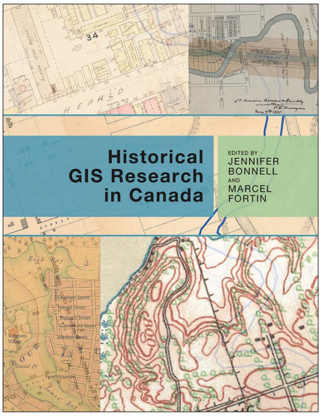

HISTORICAL GIS RESEARCH IN CANADA

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10

Top-down History: Delimiting Forests, Farms, and the Census of Agriculture on Prince Edward Island Using Aerial Photography, ca. 1900–2000

Joshua D. MacFadyen and William M. Glen

INTRODUCTION

This chapter examines Prince Edward Island's agro-ecosystems from the top down using remote sensing data from aerial photographs in a Geographical Information System (GIS). The total area of crop land and other "improved" land on farms has been investigated by censuses and other routinely generated sources for almost two centuries. The quantity of improved agricultural land has thus been a common way to measure deforestation.[1] The development of historical forest inventories using GIS and aerial photography, however, shows that the *Censuses of Agriculture* were at best an approximate measure of deforestation until the mid-twentieth century. There was slightly more cleared land and far less forest than what appeared in the census, and the discrepancies were quite large in some areas. In the post-war period, the presence of abandoned farms and a growing number of non-census farms made census estimates even less useful for understanding changing land use patterns on Prince Edward Island. The inventories also offer a new perspective on the process of land reverting to forest in areas of agricultural decline. When examined at the property-level, the data reveal acute inequalities in the processes of farm settlement and abandonment. This methodological examination of new sources calls into question the previously held estimates of agricultural activity, its ecological impact, and the rates of forest regrowth in agro-ecosystems.

Remote sensing sources are only beginning to influence the way historians see the Canadian environment, and Prince Edward Island offers a unique case study due to its rich collection of historical aerial photographs and the provincial government's ability as a small province to create complete land-use and forest inventories. The province's small size meant that it has been entirely photographed in multiple intervals since 1935. Complete inventories were created that now allow historians to examine land-cover and land-use change on all crown and private land, including the Prince Edward Island National Park. These processes were not possible in larger jurisdictions, but the example of property sampling in Prince Edward Island offers a spatially explicit model for studying land-cover and land-use change anywhere in Canada. The necessary sources for this analysis, aerial photographs and cadastral maps, exist in varying degrees of completeness for most populated areas of the country, and they offer students of environmental and social history a new glimpse of the country from above.

In Prince Edward Island, inventories allow the measurement of forest areas and compositions at a number of points in time and for any defined geographic area. Preliminary analysis of three sample watersheds and a selection of private parcels suggests that the extent and composition of forest cover are indicators of both the limitations and the ecological impacts of intensive farming in the early twentieth century. When forest cover is examined at the property level, representative samples can be created to study the full range of productive capacities of farms. The Canadian *Census of Agriculture* was designed to capture these elements of rural life, and its estimates of "improved land" have been a crucial part of scholarly research in these areas. Exploring history from the top down, from state-produced aerial photos, uncovers another side of rural production and a significant segment of agricultural land use that was overlooked by enumerators.

METHODS AND LITERATURE

Geographers N. Ramankutty and J. A. Foley have argued that new historical data are needed to fully understand the human land-use activities that drive global environmental change. Using a combination of satellite-borne remote sensing data and historical statistics, their research over the last decade has modified the estimates of cropland change globally.[2] Ramankutty, E. Heller, and J. Rhemtulla recently established a critique of the "regrowth" narrative of twentieth-century forest history in the United States.[3] They provide useful new estimates of historical cropland change in the United States, accounting for changes in definitions and political boundaries, but they ignore the problem of land use on the growing margin of private land that did not fit either forest or cropland categories. We address this by questioning the meaning and accuracy of "improved land" in the census and by offering a unique example of forest reversion rates in Prince Edward Island.

Like most colonies based on primary industries, Canada was preoccupied with "improved land" as a measure of agricultural progress in the nineteenth and much of the twentieth centuries. This preoccupation generated historical documents valuable not only for examining land-use activity and society in a period of extensive agricultural settlement but also for modelling the influence this activity had on the environment.[4] In woodland ecosystems, it is generally assumed that land that was not "improved" by settlers or cleared for other forms of development remained, or returned to, some form of forest cover. What the census called "natural forests" were far from undisturbed environments, but nevertheless environmental historians can make some basic assumptions about their composition. Occupied farmland was usually divided into "improved" and "unimproved" categories, and the latter included privately owned woodlots or "natural forest" as well as "marsh or wasteland."[5] Definitions varied slightly according to the governing body performing the censuses or assessments, but "improved land" typically meant cleared land on farms that had been ploughed at one point for the purpose of agriculture.

Great pains were taken by the state to ensure that its lands were carefully surveyed and measured. Yet, historians have identified many limitations and inconsistencies. Variables such as the number of farms are misleading in some censuses and inconsistently defined in others.[6] O.F.G. Sitwell identified a discrepancy in earlier counts of improved acreage in Canada that he argued was caused by confusion about whether some pasture and summer fallow land qualified as improved acreage.[7] In some years, improved land was called "arable land" and appeared to mean land that had the potential for cultivation. In other years, the definition seemed to indicate any land that had been ploughed in the past, even if it was only fit for grazing.[8] Different censuses explained the terms to farmers in varying levels of detail, and Donald Akenson noted that census takers were "more strict in defining 'improved' land than were the assessors in defining 'cultivated' land for tax purposes."[9] Beginning in 1931, census officials listed the acreage and improved acreage of abandoned farms, although it was only summarized for census districts and it is curious how they determined the figure if the previous occupants were absent. As Ruth Sandwell has argued, the tabulations in the early twentieth century Canadian printed censuses accorded with one definition of agricultural activity and ignored others, such as subsistence farming, gardening, and other forms of production usually attributed to women.[10]

To land owners and protected tenant farmers, the work of improving farmland translated to improving one's social and economic prospects,[11] but, to the state, "improved land" had a different kind of importance. James Scott argues that the primary objective of census projects and other forms of cadastral reckonings in the period of high-modernist agriculture was to make local knowledge legible to the state, especially for the purpose of levying taxes. The real incentive behind the scientific system was, according to Scott, "the precondition of a tax regimen that comprehensively links every patch of land with its owner – the taxpayer."[12] But making local knowledge available to the Canadian state was about more than just good fiscal policy. Real property taxes were only a distant secondary tax revenue for the Upper Canadian government, and for new immigrants they paled in comparison to what they would have paid for property in the British Isles.[13] In the twentieth century, the Maritime provinces were the only Canadian jurisdictions to make real property taxes a serious form of revenue.[14] Mapping Canadian land and resources was also about the emergence of the scientific and nationalist state, and Suzanne Zeller has shown how the development of several agencies that employed scientific cartography was an important part of nation-building.[15]

Gathering data on improved acreage increased in importance toward the end of the nineteenth century, and some censuses have been extremely diligent in showing the quality and quantity of improved land. Some, like the 1871 *Census of Prince Edward Island*, categorized all enumerated land as first-, second-, or third-rate farmland. In 1883, Manitoba paid careful attention to the rates of settlement, even differentiating between land that had been cultivated in earlier years and land that was recently broken.[16] Early censuses of prairie agriculture recorded the number of acres broken in the previous crop year as well as the acres seeded in the spring when the census was taken.[17] However, for historians who are interested in how land use influenced the environment, improved land alone does not tell the whole story. Geoff Cunfer's research on the Great Plains demonstrated the importance of studying land use as a percentage of total area. He showed that farmers actually altered a relatively small portion of the plains and were unable or unwilling to expand beyond certain levels of grassland cultivation.[18] Agricultural censuses are also problematic for studying land-use change over time because the basic units of analysis, the census divisions and subdivisions, changed frequently in areas of rapid settlement or other population growth.

This paper is the first to compare Canadian statistics with land-use and forest inventories over a long period, but it is only one of several recent studies to focus on the accuracy of historical statistics. In little more than the last dozen years, scholars have updated many standard sources for historical statistics. The *Historical Statistics of the United States* corrected errors and brought an entire set of agricultural statistics up to date. Ramankutty and others have established an updated estimate of land use for North American crops and forests and have identified inconsistencies in the data for the United States. M. L. Liu and H. Q. Tian have created new estimates for Chinese land-cover and land-use change using similar spatially explicit models.[19] Many of these scholars have helped isolate and reinterpret obvious errors in data gathered by routinely generated sources.

Remotely sensed data from aerial photographs were added to the cartographer's toolbox in the early twentieth century, and the documents offer a new perspective to the question of land-cover and land-use change. The historical GIS research in this chapter was made possible by a series of photographic images taken from the skies above Prince Edward Island at various points in the twentieth century, beginning with a relatively high-quality and practically complete coverage of the province in 1935 and 1936. This remarkable source, and most of the aerial photographic surveys that followed, have been used for a range of academic and official projects on Prince Edward Island, from land-use studies and partial surveys to soil maps and complete land-use and forest inventories created by the provincial departments of Agriculture and Forestry.[20]

Canadian surveyors had used photography for mapping and surveying on land since the late 1880s.[21] The first aircraft used by foresters were flown in 1915 in Wisconsin, and by 1919 Canadian businesses such as Laurentide Paper in Grand Mère, Quebec, used two planes owned by Department of Marine to spot forest fires and survey forest resources. In the latter year, Canadian pilots and surveyors conducted the world's first extensive aerial survey by photographing over 13,000 images of southern Labrador for a Massachusetts pulp and paper company.[22] Within five years, forest surveys using both oblique and vertical aerial photography had become standard practice in the Department of the Interior, the Dominion Forest Service, and several provincial departments and private companies. In the late 1920s, Canadians experimented with winter air surveys, developed new methods for calculating the volume of forests using shadow lengths and locations, and agreed to perform a national forest survey. The meeting was struck in 1929 by Minister of the Interior Charles Stewart, and the provinces agreed to gather aerial survey data while the Dominion Forest Service would collate and compile the national project. Unfortunately, the Great Depression interfered with the national survey, but Richard Rajala argues that in the 1930s Canada's aerial photographic mapping was unrivalled in both technique and coverage. Several federal agencies and the Royal Canadian Air Force had by then photographed over 800,000 square kilometres of land and mapped about 320,000 square kilometres of forest from the air.[23] The federal government's photographic surveying was obviously widespread and included lands from western Manitoba to southern New Brunswick.

