), and the site level (plot monitoring). The Niagara Escarpment Biosphere Reserve Landscape Change Study illustrated that the regional level monitoring provided an assessment of the significant landscape patterns and trends, and identified the areas of significant ecological importance with respect to human development pressures. The area level monitoring provided an ability to link the cause (human development) with the ecological effect (forest fragmentation) - see above. And the site level monitoring targeted specific threats identified in the regional and area monitoring.

4.4 Options for Landscape Change Studies: Land Surveys, Aerial Photos or Satellite Imagery

The options for conducting landscape change studies using land surveys, aerial photos or satellite imagery have their strengths and weaknesses (see Table 3).

Historical land surveys are valuable in describing pre-settlement land cover. Land surveyor records consist of point source descriptions of forest cover that the land surveyor recorded along concession lines. These land surveyor records can be mapped to provide a valuable picture of pre-settlement land cover. For example, Mont St. Hilaire Biosphere Reserve was able to use land surveyor and topographical maps from 1761, 1815, 1839, 1867 and 1914 of the Richelieu area for early estimates of forest cover. Recent topographical maps are also valuable as Long Point Biosphere Reserve demonstrated in their use of topographical maps from 1985 and 1990 to compare forest cover with earlier land surveys.

Aerial photos are particularly useful in describing land cover over the past 50 years. The photos are usually black and white stereo images at 1:15,000 representing summer seasonal resolution. For example, Riding Mountain Biosphere Reserve used air photos from 1928/9, 1948/9, 1970, and 1986 of the Regional Municipality of Clanwilliam for identifying land cover.

Satellite imagery is valuable for describing recent (last 25 years) land cover, but it is expensive to purchase images and then have them interpreted. For example, Waterton Biosphere Reserve used a 1996 SPOT satellite image for land cover.

TABLE 3

Summary of Methods Used for Biosphere Reserve Landscape Change Study

Method	Strengths of Method	Weaknesses of Method	Biosphere Reserve Using Method
Land Surveys	Historical data	Less accurate due to individual bias of surveyor	Mont St. Hilaire, Long Point
Aerial Photos	Subject to availability along certain flight lines	Relatively recent	Riding Mountain, Waterton, Niagara Escarpment
Satellite Images	Accurate	Recent, expensive	Waterton, Niagara Escarpment

4.5 Quantitative versus Qualitative Landscape Change Studies

There is great value in conducting both quantitative and qualitative land-use change studies (see Table 4). For example, quantitative analysis using a functional geographic information system (GIS) allows for proper inventory, management, analysis and multi-function query abilities such as that used by the Riding Mountain Biosphere Reserve. Qualitative analysis, using the "map and crayons" approach, was applied by Charlevoix Biosphere Reserve. Although less technologically-driven and statistically-sure, the Charlevoix approach still provides valuable estimates and insights about changes in land cover.

TABLE 4

Summary of Techniques Used for Biosphere Reserve Landscape Change Study

Technique	Strength	Weakness	Biosphere Reserve using technique
Map and crayons	Inexpensive, low-technological requirements or expertise	Time consuming, less accurate, non-quantifiable	Charlevoix
Geographic Information Systems	Comprehensive, database creation, querying capabilities	Expensive, high technological and expertise requirements	Riding Mountain, Waterton, Long Point, Niagara Escarpment, Mont St. Hilaire
FRAGSTATS	Analytical tool for assessing fragmentation of forests	GIS and expertise required	Niagara Escarpment

5. Specific Results

5.1 Waterton Biosphere Reserve

The road density in the Castle Region (see Figures 2 and 3) that includes Waterton Biosphere Reserve is 0.912 kilometers per square kilometer (Stewart *et al.*, 1998), a density that researchers estimate is responsible for at least a 25 percent habitat loss for elk (Lyon, 1979). Unfortunately, these roads often follow valley bottoms through the banks of rivers that are inherently good habitat for grizzly bears. Many species, including grizzly bear and elk, avoid roads and habitat adjacent to roads. The habitat loss extends beyond the physical dimensions of the road itself since wildlife avoids the habitat near and around roads as well. Researchers have found that grizzly bears avoid areas within

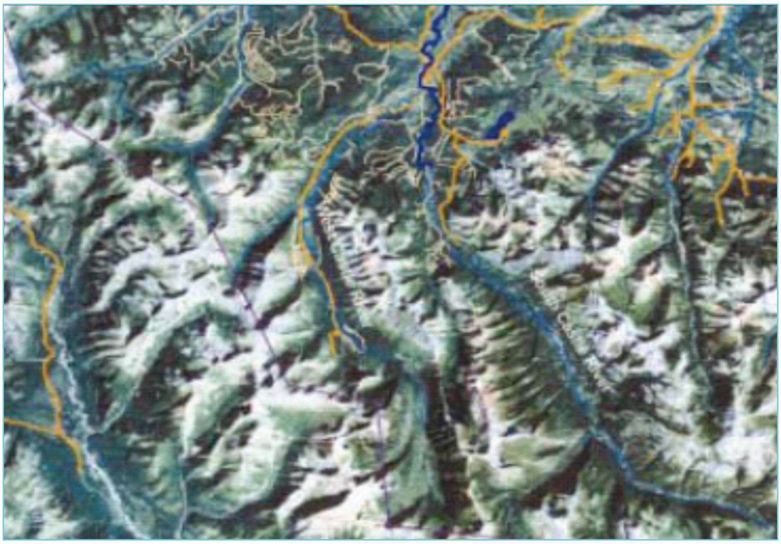

FIGURE 2
Roads in the Castle Region, Alberta, Canada 1951 (Source: Stewart *et al.*, 1998).

FIGURE 3
Roads in the Castle Region, Alberta, Canada 1997 (Source: Stewart *et al.*, 1998).

900 meters of roads (Kasworm and Manley, 1990) and elk reduce their use of habitat 800 meters from the road edge (Perry and Overly, 1976.). Therefore roads that are constructed for the logging industry and left open for vehicle access following operations may decrease the use of clearcut areas by grizzly bears, even if favourable plant material is available as a food source. This leads to what scientists call "effective habitat loss" or an unwillingness of animals to use otherwise suitable habitat (Gibeau *et al.*, 1996).

5.2 Niagara Escarpment Biosphere Reserve

Forest cover in the north Halton study area increased from 3,545 ha in 1974 to 3,696 ha in 1994 (Braid and Ramsay, 1998) - a 4 percent increase mainly associated with minor size increases in shrubland, open mixed, and woodland vegetation types at the outer boundaries of forests. However, connections between the forests were poor or non-existent. Less than 50 percent of the major woodlands (>100 ha) and large forests (20 - 100 ha) provided interior habitat conditions (see Figures 4 and 5). All of the medium and small forests were entirely composed of edge habitat. A decrease in forest interior area due to decreased size of forests and more irregular forest patch shapes is a negative change for indicator species such as the Scarlet Tanager (Geomatics International, 1997). The Scarlet Tanager is a forest interior bird species that requires large (>100 ha), undisturbed, mature to semi-mature deciduous forests. This species is particularly sensitive to disturbances associated with edge effects (Ramsay, 1996).

5.3 Long Point Biosphere Reserve

The historical (1790) forest cover (see Figure 6) and the present (1990) forest cover (see Figure 7) reveal no surprises with the most striking difference being the decrease in regional forest cover (Wilcox, 1998). The agricultural and resource based economies of the Long Point area in the 19th century required extensive forest clearing. It is well documented that by the turn of the 19th century, the amount of forest cover had dropped to levels that were as low as or lower than what is present today. In the early 1900s, forest lands in the entire Long Point region had been reduced to 11 per cent (Barrett, 1977). Farms were turned into blow-sand deserts as a result of the loss of forest cover and were being sold or abandoned. Some lands began to revert back to forest and vast areas were reforested. Those areas where increases in forest cover occurred were largely a result of early forestry efforts, such as those through the St. Williams Forestry Station, and the natural succession of marginal farmland back to forest. Even to this day, most of the remaining forest cover is concentrated in ravines or areas of rugged topography, wet areas such as swamps, and other areas that were unsuitable for cultivation.

FIGURE 4
Minimum Required Habitat for Scarlet Tanager at North Halton Area of Southern Niagara Escarpment, Ontario, Canada 1974 (Source: Braid and Ramsay, 1998).

FIGURE 5
Minimum Required Habitat for Scarlet Tanager at North Halton Area of Southern Niagara Escarpment, Ontario, Canada 1994 (Source: Braid and Ramsay, 1998).