In the summers of 1935 and 1936, the Geodetic Photographic Detachments of the Royal Canadian Air Force photographed the surface of Prince Edward Island, presumably as part of the Dominion Forest Service's larger surveying projects. Fortunately, the photographs, negatives, and flight reports survived and have been reproduced and indexed by the Forestry Division of the Prince Edward Island Department of Agriculture and Forestry. The original photographs were taken using a Bellanca Pacemaker aircraft, a single-engine, high wing aircraft fitted with floats. The flights were operated out of Shediac (New Brunswick) and Charlottetown, and they photographed 99 per cent of the island's surface. Some areas were missed because the lightweight plane had blown off course.[24] The pilots attempted to maintain an altitude of 10,000 feet for all photographs, and the resulting documents produced a geospatial time slice of nearly the entire province at a scale of approximately 1:14,300.[25]

The 1935/36 imagery was followed in June 1958 by another complete photographic survey of the island. The 1958 photographs were contracted by the RCAF to a local company operating a single-engine 1956 Cessna 180. Flying at 8,200 feet, the pilot and photographer produced a second set of photographs for the entire province over three months and with a scale of approximately 1:15,840. With the acquisition of the 1958 photographs, Prince Edward Island became the first province to have two complete sets of aerial photography. Further sets of aerial photos were also taken in 1968, 1974, 1980, 1990, 2000, and 2010.[26]

The remotely sensed data in these photos were critical for a broad range of surveys and topographical maps created by forestry companies and federal offices such as the Department of National Defense, the Department of the Interior, and the Geological Survey of Canada (GSC).[27] A well-known photo interpretation technique meant that most photographs were taken with enough overlap to allow stereo imagery. Stereoscopic imagery gives a three-dimensional effect that enhances the features in the photographs and allows interpreters to identify aspects of tree height and elevation as well as land-use and forest-cover types. By combining aerial photo interpretation with surveys and field observations, Canadian cartographers were able to plot comprehensive topographical maps for most of the country's inhabited regions. These had various incarnations but became known as the National Topographic System (NTS) in 1927.[28] The most detailed of these were called "one-mile maps" because of their scale of one inch to one mile (1:63,360). Don Thomson explained how the NTS was "indispensible to any extended, efficient mapping program in this country … and to the development of Canadian air navigation charts."[29] The NTS maps are an important source for environmental historians as they identified features in the built environment such as roads, dams, residential, community, and industrial buildings, and they also offer a view of the natural environment, including features such as surface hydrology, wetlands, coastlines, and a basic breakdown of forest-cover types. Comparing these documents to more recent data in a GIS allows historians to identify patterns in land-cover and land-use change, and often they reveal the origins of disturbances ranging from deforestation and stream siltation to brown fields and other residual forms of pollution.

Historical maps like the NTS are a valuable source to environmental historians, and GIS has presented a new way to read, visualize, and analyze the documents. However, aerial photographs and the subsequent forest inventories carried out using the photography present a much finer level of detail and greater potential for research. These data effectively fill in the spaces on the map – spaces that to most historians in the twentieth century were simply cadastres with names, property lines, and occasional topographical features. Now historians can identify the built environment, field and forest outlines, land-use and forest-cover types, and even some tree species. This analysis is possible at the township, watershed, or county level and, in the unique case of Prince Edward Island, for the entire province.[30] The documents represent a staggeringly large body of information, even for a small province. Just as computing technology in the 1970s allowed historians and other scholars to process large datasets like the censuses in new ways, increased processing power and the efficiency of GIS allow scholars to better understand and leverage these early remotely sensed data. If the NTS maps were a sort of enumeration of the Canadian environment in certain years, then the original aerial photos were the manuscripts behind the census, and historians and foresters are just beginning to query the data they contain.[31]

Measuring the extent and health of the forest has been a relatively recent endeavour in Prince Edward Island. During the early twentieth century, when industry and the federal government were so focussed on creating forest surveys and managing forest resources, the government of Prince Edward Island took little interest in either surveying or protecting its forests. The province passed an act to establish a "forestry commission" in 1904 and two forest fire prevention acts in the 1930s, but the first *Forestry Act*, which placed restrictions on clear-cutting and burning, was not implemented until 1951. The province's first tree nursery was built the following year.[32] Thus, for the first half of the twentieth century, the province passed on the responsibility of mapping and monitoring its forests to Ottawa. In the 1980s, the province's Department of Forestry began to commission decennial inventories, starting with a forest biomass inventory using the 1980 photographs and field surveys, authored by Dendron Resources in Ottawa.[33] The 1990–1992 Prince Edward Island Forest Biomass Inventory was created by the Prince Edward Island Forest Division using the 1990 false-colour infra-red photographs (scale 1:17,500) and 1991 field surveys of 1,200 ground flora and tree species sampling points. In the 1990s the Department of Environment, Energy and Forestry also used the earlier historical photographs to create forest-cover maps using the 1935/36 and 1958 photography.[34]

The Prince Edward Island forest and land-use inventories were made possible, in part, because the province contains a dense and regular network of roads. Roads and railways were used as control features for georeferencing aerial photographs to the base map. The delineated features on the aerial photographs were transferred to the base map using a light table. This was only possible due to the high density of control features noted above. In the 1958 inventory, land-use categories were created for forest cover, clearcut, partial cut, reverting land, cleared land, roads, railways, and several smaller categories. Reverting land consisted of 5–10-year-old stands of trees growing on cleared land that were large enough to identify but small enough that they could be ploughed under. In other words, reversion was not necessarily long-term and it did not necessarily result in full forests, but the land had clearly not been used for crops or heavy grazing in a decade or more. The availability of more resources for the creation of the 1935/36 inventory meant that the forest-cover category was subdivided into five generalized types (identifying the mix of hardwood and softwood) and classes for reverting land and harvested forest. Specific species were also identified in the 1935/36 photos where possible, such as alder, black spruce, cedar, larch, white spruce, and poplar. Finally, the origin of the forest cover was coded wherever it could be identified; this was often the case with old fields that had grown up in white spruce or larch.[35] Figure 10.1 shows a simplified map of the forest outline based on the 1935 inventory, but what is not visible at this scale are the forest types and land uses within the forest outline. Land that is not identified as forest in this image was either wetland, cleared, or otherwise developed. Figure 10.2 shows the same data from the 2000 inventory.

The 1935/36 inventory is a benchmark for this study, but there are two ways to use historical inventories to estimate land use and forest cover at other points in the early twentieth century. First, because the rural population of Prince Edward Island was in decline for the

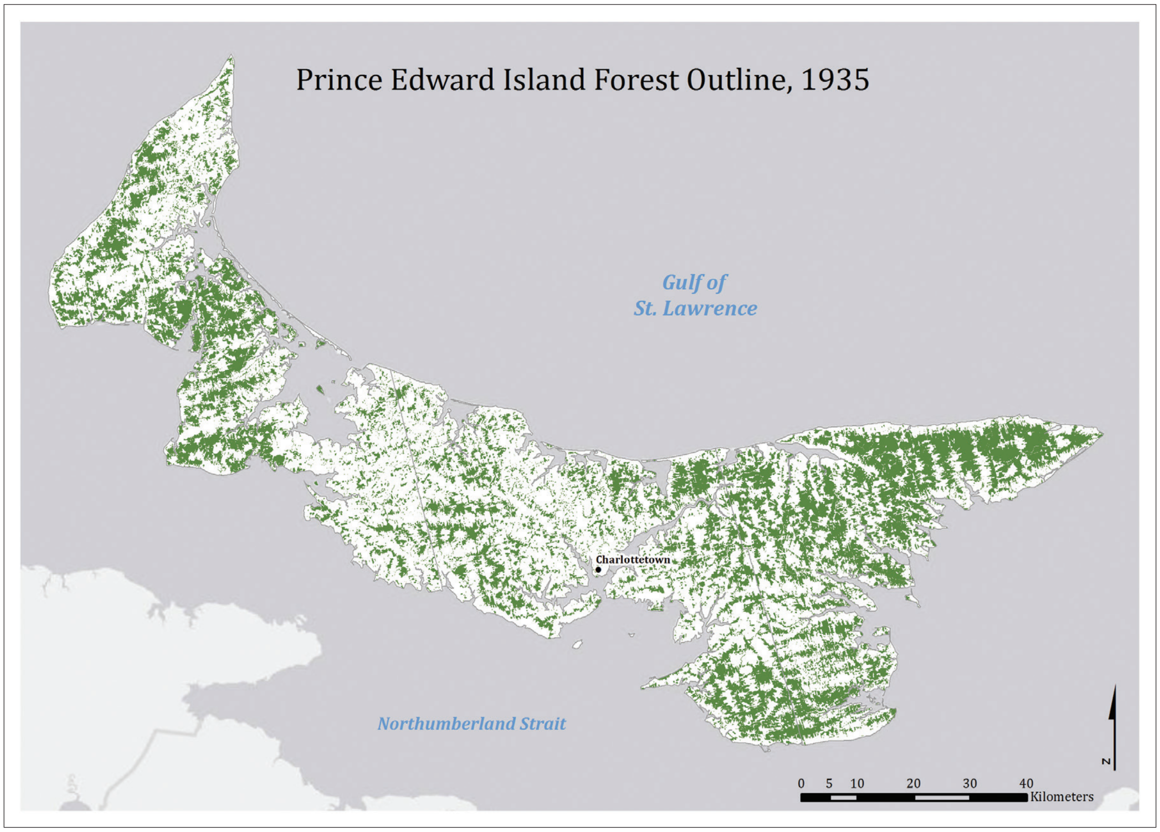

Fig. 10.1. Prince Edward Island Forest Outline, 1935. (Prince Edward Island, Department of Environment, Energy & Forestry, Forests, Fish & Wildlife Division, 1935 Forest Outline, Coastline, Last modified 31 December, 2003. Software: ESRI ArcGIS 10.1, Adobe CS 4 Illustrator.)

first six decades of the twentieth century, agricultural land declined and the forest experienced a general expansion rising from 32 per cent to 49 per cent of the area of the province between 1935 and 1990. Therefore researchers can use simple straight-line interpolation (estimating data points between two known data points) when the rate of forest reversion is known in order to estimate the general forest cover and the amount of cleared land. Second, by coding the origin of old fields, the 1935/36 inventory allowed researchers to create a map of the Prince Edward Island forest at close to its smallest point. Far more accurate than extrapolation, this process involved removing those stands that had regenerated on old fields and the areas of new reversion from the 1935/36 mapping. This process resulted in the earliest forest outline, *circa* 1900, showing forest on only 31 per cent of the province's land mass. Some new clearing might have occurred in isolated areas of agricultural expansion in the period between 1900 and 1935/36, but for the most part this is an accurate estimate of the province's forest at its lowest point of coverage.[36]

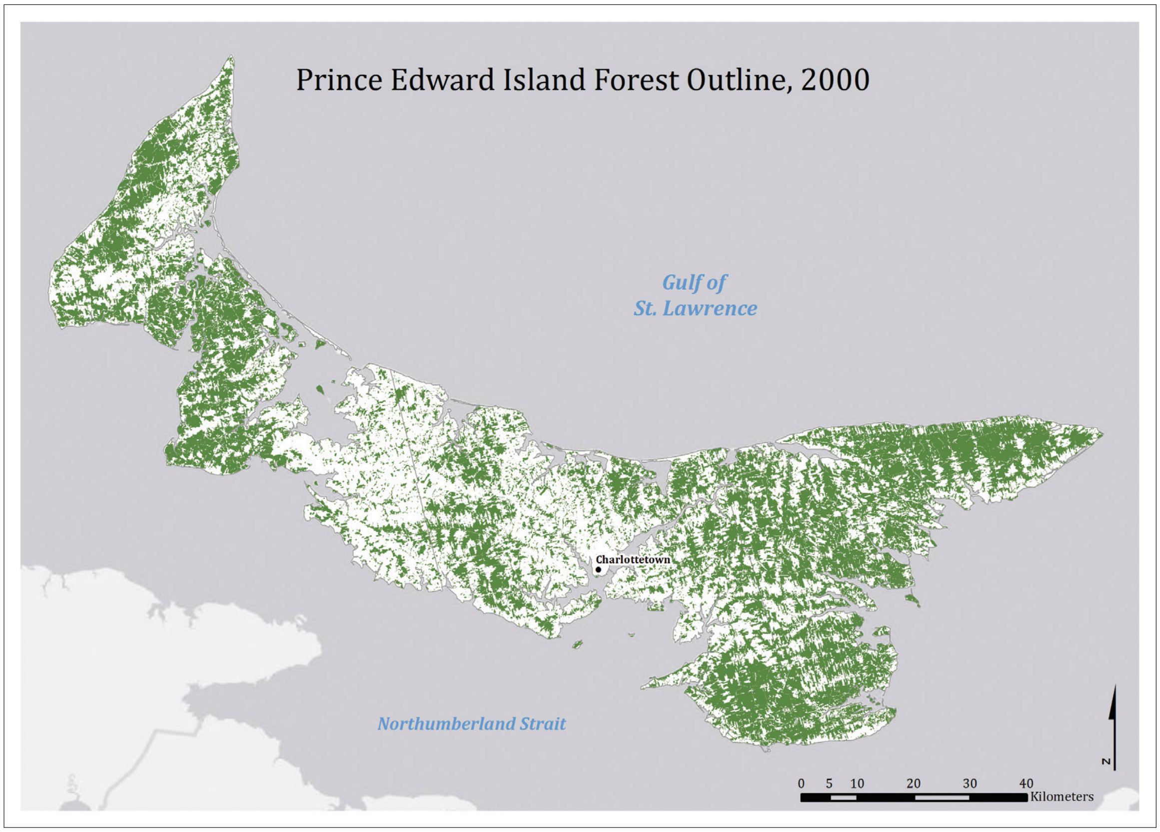

Fig. 10.2. Prince Edward Island Forest Outline, 2000. (Prince Edward Island, Department of Environment, Energy & Forestry, Forests, Fish & Wildlife Division, 2000 Forest Outline, Coastline, Last modified 30 November, 2010. Software: ESRI ArcGIS 10.1, Adobe CS 4 Illustrator.)

PROBLEMS WITH THE TRADITIONAL SOURCES

The Prince Edward Island forest and land-use inventories identify significant problems with the traditional sources used to map changing environments. The province offers an exceptionally useful case study of historical forests in private hands precisely because it has completed inventories of all land regardless of ownership. Early nineteenth-century surveys usually focussed on cadastral characteristics of private land such as property dimensions and occupancy, but, later in the century, bureaus in agriculture, natural resources, geology, meteorology, and other scientific interests of the state began to survey large tracts of the country's public land on regular intervals. Thanks in large part to the efforts of William Edmond Logan and subsequent officials in the Geological Survey of Canada, the Dominion mapped more of its difficult terrain than most other places on Earth.[37]

For the most part, natural resource surveys in the past were preoccupied with public lands.[38] There were a few exceptions to this norm in the Maritimes. In 1895, Robert Chalmers created maps for the GSC that included a forest outline and origin classification ("old forest growth" and "recent forest growth") for New Brunswick and the western half of Prince Edward Island. However, Chalmers' sources are unknown, and, when compared to the *circa* 1900 outline, his map of western Prince Edward Island proves to be much more of a general estimate than a detailed survey.[39] Other estimates of the forest cover were prepared by provincial officials such as O. L. Loucks and by academics such as F. A. Stilgenbauer and Andrew H. Clark, but these should also be used carefully and compared to the historical inventories.[40] In 1912, the region's first provincial forest inventory was mapped for Nova Scotia by Bernhard Fernow and his University of Toronto students, including C. D. Howe. This survey was impressive, considering the modest budget and "often very inaccurate" base maps the foresters had to work with, but ultimately the source data were simply estimates volunteered by local landowners and lumbermen. Even though Fernow was impressed by the "unusual number of intelligent and well informed men throughout the country," he admitted that "it is only the grand total or the average that is approximately correct and of value."[41] The most comprehensive survey of land use on private properties at this point remained the *Census of Agriculture*.

The census account of human activity in areas of agricultural settlement has been an invaluable source for understanding the economic and ecological impacts of farming. However, in Maritime Canada, the census does not show an accurate trajectory of changes in either cleared land or forest areas over the twentieth century. In the late twentieth century, the censuses recorded only cropland, and, although cropland has been the main historical variable used by geographers such as Ramankutty, it gives only a partial, and we argue incorrect, picture of land use and obviously says nothing about forest-cover types. Most macro-historical studies of global land use tend to use data for cropland and improved land with relatively few checks for the accuracy or comprehensiveness of the data.[42] It is not possible to use the censuses to trace the changing size of the forest, even in a province such as Prince Edward Island, which had practically no public lands before the Second World War. This province's *Censuses of Agriculture* suggested that woodlots and other "unimproved land" occupied a relatively consistent surface area through the twentieth century. The forest and land-use inventories present a much different story.

The census figure for cropland, furthermore, says nothing about the total area cleared for transportation, industry, housing, recreation, and commerce, and due to the omission of abandoned farms and many subsistence operations it presents only a partial image of land used for growing. In places like the Maritimes, these small operations can represent a significant portion of cleared land. Statistics Canada sometimes reports cropland as a comprehensive measure of human disturbances. "Total cropland in Canada now stands at almost 89 million acres or 53.1% of all land," it claims on its website.[43] This, of course, refers to all land in farms; cropland itself represents less than 6 per cent of the total land area of Canada. By way of comparison, the total land area in the United States is over 23 per cent cultivated and Eastern Europe is well over half in crops.[44] For a country with less than 6 per cent of its land in crops, the Canadian *Census of*

Table 10.1. Two Descriptions of Deforested Land in PEI, ca. 1900–2000.

Area (ha)	**1900**	**1910**	**1930**	**1940**	**1955**	**1960**	**1980**	**2000**
Census:	improved	improved	improved	improved	improved	improved	improved	improved
PEI	293,917	309,144	*311,690*	*300,152*	261,222	232,467	190,620	200,375
Prince		109,148	*110,700*	*108,774*	100,657	88,975	74,292	81,746
Queens		125,504	*127,460*	*122,505*	109,351	100,379	82,326	83,537
Kings		74,492	*73,531*	*68,874*	51,214	43,113	33,615	35,095
Inventory:	cleared	cleared	cleared	cleared	cleared	cleared	cleared	cleared
PEI	359,577	359,577	327,765	316,227	292,899	285,625	248,414	236,935
Prince		131,516	114,854	112,928	108,509	107,164	93,904	88,814
Queens		140,317	132,142	127,188	116,682	113,437	103,158	99,893
Kings		87,744	80,769	76,111	67,708	65,025	51,352	48,229
Difference (as % of the inventory)								
Low-end estimate								
PEI	–18.3%	*–14.0%*	*–4.9%*	*–5.1%*	–10.8%	–18.6%	–23.3%	–15.4%
Prince		*–17.0%*	*–3.6%*	*–3.7%*	–7.2%	–17.0%	–20.9%	–8.0%
Queens		*–10.6%*	*–3.5%*	*–3.7%*	–6.3%	–11.5%	–20.2%	–16.4%
Kings		*–15.1%*	*–9.0%*	*–9.5%*	–24.4%	–33.7%	–34.5%	–27.2%
Upper-end estimate								
PEI		n/a	*–11.6%*	*–11.8%*	–13.8%	–21.6%		
Prince		n/a	*–13.4%*	*–13.5%*	–8.7%	–18.5%		
Queens		n/a	*–7.7%*	*–7.8%*	–9.7%	–14.9%		
Kings		n/a	*–15.5%*	*–16.1%*	–29.2%	–38.6%		

1. Italics indicate where abandoned farms were included in "improved land."

2. Improved land in 1980 is estimated through interpolation.

Table 10.1. Two Descriptions of Deforested Land in P.E.I., ca. 1900–2000. (Census data: Census of Canada, 1901, 1911, 1931, 1941, 1956, 1960, 1980, 2000. Inventory data estimated by interpolation using the following datasets: Prince Edward Island, Department of Environment, Energy & Forestry, Forests, Fish & Wildlife Division, 1900 Forest Outline, Last modified 4 November, 2010, 1935 Forest Inventory, Last modified 25 November, 2010, 1958 Forest Outline, Last modified 28 February, 2008, 1980 Forest Outline, Last modified 4 November, 2010, 1990 Forest Outline, Last modified 25 November, 2010, 2000 Forest Outline, Last modified 30 November, 2010. PEI Watershed Boundaries, Last modified 6 April, 2005. Software: ESRI ArcGIS 10.1, Microsoft Excel 2011, Adobe CS 4 Illustrator.)