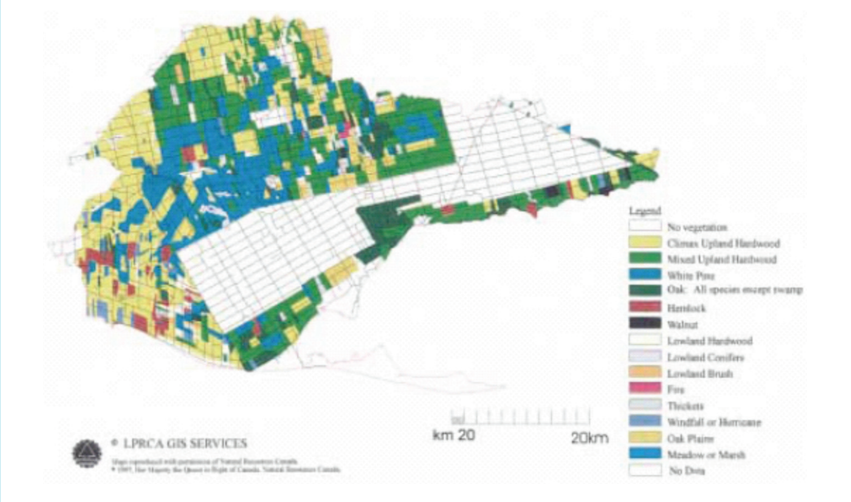

FIGURE 6

Vegetation at the Long Point Biosphere Reserve, Ontario, Canada ~1790. (Source: Wilcox, 1998).

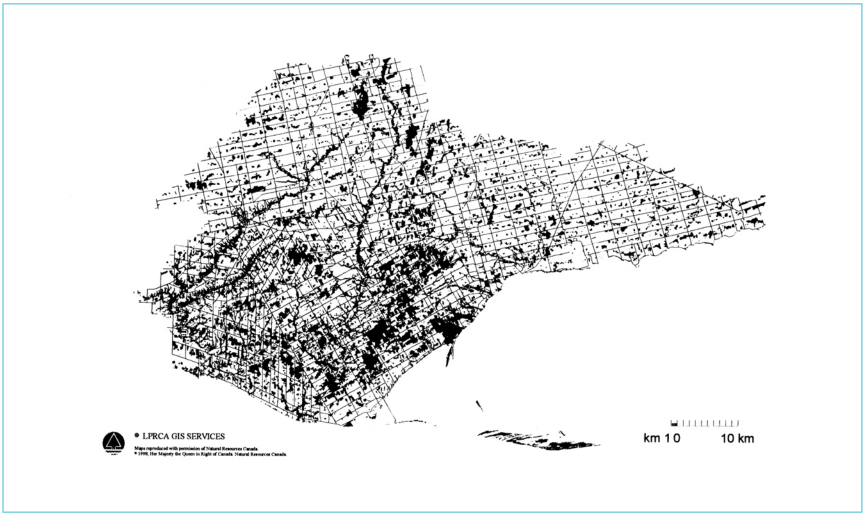

FIGURE 7

Vegetation at the Long Point Biosphere Reserve, Ontario, Canada 1990. (Source: Wilcox, 1998).

5.4 Charlevoix Biosphere Reserve

In 1970 (see Figure 8), the agricultural land was located primarily along rural roads, and there is evidence that these same lands are still heavily used for agriculture (Duschesne, 1998). By 1990 (see Figure 9), agricultural lands had declined severely in many areas, representing no more than one third of their former abundance of 1970. This decrease in agricultural lands corresponds to the regional decrease of agriculture observed in western Charlevoix - a decrease that is still observed today. In 1970, abandoned agricultural land cover (fallow lands) was extensive throughout the study region and the number of abandoned properties in fallow lands was relatively high. Even though agriculture remains important in the area, there was a severe decline in agriculture landscapes because the fallow lands were abundant and well-distributed throughout the entire study area. By 1990, the size of the fallow lands was smaller and reduced in number. The lands used for agriculture in the valleys have much better soil quality whereas the growth in fallow lands has occurred in areas of poorer soil quality. This probably explains why the agricultural activity in the study area is decreasing. This raises the question as to whether these areas with poorer soil quality should be used for agriculture, or whether these areas should be adapted for another types of land-use.