Agriculture is actually of limited use to historians interested in land-use changes over broad areas. It tells historians nothing about land not in farms, relatively little about farmland not in crops, and it reports incorrect data for cleared land on census farms. In the discussion that follows, we suggest that farmers reporting land in the census routinely, perhaps subconsciously, under-reported the amount of cleared land in their possession.

It is not unusual to find isolated errors in census variables in certain years. In Canada, for example, the 1980 figure for unimproved land was flawed and has been ignored by recent studies.[45] But a discrepancy in cleared land in the Prince Edward Island census and inventories points to something more systemic. The discrepancy existed in all districts in the early twentieth century and widened in later years (Table 10.1).

The earliest forest inventory, *circa* 1900, indicated that sometime around the end of the nineteenth century, farmers in Prince Edward Island had reached the maximum cleared area in the province's history. Almost 360,000 hectares, or 64 per cent of the land in the province's rural townships, had been ploughed at some point in that early period. However, the most improved land the census ever reported in one year (1930) was almost 48,000 hectares short of that amount. It is not possible to compare the *circa* 1900 inventory estimate to a specific census year since the stands of white spruce on old fields had grown up at different times, but, by 1930, we can estimate the extent of the province's forest and cleared land by extrapolating backward five years from the 1935/36 inventory.

The inventory data for 1930 reveal an amount of cleared land much closer to the census figure, but still our most conservative estimate puts the census at approximately 4.9 per cent lower than the cleared land reported in the forest inventory. An upper-end estimate of cleared land in the inventory would suggest a level of under-reporting in the census closer to 12 per cent because of the amount of cleared land reverting to forest. It is likely that farmers reported these areas as unimproved land because the land was currently incapable of growing crops; technically, the land was improved, and, depending on the degree of reversion, it could be ploughed without cutting and stumping the trees.[46] We provide two estimates whenever possible to show how reverting land influenced the *Census of Agriculture*, a document that was not designed to account for this form of land-use change. The low-end estimate shows that at the very least the census figure for improved land was off by 5 per cent; the high-end estimate (12 per cent) suggests that farmers were quick to remove their reverting lands from the record, as well as from active production.

The county-level breakdown shows that the discrepancies varied significantly by region; the low-end estimates appeared much worse in Kings County (9 per cent) than Queens County, which was only below the inventory by 3.5 per cent in 1930. Figure 10.3 shows the spatial variation in the errors between the census and the forest inventory for 1931. Cleared land in most townships was at least 3 per cent higher than the census, but an obvious cluster of townships along the north shore in eastern Kings County under-reported cleared land by more than 10 per cent. If reverting land is added to the figure for cleared land, the discrepancies are even wider.

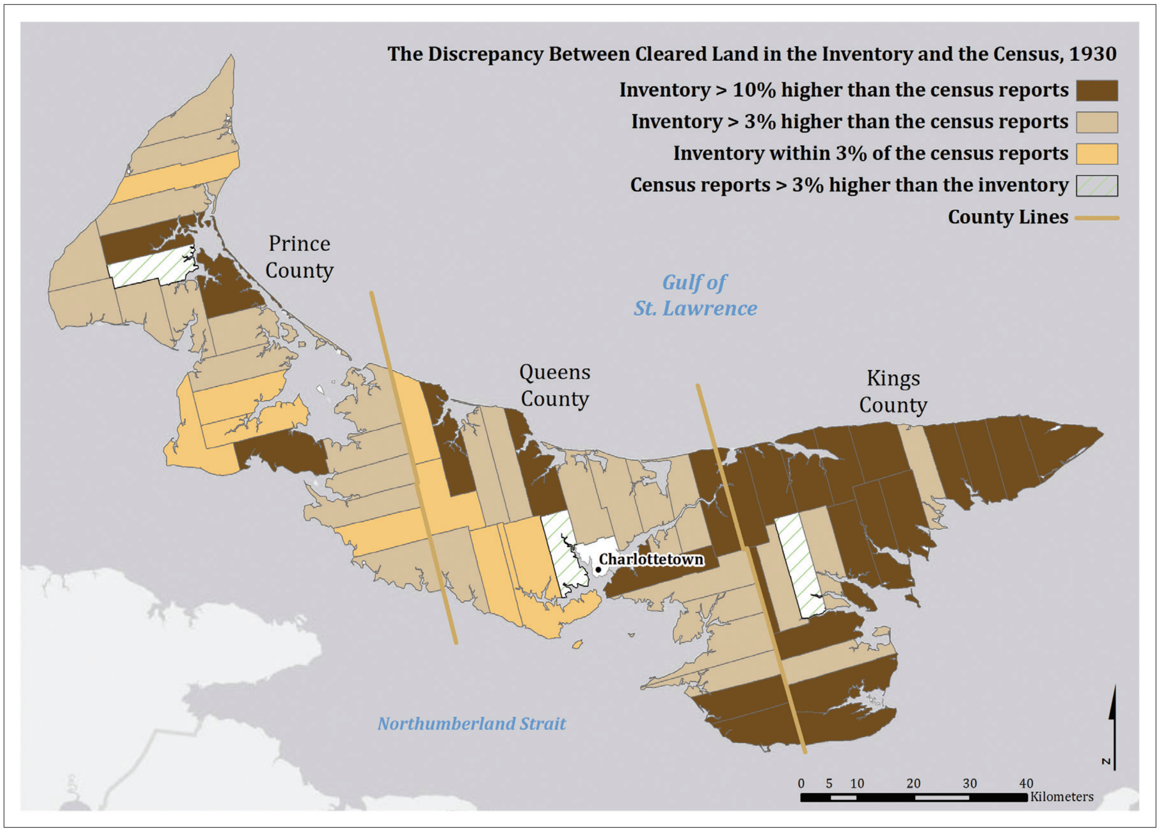

Fig. 10.3. The discrepancy between cleared land in the inventory and the census, 1930. (Prince Edward Island, Department of Environment, Energy & Forestry, Forests, Fish & Wildlife Division, PEI Lot / Townships, 2005. Software: ESRI ArcGIS 10.1, Adobe CS 4 Illustrator.)

Under-reporting cropland and improved land was likely a common phenomenon throughout Canada, and several scholars have argued that it is a regular part of agricultural statistics worldwide. In China, for instance, official estimates for agricultural land are understood to be up to 50 per cent lower than the actual area as determined by remote sensing.[47] The Dominion Bureau of Statistics studied the quality of Canadian agricultural data extensively in 1961, and they formed new estimates of improved land in sample areas of the Maritime provinces that were 16 per cent higher than the census reports for the 1960 crop year.[48] Table 10.1 shows that the 1958 inventory identified slightly more cleared land, at least in Prince Edward Island, and that under-reporting had been a common part of agricultural statistics in earlier decades, as well.

The land on census farms became an even less useful indicator of environmental change in the late twentieth century. Not only did the census reports for cleared land fall significantly short of the 1935/36 and 1958 forest inventories, but the discrepancy grew to about 23 per cent in the 1980 and 1990 censuses. A large part of the problem is simply that the *Census of Agriculture* did not record information about land use on all private properties or on any public land. The total area of occupied census farms in Prince Edward Island declined over the twentieth century, from 87 per cent of the province's land in 1911 (including abandoned farms) to almost half that proportion (44 per cent) in 2006. After 1955, this category did not include land on abandoned farms and subsistence farms, two important property classes in the Maritime provinces. In most years, the census definition of a "farm" was based on the rather arbitrary cutoff of agricultural production yielding $50 or more.[49] In 1961, this meant the census ignored the equivalent of two whole townships (18,074 hectares) of "subsistence" farms in Prince Edward Island, or over 4 per cent of occupied farmland across the province. In Nova Scotia and New Brunswick, it meant ignoring human activity on 371,157 hectares – over twice the area of farms excluded by the census in Ontario.[50] Information on abandoned farms was also not recorded after 1941, making that growing class of land use impossible to follow.

It may be that the census data for 1930 and 1940 are the most reliable for comparison to the inventory because they included improved land on both census farms and abandoned farms. But even in these two years there is still the problem of land that was not covered by the census (13 and 14 per cent of the total land mass, respectively). We account for the problem of land excluded by the census in two ways. First, almost all of the province's roads, railways, wetlands and inland water would not have been included by the census, and they represented over forty thousand hectares or half of the land not classified as occupied or abandoned land in these townships. Developed land in villages also accounted for a small amount of land not in farms. Second, we know that farmland that was not developed, cultivated, or grazed intensively quickly reverted to forest in Prince Edward Island, usually to white spruce. It is highly unlikely that other land remained clear if it was of such poor quality that it did not appear on either occupied or abandoned farms. Wetland, urban development, and roads were already removed from the forest inventories; therefore, we conclude that the discrepancies of between 5 and 12 per cent were errors in the enumerated amount of improved land.

Perhaps farmers' main incentive for under-reporting the amount of cleared land to enumerators was a fear that accurate reporting would increase the land's assessed value and by extension the amount of property taxes paid. Taxation and production quotas were apparently the primary reason for under-reporting cropland on both communal and privatized farms in China,[51] but in Canada the rationale was not as obvious. Farmers had no reason to lie to the *Census of Agriculture*, as it was not a taxation instrument. However, if land owners were accustomed to giving lower figures to municipal and provincial tax assessors, there would have been no reason to come up with a different amount for enumerators. The province's revenue from real property tax was initially a relatively small proportion of indirect taxation, but it grew significantly in the period of this study. In the 1880s, the land-tax was temporarily cancelled, and in 1914 it represented a fraction of other revenue sources. For example, income tax generated twice the amount of property taxes, and the lucrative "fox tax" brought in ten times that amount from the island's fox farmers. The intensely local nature of property taxation may

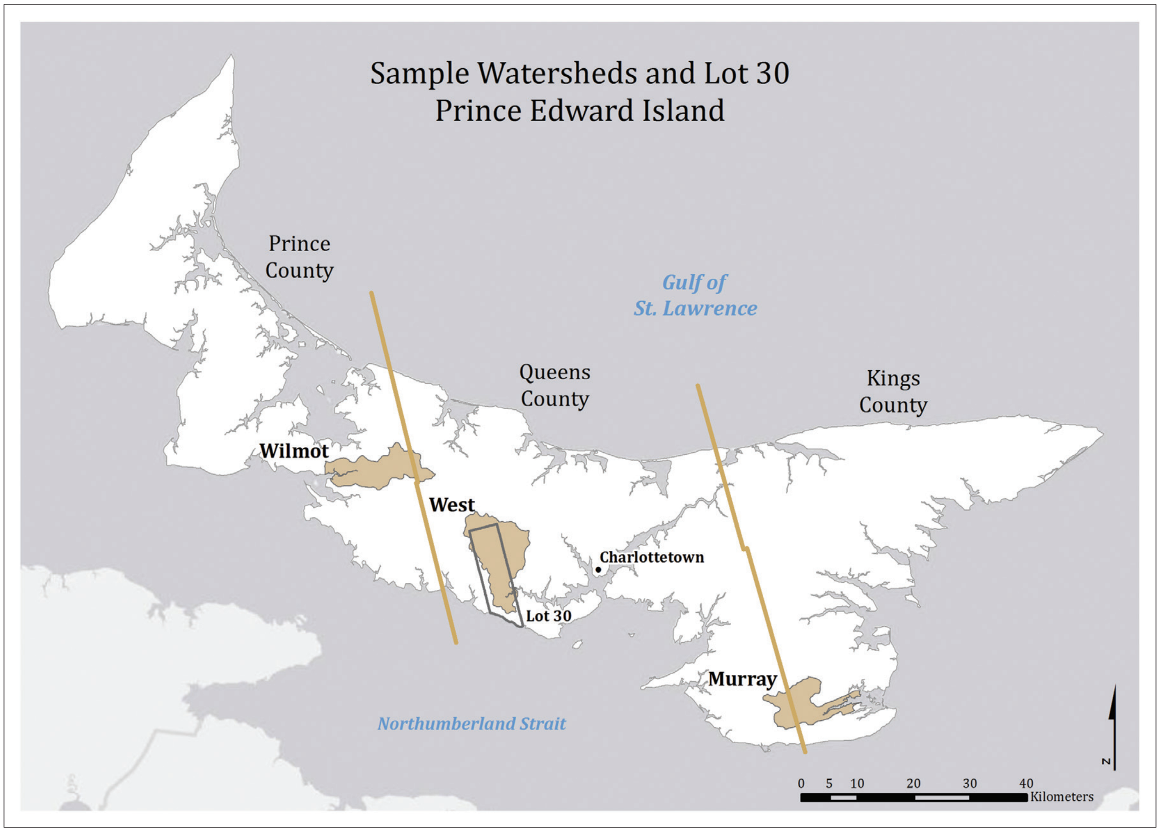

Fig. 10.4. Sample watersheds and Lot 30, Prince Edward Island. (Prince Edward Island, Department of Environment, Energy & Forestry, Forests, Fish & Wildlife Division, PEI Lot / Townships, 2005, PEI Watershed Boundaries, Last modified 6 April, 2005. Software: ESRI ArcGIS 10.1, Adobe CS 4 Illustrator.)

help explain the regional differences visible in Fig. 10.3. J. E. Lattimer has shown that when the province's school taxes were assessed and levied independently by over six hundred local school districts, both the rates and the assessments varied widely from year to year and from district to district.[52]

NEW RESEARCH POSSIBILITIES USING FOREST INVENTORIES AND GIS

In North America, the predominant land-use narrative of the twentieth century was the end of agricultural clearing and the acceleration of forest regrowth. Large tracts of farmland in the Northeast states were reverting to forest, and Prince Edward Island was experiencing similar patterns. The white spruce (*Picea gluaca*)

Table 10.2. Sample Watershed Summaries, ca. 1900–2000.

Watershed	Area (ha)	ca. 1900	1935	1958	1980	1990	2000
West River	high forest	3,018	3,449	4,433	5,511	5,443	5,046
	softwood	140	571	–	1,379	1,131	829
	mixedwood	1,899	1,899	–	1,955	1,304	1,057
	hardwood	978	979	–	2,178	3,008	3,159
	other forest	488	742	540	226	295	775
	total forest	**3,506**	**4,190**	**4,973**	**5,737**	**5,737**	**5,821**
	cleared land	7,686	7,002	6,209	5,343	5,381	4,983
	developed land	203	203	203	300	270	515
	wetlands	18	18	28	33	25	93
	Total Area	**11,413**	**11,413**	**11,412**	**11,413**	**11,414**	**11,412**
Wilmot River	high forest	855	973	1,189	1,109	1,025	822
	softwood	224	343	–	280	134	106
	mixedwood	569	569	–	377	363	271
	hardwood	61	61	–	452	529	446
	other forest	140	312	42	183	125	146
	total forest	**994**	**1,285**	**1,231**	**1,292**	**1,151**	**968**
	cleared land	7,146	6,855	6,843	6,644	6,730	6,600
	developed land	191	191	190	332	380	574
	wetlands	30	30	75	71	80	197
	Total Area	**8,361**	**8,360**	**8,338**	**8,339**	**8,340**	**8,339**
Murray River	high forest	2,700	2,825	–	4,722	4,898	4,191
	softwood	730	853	–	1,598	870	847
	mixedwood	1,628	1,628	–	1,863	2,828	1,970
	hardwood	343	343	–	1,261	1,200	1,375
	Other forest	984	1,239	4,491	292	213	621
	total forest	**3,684**	**4,065**	**4,491**	**5,014**	**5,111**	**4,813**
	cleared land	2,990	2,613	2,146	1,546	1,461	1,519
	developed land	158	158	161	276	308	443
	wetlands	278	278	296	254	216	317
	Total Area	**7,111**	**7,114**	**7,095**	**7,091**	**7,097**	**7,091**

Table 10.2. Sample Watershed Summaries, ca. 1900–2000. (Prince Edward Island, Department of Environment, Energy & Forestry, Forests, Fish & Wildlife Division, 1900 Forest Outline, Last modified 4 November, 2010, 1935 Forest Inventory, Last modified 25 November, 2010, 1958 Forest Outline, Last modified 28 February, 2008, 1980 Forest Outline, Last modified 4 November, 2010, 1990 Forest Outline, Last modified 25 November, 2010, 2000 Forest Outline, Last modified 30 November, 2010. PEI Watershed Boundaries, Last modified 6 April, 2005. Software: ESRI ArcGIS 10.1, Microsoft Excel 2011, Adobe CS 4 Illustrator.)

was the first species to capitalize on the new habitat, making its way across old fields from self-seeding hedgerows. L. M. Montgomery framed the language of reversion as a land-use decision in *Jane of Lantern Hill*. "Nothing had changed really," claimed Jane on returning to Prince Edward Island, "though there were surface changes.… Big Donald had repainted his house … the calves of last summer had grown up … Little Donald was letting his hill pasture go spruce. It was good to be home."[53] But just as scholars like Ramankutty have used remote sensing and revised historical statistics to show the local patterns within the larger trend of forest regeneration in North America, Prince Edward Island forest inventories show that "going spruce" was only one part of a complex suite of land-cover and land-use changes taking place in the twentieth century.[54]

The inventories and aerial photographs also present the ability to examine land use at multiple geospatial scales. Examining land-use data within boundaries such as township lines can be precarious. Communities were not formed along such arbitrary boundary lines, and business did not stop at census subdivisions.[55] The data derived from aerial photograph interpretation allow large areas to be broken up according to geophysical features such as watershed boundaries. Forest inventories and aerial photo data allow for analysis of land-cover and land-use change for all watersheds on Prince Edward Island. For this study, we focussed on three sample watersheds, selected for their similar sizes (7,100 to 11,500 hectares) and their diverse geographies and land-use histories (Fig. 10.4). The Wilmot River in eastern Prince County flows through some of the province's best agricultural land. The West River watershed is found in central Queens County on steep slopes and shallow soils. In Kings County, the Murray River watershed drains sandy infertile soils.

Table 10.2 shows the forest cover in these three watersheds at various points throughout the twentieth century. The West River watershed experienced the largest regrowth of forest with increases in every inventory; Murray River forest cover increased steadily but experienced a small loss of mixed-wood forest in the 1990s; forest cover in the Wilmot watershed increased only slightly and then experienced a net loss in the 1980s and 1990s. The forest regrowth and abandonment of cleared land in all three areas characterizes the second act in the Maritime historiography of farm expansion into inferior soils and slopes.[56] By examining land-use changes and the amount of reverting land, we can see how the limits of agricultural expansion were reached at different times in different places. For example, the amount of cleared land in each watershed declined as a percentage of total area, but the decline was most severe in West River and quite minor in Wilmot. Reverting land points to a prolonged process of abandonment in West River and suggests that abandonment was most pronounced in Murray River in the early 1900s when almost 9 per cent of its cleared area was reverting to forest.

Developed land took a rapidly increasing share of land use in these watersheds toward the end of the twentieth century. The single largest threat to forests in terms of land-use change in the United States is urban development. Between 1982 and 1992, that country's urban land increased by 14 million acres, and about 5.4 million acres were at a net loss to the forest.[57] A similar trend is occurring in Prince Edward Island, where a significant amount of cleared and forest land is being lost to housing.

The forest-cover type also changed in different ways for each watershed. Murray River saw a modest increase in softwoods, mixedwoods, and hardwoods, but the other two watersheds saw hardwoods rise dramatically and overtake softwoods and mixedwoods cover types. The biggest winner in each watershed was hardwood, and this fits the general pattern for the province.[58]

By combining cadastral maps such as the Cummins Atlas (1928) with the forest inventories at either the township or watershed levels, we can also analyze forest-cover and land-use change on any number of individual properties.[59] We created a land-use database for twenty-seven randomly selected properties from the Cummins cadastral map of Lot 30 (Fig. 10.4). These properties were 54 per cent cleared in 1935/36, which compares favourably with the figure of 57 per cent cleared land in the entire township.