5.5 Riding Mountain Biosphere Reserve

Forest cover has declined from 82% in 1873 (see Figure 10), to 46% in 1948 (see Figure 11), with a further reduction to 34% by 1993 (see Figure 12) (Sobkowich, 1998). The amount of forest clearing done between 1873 and 1948, using mostly non-mechanized means, is surprising. The mechanized era of prairie agriculture essentially began after World War II. The effects on the ecosystem are substantial. The grassland, aspen parkland, and mixedwood forest habitats found throughout the entire Riding Mountain Biosphere Reserve prior to 1873 are now restricted to Riding Mountain National Park, and have been replaced in the area surrounding the Park by a mosaic of annual cropland, perennial forage, and exposed soil (summer fallow). Remaining forest habitat is highly fragmented. Ecological effects in the lands surrounding Riding Mountain National Park have been most severe on large animals, whose presence is not compatible with modern agriculture. Wolves, moose, and elk are visitors to this area, and often are shot as soon as they leave Riding Mountain National Park. The fragmentation of remaining natural habitat in the area surrounding Riding Mountain National Park has made animal movement throughout the whole region difficult, and has increasingly restricted large mammals to the Park. Ongoing research is showing genetic isolation, the implications of which do not bode well for the continuation of such populations over the long term.

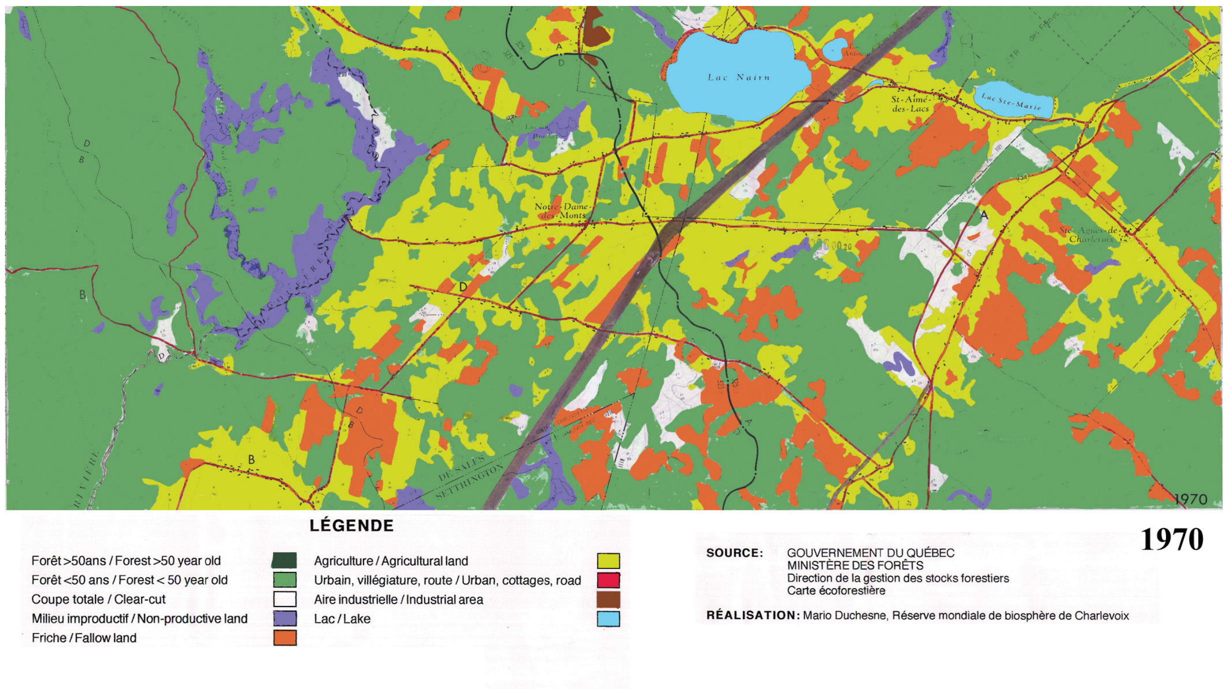

FIGURE 8

Land Cover South of the Laurentian Foothills at Charlevoix Biosphere Reserve, Ontario, Canada 1970 (Source: Duschene, 1998).