When we examine the forest cover on even these relatively early farms, we see forests shaped in large part by human hands. The extent of clearing on farms in 1935 influenced not only the size of the forest but also the type of forest that remained. As properties in the sample began to approach total clearing, their remaining woodlots were more likely to contain hardwood and hardwood/softwood cover types (Fig. 10.5). These farms were also the most likely to contain harvested parcels and the least likely to contain any reverting land. Thus, harvested forest areas tended to favour the growth of hardwood, and the absence of reverting old fields tended to discourage new stands of white spruce. Woodlot owners placed pressure on the forest for a variety of reasons, and these changed with the market for agricultural and forest products. Clear-cutting was not only the first step to land-clearing, but it was often a reflection of the value of the wood harvested. In the 1950s pulpwood was a significant source of income in Prince Edward Island, and a significant strain on softwood stands. In the 1980s, fuelwood was important, and in the 1990s there was a strong market for studwood (small logs).

It is not possible to identify abandoned farms with any certitude from one set of aerial photographs, but the forest-cover type and the presence of clear-cuts and reverting parcels all point to farms that were strong candidates for downsizing in this period. The most intensively farmed parcels in the 1930s contained very little softwood and practically no reverting stands, and what forest did remain was predominantly hardwood and harvested land, presumably to supply the family's fuel and lumber needs. Conversely, properties with the lowest proportion of farmland contained the largest stands of reverting land and softwood stands on old fields. The combined forest inventory and cadastral map data suggest that land-use trends visible on these properties in the 1935/36 aerial photographs had clearly been in motion for decades.

We can also use the property boundaries from 1935 as a footprint for future land use on those parcels. Each one of these records in the sample represented the hopes and challenges of real historical actors. Figure 10.6 shows that Thomas McDougald's farm on New Argyle Road was mostly regrown and in the process of reversion in 1935, but it was probably not due to the quality of the land. Later inventories show that this land was mostly cleared and regularly farmed in the late twentieth century. A number of social and economic pressures could have caused the McDougalds to allow reversion on

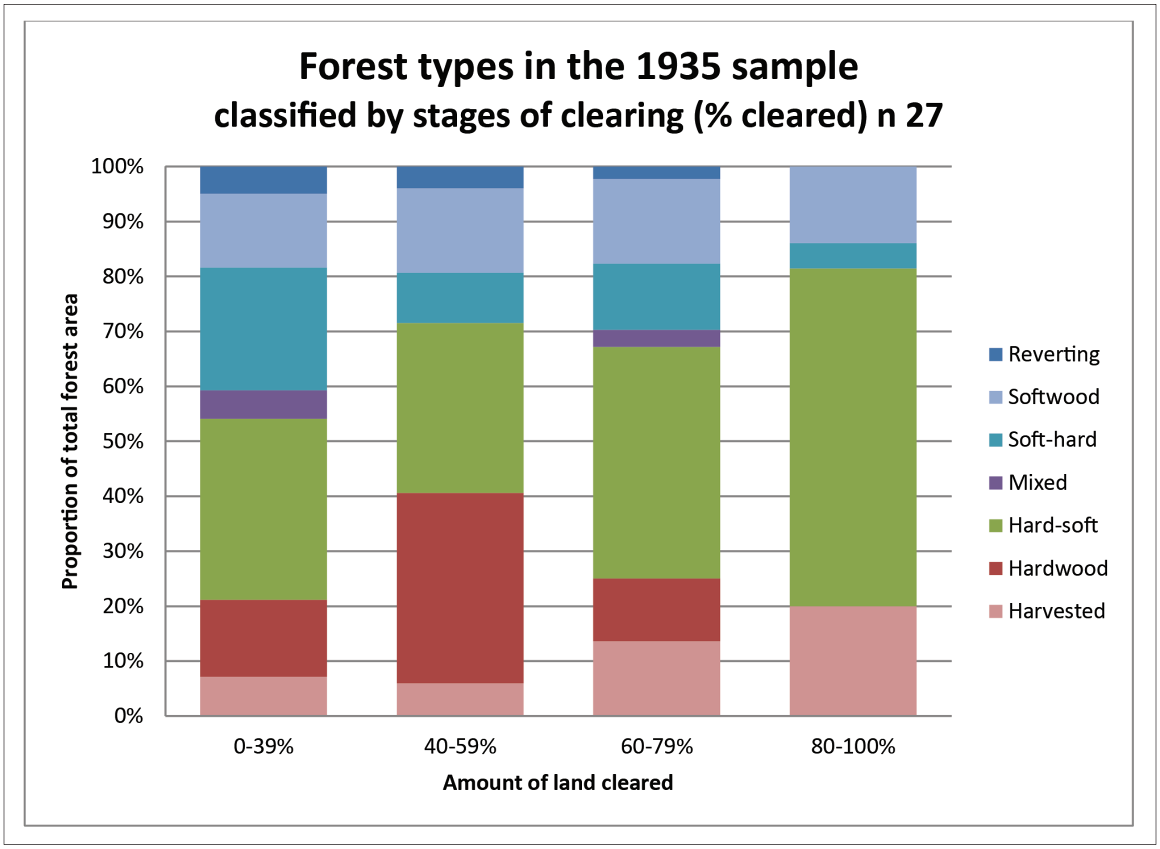

Fig. 10.5. Forest types in the 1935 inventory sample, Lot 30. (Prince Edward Island, Department of Environment, Energy & Forestry, Forests, Fish & Wildlife Division, 1935 Forest Inventory, Last modified 25 November, 2010. Property boundaries from Atlas of Province of Prince Edward Island, Canada and the World, 1927 (Toronto: Cummins Map Company, 1928). Software: ESRI ArcGIS 10.1, Adobe CS 4 Illustrator.)

such a large portion of their farm, including a death or a gap in the family labour supply or simply the economic difficulties experienced in this period of Maritime history.

Another property in Green Bay, a farm belonging to Frank Costello on the corner of Eliot River Road and Riverdale Road, consisted of hilly farmland showing the edge effect between the hardwood uplands of the Appin Road area and the farmland of Emyvale (Fig. 10.7). This property was almost entirely cleared in 1935 despite the hilly terrain and substantial wetland. It was undergoing more clearing in 1935 and does not appear to have reverted at any point since. Finally, the next property north of Costello's on Riverdale Road, toward Emyvale (not pictured here), was used mainly for its forest products over the twentieth century. Owned by Frank Dougherty in 1935, it was half-forested, mainly in hardwood with some softwood growth on old fields and with clear evidence of harvesting either for fuel or

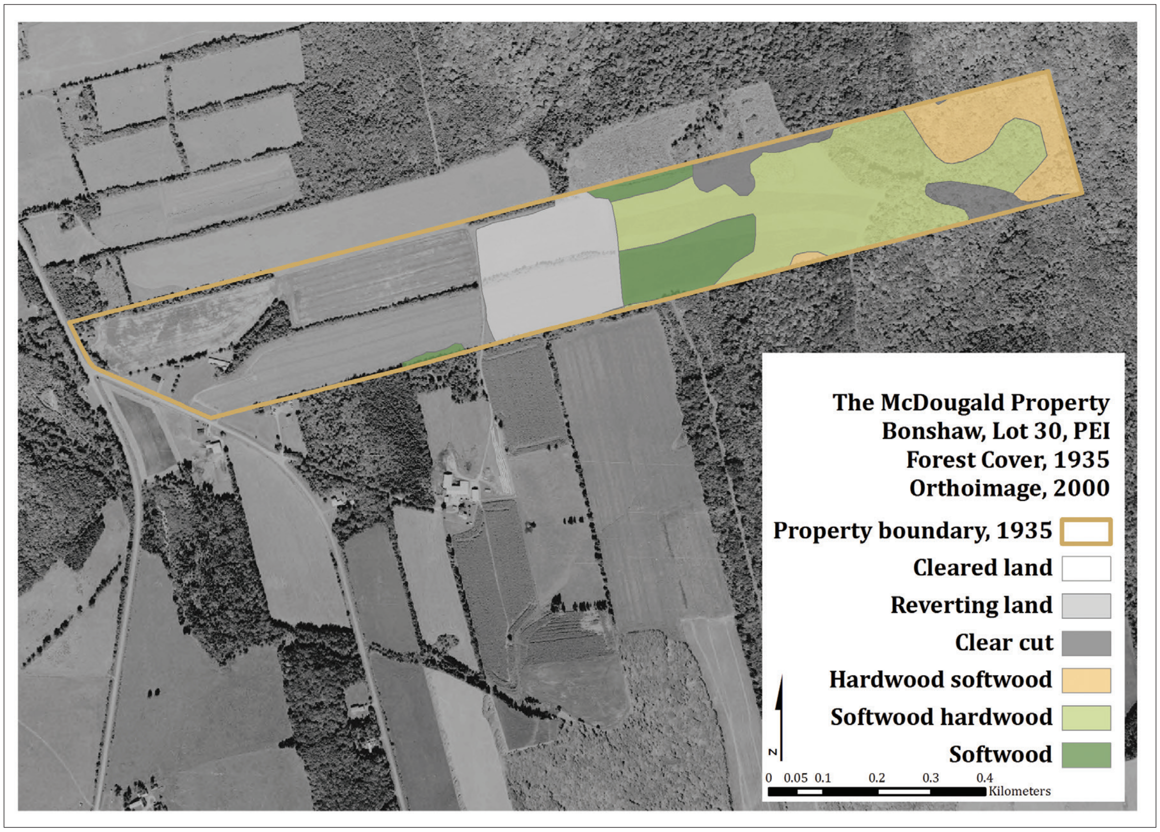

Fig. 10.6. Forest cover on the McDougald property, Bonshaw, Lot 30. (Prince Edward Island, Department of Environment, Energy & Forestry, Forests, Fish & Wildlife Division, 1935 Forest Inventory, Last modified 25 November, 2010, PEI 2000 Orthomap, Last modified 10 December, 2010. Property boundaries from Atlas of Province of Prince Edward Island, Canada and the World, 1927 (Toronto: Cummins Map Company, 1928). Software: ESRI ArcGIS 10.1, Adobe CS 4 Illustrator.)

lumber. By 1958, most of the farmland had reverted, and today the entire property is fully forested or in reversion with a small parcel of land for a home and outbuildings.[60] Costello's and McDougald's properties exemplified the two extremes of the spectrum shown in Fig. 10.5. Costello's small woodlot consisted of mostly hardwood, and McDougald's large and expanding woodlot was under less pressure and had become home to a variety of softwoods.