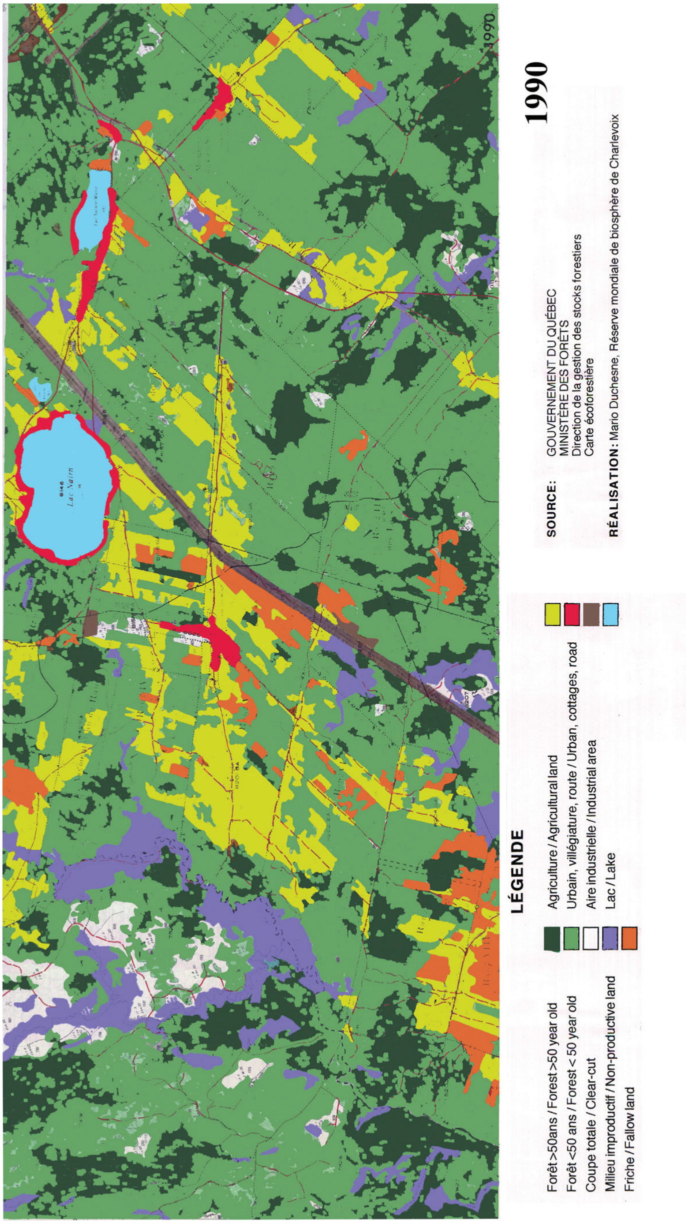

FIGURE 9
Land Cover South of the Laurentian Foothills at Charlevoix Biosphere Reserve, Ontario, Canada 1990 (Source: Duschene, 1998).

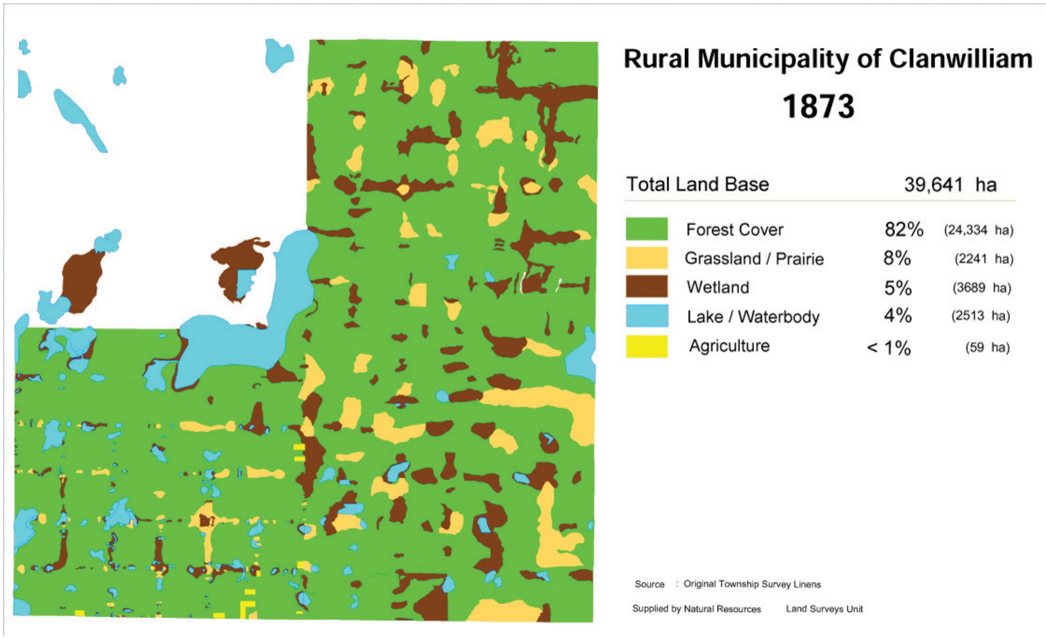

FIGURE 10
Land Cover of the Rural Municipality of Clanwilliam, Manitoba, Canada 1873.
(Source: Sobkowich, 1998).

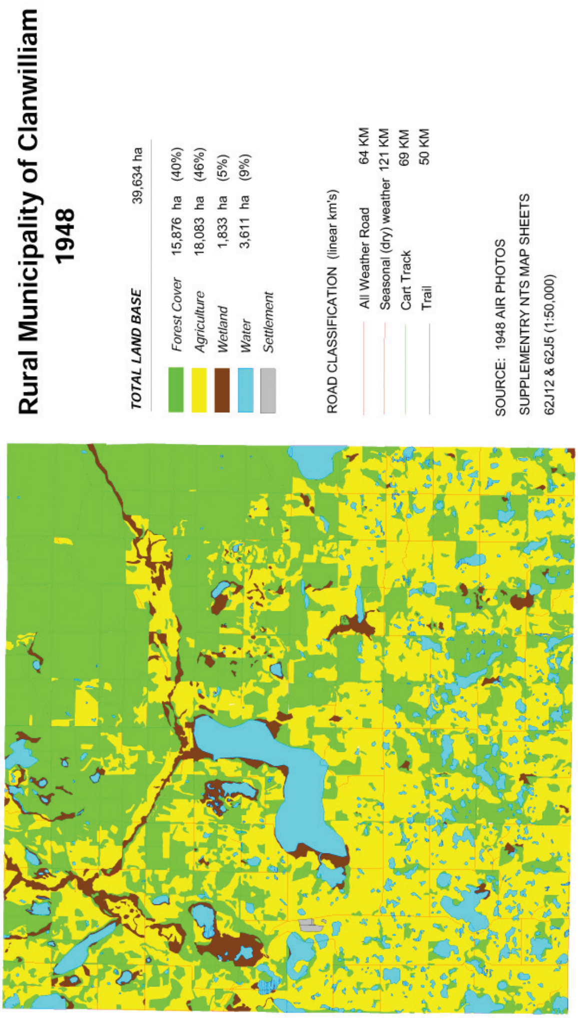

FIGURE 11
Land Cover of the Rural Municipality of Clanwilliam, Manitoba, Canada 1948. (Source: Sobkowich, 1998).

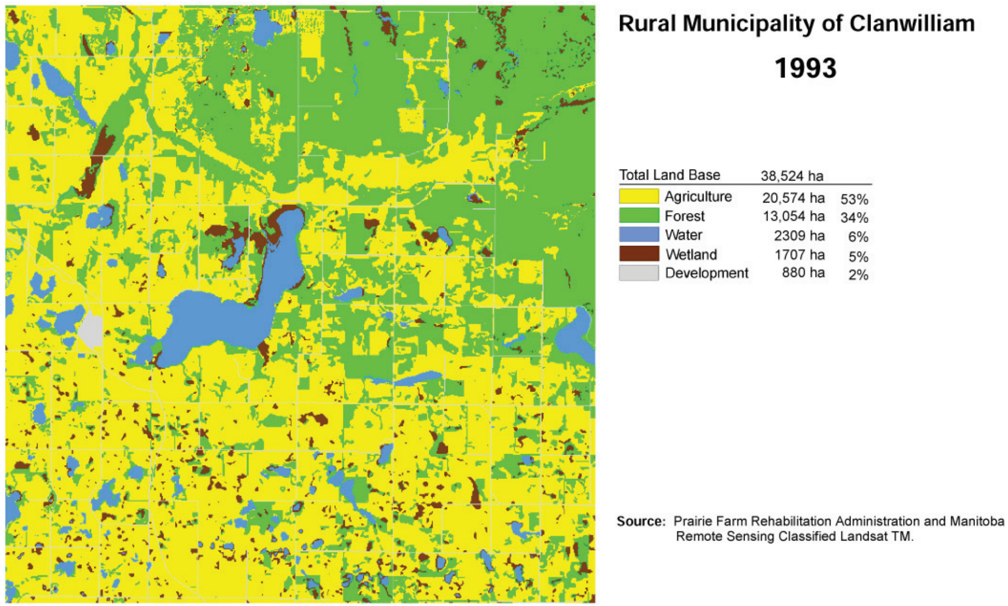

FIGURE 12
Land Cover of the Rural Municipality of Clanwilliam, Manitoba, Canada 1993.
(Source: Sobkowich, 1998).