The image we see of the province *circa* 1900 was a landscape completely transformed by human activity. Pre-contact ecosystems had all but vanished in certain areas, wild life was at an all-time low, and forests had been profoundly altered. Unlike some provinces, however, Prince Edward Island farmland began to revert to forest for a variety of reasons, and the local environment began another form of change. The forest inventories show that farm abandonment and forest reversion were already well in motion by 1935. However, reversion did not occur evenly. We see, for instance, that townships with 75 per cent or more of their

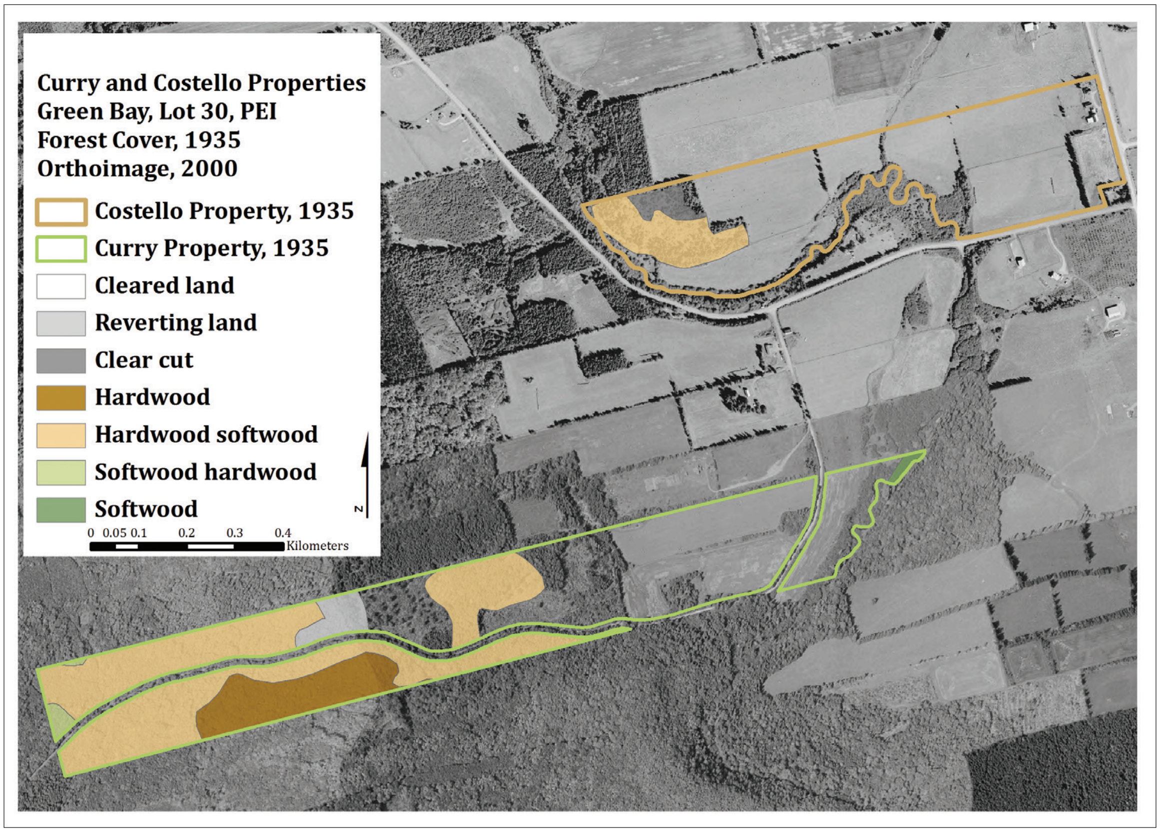

Fig. 10.7. Forest cover on the Curry and Costello properties, Green Bay, Lot 30. (Prince Edward Island, Department of Environment, Energy & Forestry, Forests, Fish & Wildlife Division, 1935 Forest Inventory, Last modified 25 November, 2010, PEI 2000 Orthomap, Last modified 10 December, 2010. Property boundaries from Atlas of Province of Prince Edward Island, Canada and the World, 1927 (Toronto: Cummins Map Company, 1928). Software: ESRI ArcGIS 10.1, Adobe CS 4 Illustrator.)

total area cleared in 1935 only saw about 4 per cent of that area return to forest by 1958. By comparison, the rest of the province was reverting to forest at three times that rate. The inventories are not the only way to measure these trends; the censuses also show us this in "improved acreage" figures. However, as we have shown, problems with the way cleared land was identified in the census result in exaggerated figures for improved land. Thus, the same townships with 75 per cent or more of their land "improved" actually appeared to lose 13 per cent of that land by 1961, and farms in the rest of the province relinquished over a quarter of their improved land to the forest. The forest inventories show a more even decline in cleared land because they captured all properties across the province, including those termed "abandoned" or "subsistence" farms by the *Census of Agriculture*.

None of our sample properties was in a complete state of reversion in either 1935 or 1958. Thus, we must be careful not to equate reverting land with abandoned land. Our sample suggests that reversion was a land-use decision followed by a relatively small number of farms; mainly it was a decision to reduce crop production. In our Lot 30 sample, reverting land occurred on only one quarter of properties. Most other areas in Queens County experienced lower reversion rates, so we can assume that well over three quarters of farmers in the county did not take farmland out of crop rotation long enough for reversion to occur. In townships with a higher proportion of cleared land in reversion, it is certainly possible that more farmers were downsizing, but this practice was far from ubiquitous in the 1930s. Some properties experienced relatively rapid reversion from average farms to almost completely treed plots. On Frank Dougherty's property, only a small parcel of cleared land remained at the end of the twentieth century for residential dwellings and small business activity. The 11.5 hectares of reverting land on this property, in 1935, was the largest parcel of new forest in our sample; the average property with reverting land contained only 3.2 hectares. The Dougherty's forest history shows how entire farms could "grow over" in less than half a century.

Using GIS we can query the parcels of cleared land in 1958 that had been in the process of reversion in 1935. The result shows that 3,664 hectares were reverting in 1935 but had been cleared a second or perhaps even a third time before 1958. Clearing on Prince Edward Island was not always a single event that led to a long-term land-use activity. Instead, the residents of this declining agricultural region explored a variety of options including part-time farming, renting, and allowing some fields to revert to forest.

CONCLUSIONS

If, as James Scott has argued, cadastral maps and scientific censuses made local information available to the state, then GIS and aerial photographs attach a time and a place to remotely sensed data and make it available to historians. After all, each cell of remotely sensed information was part of a local narrative. As we interpret the aerial photographs, we are gazing down on hundreds of human agents who probably glanced upwards from farmyards, fishing boats, and woodlots at this marvel of aeronautical engineering and symbol of a changing world. The story of their worlds has mainly been told by the census, the most extensive historical record for the majority of rural, and usually voiceless, Canadians. But, the twentieth century censuses of agriculture missed large tracts of land in Atlantic Canada, even in Prince Edward Island where a vast majority of land was privately owned and used for agricultural production.

Historians can now see this new side of the Canadian environment in many regions, especially the forested areas that attracted aerial photographers from government or industry. GIS allows historians to use the census in conjunction with new sources such as forest inventories and aerial photographs; on its own the census simply cannot provide an accurate portrayal of land-use activity. The *Census of Agriculture* provides an excellent starting point toward an understanding of environmental change in Canada, but, as we have shown, it has its weaknesses. Environmental historians should be attentive to the proportion of land enumerated in any given census year before using the census to make estimates of the size of the forest and the amount of deforestation. Even in areas where commercially farmed private land made up over 85 per cent of total land mass, as it did in Prince Edward Island in 1930 and 1940, historians should expect some degree of under-reporting of cleared land in the *Census of Agriculture*.

To economic historians who use improved land as an indicator of farm value, the revised estimates based on aerial photography suggest that farmland has been undervalued. The amount of improved acreage was critical for estimating the value of land and the costs of farm-making.[61] Furthermore, historians commonly use acreage to measure the productivity of farming as an economic activity since, as Marvin McInnis states, land is "an obvious starting point" for analysis as it "is the most directly measurable input."[62] To environmental historians, the census over-estimated the total biomass available on farms, and it ignored forest and other land cover on a growing number of properties in the late twentieth century. Historians need to understand these standard units of production if they are to ask questions about human interactions with the environment. Recent research emphasizes material and energy flow analysis as a way to measure the effects of human activity on natural ecosystems, and the symbiotic effects of environmental change on quality of life.[63] Land-cover and land-use change are fundamental variables in this research, and the forest inventories help to establish more spatially explicit land-use models.[64] In the Maritime provinces, and other areas that experienced agricultural decline, these sources also introduce the category of reverting land. Reversion occurred only on a small percentage of farms, but it was capable of returning entire properties to forest in a matter of a few decades.

The land-use and forest inventories and the aerial photographs they were built from are a powerful resource for historians and geographers. By interpreting the data in a GIS, users can investigate the land-cover and land-use change at any level, from the individual property to the townships, municipalities, watersheds, and larger jurisdictions such as the census district or the province as a whole. Where they exist, these sources would also allow for a more extensive project that performs sample inventories from aerial photographs across the country – a kind of "environmental census" for representative regions. Although the *Censuses of Agriculture* offer a limited view of human activity in forest and agro-ecosystems, a more comprehensive picture may be created by combining inventory samples with cadastral data and linking them to digital censuses of population and other geospatial databases. Air photos are some of the best time-slices of Canada's vast and diverse environments, and dynamic systems such as GIS allow historians to extract, manipulate, and link the information to other geospatial databases. These linkages present a clearer picture of past land use in order to better understand environmental change and changing land use practices over time.