5.6 Mont St. Hilaire Biosphere Reserve

The total forested area of the study region changed significantly from 1761 to 1993 (see Figures 13, 14, 15 and 16) as a result of human activity causing deforestation (Uhde, 1998) - a transformation of the use of land from forested land to agricultural land, road or dwelling construction. The situation in 1761 serves as the point of departure when the territory was virtually untouched by European civilisation: the approximate 160 km^2 study zone then contains almost 100 km^2 of uninterrupted forest. By 1815, the forest cover had decreased by half (Cobban and Lithgow, 1952). Agricultural land occupied most of the northern half of the study region; five road segments were constructed, along the interior bank of the two rivers and on the deforested area in the North; dwellings were regularly spaced on the North-South roads. The railway that cuts through the study region was constructed by 1867 and more road segments were constructed. The density of dwellings in the southern portion of the territory has increased significantly, particularly immediately south of the mount. These 28 years of fast development caused the limits of the large forest covering Mont St. Hilaire to recede considerably and this forest patch, now distinctly bigger than any other, becomes tightly shaped around the mountain at a contour of about 125 meters. Generally, the forested landscape became much more fragmented by 1867: everywhere south of Mont St. Hilaire is patchy; up to then, the north-eastern forest had become more fragmented and the position of the forest has changed. From 1932 on, the forest area continued to shrink. By 1932, straight lines have appeared in the forested landscape. This period marks the end of the economic crisis, when the steady decline in rural population stopped. Where the railway meets the road boarding the Richelieu River, a housing agglomeration has developed. From then on, deforestation does not remove huge tracts of forest like it did between 1839 and 1867, but rather causes the creation of new forest patches and the slow shrinkage of existing ones. In 1963, the housing development located south-west of Mont St. Hilaire on the east bank of the Richelieu has evolved into a town easily occupying twice as much land as thirty years earlier. The pattern of progressive reduction of forest patch area continued until 1963; the patch of Mont St. Hilaire is then completely detached from the southern forested landscape.

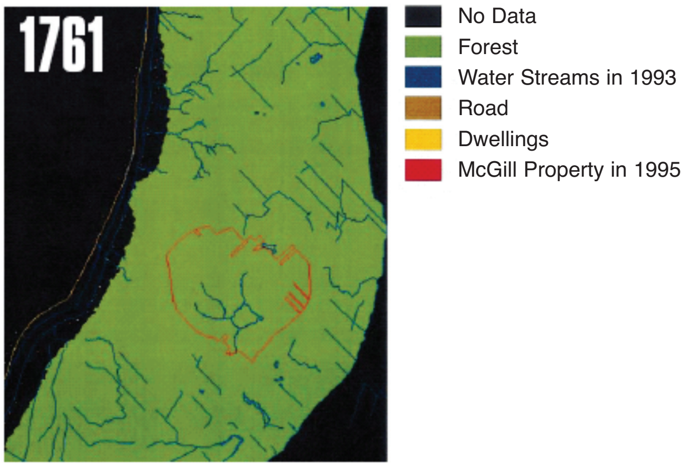

FIGURE 13
Land Cover at Mont St. Hilaire Biosphere Reserve, Quebec, Canada 1761.
(Source: Uhde, 1998).

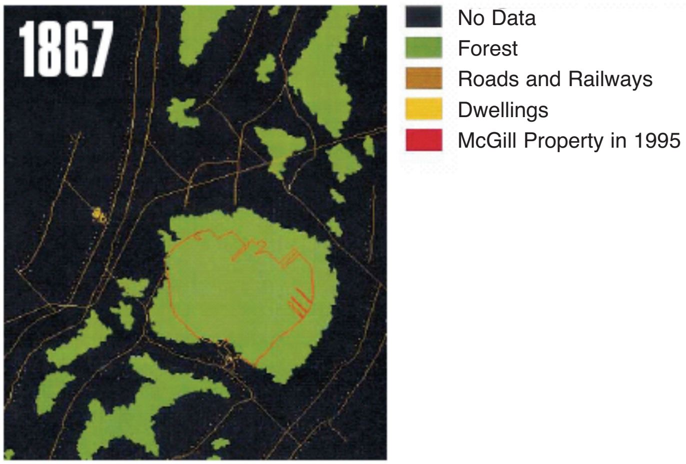

FIGURE 14
Land Cover at Mont St. Hilaire Biosphere Reserve, Quebec, Canada 1867.
(Source: Uhde, 1998).

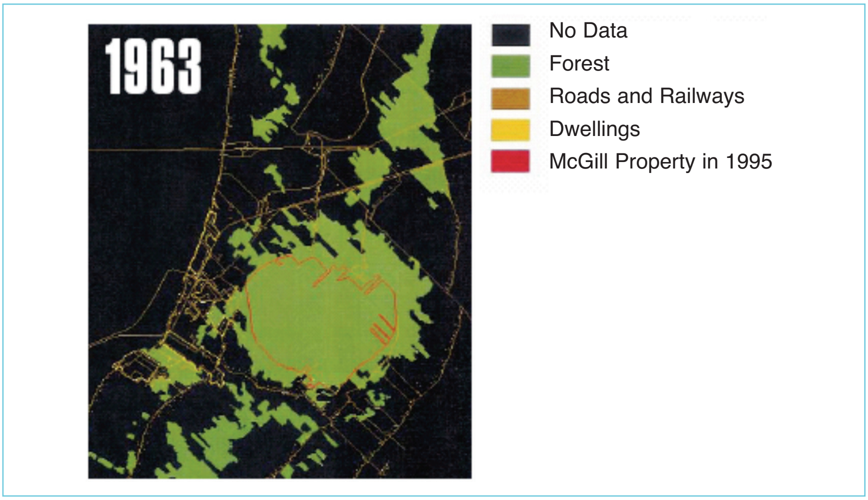

FIGURE 15
Land Cover at Mont St. Hilaire Biosphere Reserve, Quebec, Canada 1963.
(Source: Uhde, 1998).

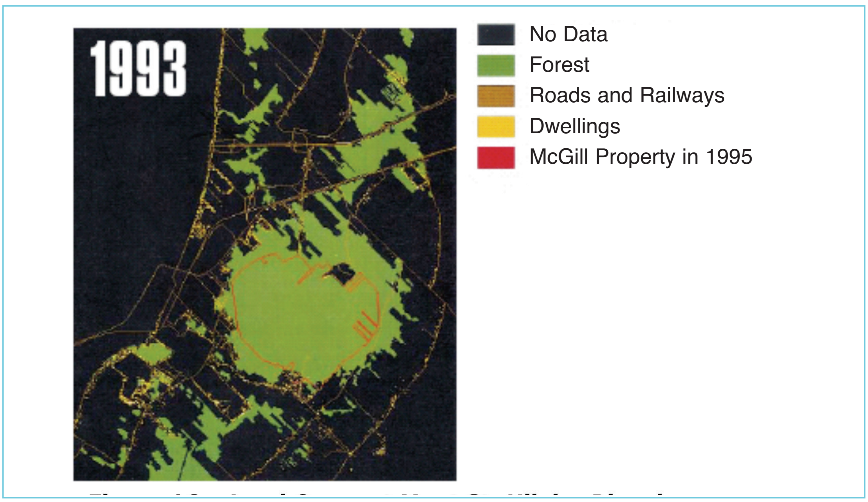

FIGURE 16
Land Cover at Mont St. Hilaire Biosphere Reserve, Quebec, Canada 1993.
(Source: Uhde, 1998).

6. Next Steps and Conclusions

The partners of this project will use the results and lessons learned from the study in different ways. Maps generated from this study have been shared at events of Biosphere Reserves and partners. Riding Mountain and Mont St. Hilaire Biosphere Reserves are planning to import this information into local management agencies to guide decision-making towards sustainability consistent with a community's sense of place. Each Biosphere Reserve plans to expand and build upon the initial work done as part of this study. The EMAN Coordinating Office, Environment Canada will be using the study and lessons learned to develop a landscape change indicator for use at other EMAN sites as part of an early warning system of ecological changes across Canada. The Ontario Ministry of the Environment will be sharing the protocols and lessons learned with their clients and partners including municipalities, non-government organizations and Conservation Authorities.

The Biosphere Reserve Landscape Change Project demonstrated significant insights about the changes that humans have brought on the landscape since European settlement may be documented from existing landscape data and information. These studies have provided a view of the changing natural environment in and around Biosphere Reserves and have provided information to Biosphere Reserve communities to help refine their "sense of place". Further application of the combined techniques from all of these studies is recommended to continue adding to the picture of landscape and associated ecological changes at Biosphere Reserves and elsewhere in Canada.

7. Acknowledgements

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Note: For a copy of the complete document titled "Landscape Changes at Canada's Biosphere Reserves: Summary of Six Canadian Biosphere Reserve Studies", visit **www.eman-rese.ca/eman/reports/publications/2001_cbra_acrb/brochure.pdf**

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