NOTES

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2 N. Ramankutty and J. A. Foley, "Estimating Historical Changes in Land Cover: North American Croplands from 1850 to 1992," *Global Ecology and Biogeography* 8, no. 5 (1999): 382.

3 For more on the literature surrounding abandonment, see Mark Lapping, "Stone Walls, Woodlands, and Farm Buildings: Artifacts of New England's Agrarian Past," in Blake A. Harrison and Richard William Judd, eds., *A Landscape History of New England* (Cambridge, MA: MIT Press, 2011), 130, 132; N. Ramankutty, E. Heller, and J. Rhemtulla, "Prevailing Myths about Agricultural Abandonment and Forest Regrowth in the United States," *Annals of the American Association of Geography* 100, no. 3 (2010): 502–12.

4 For example, most studies of agriculture and agro-ecosystems in projects from the *Historical Atlas of Canada* to *L'Atlas historique du Québec* used improved land or land in crops as the primary indicator of farm activity.

5 See, for example, Table II, Land Occupied According to Tenure and Condition, in Canada, *Census of Canada, 1911. Agriculture*, vol. 4 (Ottawa: J. de L. Taché, 1914).

6 R. M. McInnis, "Perspectives on Ontario Agriculture, 1815–1930," *Canadian Papers in Rural History* 8 (1992): 17–127, 103; see also R. M. McInnis, "Output and Productivity in Canadian Agriculture, 1870–71 to 1926–27," in Stanley L. Engerman and Robert E. Gallman, eds., *Long-Term Factors in American Economic Growth* (Chicago: University of Chicago Press, 1992 [reprint]), 751.

7 O.F.G. Sitwell, "Difficulties in the Interpretation of the Agricultural Statistics in the Canadian Censuses of the Nineteenth Century," *Canadian Geographer* 13, no. 1 (1969): 75. See also the danger of misinterpretation, given the exclusion of grass crops in pasture land in the "crops" category, identified by Andrew H. Clark, *Three Centuries and the Island: A Historical Geography of Settlement and Agriculture in Prince Edward Island, Canada* (Toronto: University of Toronto Press, 1959), 158; Alan A. Brookes, "'Doing the Best I Can': The Taking of the 1861 New Brunswick Census," *Histoire sociale – Social History* 9, no. 17 (1976): 70–91.

8 Early censuses such as the Prince Edward Island *Census of 1841* asked farmers for the "Number of acres of *arable* Land held by each family," and in 1911 census makers had returned to this classification of improved land as "land which has been brought under cultivation and has been cropped and *is fitted for* producing crops."

9 Donald H. Akenson, *The Irish in Ontario: A Study in Rural History* (Montreal: McGill-Queen's University Press, 1984), 385.

10 Ruth W. Sandwell, "Rural Households, Subsistence and Environment on the Canadian Shield, 1901–1940," paper delivered at *Bringing Subsistence Out of the Shadows*: *An Environmental History Workshop on Subsistence Relationships,* Nipissing University, North Bay, Ontario (3 October 2009).

11 Peter A. Russell, "Forest into Farmland: Upper Canadian Clearing Rates, 1822–1839," *Agricultural History* 57, no. 3 (1983): 338; Catharine A. Wilson, *A New Lease on Life: Landlords, Tenants and Immigrants in Ireland and Canada* (Montreal: McGill-Queen's University Press, 1994), 33–34.

12 James C. Scott, *Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed* (New Haven, CT: Yale University Press, 1998), 44.

13 Douglas McCalla, *Planting the Province: The Economic History of Upper Canada, 1784–1870* (Toronto: University of Toronto Press, 1993), 165; Catharine Wilson shows how the tax burden for Irish immigrants was much lighter in Canada than in Ireland, and she points to the "wild land tax" implemented to discourage absentee speculators from holding undeveloped land. Wilson, *A New Lease on Life*, 47, 186.

14 Harold M. Groves, "The Property Tax in Canada and the United States," *Land Economics* 24, no. 1 (1948): 24.

15 Suzanne Zeller, *Inventing Canada: Early Victorian Science and the Idea of a Transcontinental Nation* (Toronto: University of Toronto Press, 1987).

16 Public Archives and Records Office (Prince Edward Island), "Report of the Superintendent of Census Returns, Charlottetown, August 23, 1871;" Manitoba, *Report of the Minister of Agriculture of the Province of Manitoba*, 1880–83 (Montreal: Gazette Printing, 1881).

17 Manitoba, *Report of the Minister of Agriculture of the Province of Manitoba*, 1880–83, Table xiii; Canada, *Census of Population and Agriculture of the Northwest Territories, 1886*, Table XIV. Capturing agricultural data for two growing seasons was a unique characteristic of the Canadian censuses, and the 1921 and 1911 Censuses of Canada were each conducted in June to allow "ascertaining

the areas sown to field crops for the harvest years 1921 and 1911 as well as the area and production of crops for the preceding year." Canada, *Sixth Census of Canada*, *1921*, vol. v – Agriculture (Ottawa: F. A. Acland, 1925), ix.

18 Geoff Cunfer, *On the Great Plains: Agriculture and Environment* (College Station: Texas A&M University Press, 2005), 30–31, 35–36.

19 S. B. Carter, S. S. Gartner, M. R. Haines, A. L. Olmstead, R. Sutch, and G. Wright, eds., *Historical Statistics of the United States: Earliest Times to the Present*, vol. 4 (New York: Cambridge University Press, 2006); Ramankutty et al., "Prevailing Myths," Fig. 2; M. L. Liu and H. Q. Tian, "China's Land Cover and Land Use Change from 1700 to 2005: Estimations from High-Resolution Satellite Data and Historical Archives," *Global Biogeochemical Cycles* 24, no. 3 (2010).

20 L. E. Philpotts, *Aerial Photo Interpretation of Land Use Changes in Fourteen Lots in Prince Edward Island*, Economics Division, Canada Department of Agriculture, 1958; C. W. Raymond and J. A. Rayburn, "Land Abandonment in Prince Edward Island," *Geographical Bulletin* 19 (1963): 78–86; W. M. Glen, *Prince Edward Island 1935/1936 Forest Cover Type Mapping*, Forestry Division, P.E.I. Department of Agriculture and Forestry, Charlottetown, Prince Edward Island, 1997; S. M. McDonald and W. M. Glen, *1958 Forest Inventory of Prince Edward Island*, P.E.I. Department of Environment, Energy and Forestry, 2006; D. G. Sobey and W. M. Glen, "A Mapping of the Present and Past Forest-types of Prince Edward Island," *Canadian Field-Naturalist* 118, no. 4 (2004): 504–20.

21 Don W. Thomson, *Men and Meridians: The History of Surveying and Mapping in Canada, vol. 2, 1867 to 1917* (Ottawa: Queen's Printer, 1967), 255.

22 Jay Sherwood, *Furrows in the Sky: The Adventures of Gerry Andrews* (Victoria: Royal BC Museum, 2012), 57; "Aviator to Detect Forest Fires," *American Forestry*, September 1915, 914–15; Hugh A. Halliday, "The Forest Watchers: Air Force, Part 35," *Legion Magazine* 20 (October 2009); Thomson, *Men and Meridians*, 289–90.

23 Richard A. Rajala, *Feds, Forests, and Fire: A Century of Canadian Forestry Innovation*, Canadian Science and Technology Museum, Transformation Series 13 (2005), 40–41. See also Peter Gillis and Thomas Roach, *Lost Initiatives: Canada's Forest Industries, Forest Policies, and Forest Conservation* (New York: Greenwood, 1986), 211; "A Nation-Wide Inventory of our Forest Resources," *Natural Resources Canada* 8 (March 1929): 2; H. E. Seeley "The Use of Air Photographs for Forestry Purposes," *Forestry Chronicle* 12 (December 1935): 287–93; and Roland D. Craig, "Forest Surveys in Canada," *Forestry Chronicle* 11 (September 1935): 31.

24 The small gaps created by spaces where the flight lines were too far apart were corrected by using aerial photography from the subsequent survey in 1958.

25 The pilot's altitude actually ranged from 9,910 to 10,410 feet. Glen, *Prince Edward Island 1935/1936 Forest Cover Type Mapping*, 2–3.

26 McDonald and Glen, *1958 Forest Inventory*, 2–3, 4.

27 See, for example, Canada Bureau of Geology and Topography, Topographical Survey, "St. Andrews, Charlotte County, New Brunswick," Geological Survey of Canada, *"A" Series*, Map 523a (1939). The National Air Photo Library website may be accessed at http://airphotos.nrcan.gc.ca. http://www.nrcan.gc.ca/earth-sciences/products-services/satellite-photography-imagery/aerial-photos/search-air-photos/920 (accessed May 2013).

28 Several of the precursors to NTS maps surveyed privately owned farms and woodland in the early twentieth century, but these are only available in limited areas. They were surveyed by the Geographical Section of the Department of National Defence. See, for instance, Department of National Defence, "Topographic Map, Nova Scotia: Halifax Sheet, Number 201, Surveyed in 1920" [map], 1:63,360 (n.p., 1923).

29 Thomson, *Men and Meridians*, 298.

30 This form of research is also underway in other parts of the country, although more collaboration is needed. For example, Diane Saint-Laurent has used similar sets of aerial photographs to identify land-use and zoning changes in Sherbrooke and Richmond, Quebec, between 1945 and 2000. Stephane Castonguay and Diane Saint-Laurent, "Reconstructing Reforestation: Changing Land-Use Patterns along the Saint-Francois River in the Eastern Townships," in Alan MacEachern and William Turkel, *Method and Meaning in Canadian*

Environmental History (Toronto: Nelson, 2009), 286, 287.

31 The aerial photos are now stored mainly in the National Air Photo library in Ottawa, although many sets of historical air photos are also available at university map libraries and in municipal collections. The Prince Edward Island forest inventories are available for download at the provincial GIS website: http://www.gov.pe.ca/gis.

32 Colin MacIntyre, "The Environmental Pre-History of Prince Edward Island, 1769–1970: A Reconnaissance in Force," Master's thesis, University of Prince Edward Island, 2010, 126, 161–62.

33 Maritime Resource Management Service Inc., *Proposal for a Prince Edward Island Inventory Pilot Study: Prepared for P.E.I. Dept. of Energy and Forestry* (Amherst: Maritime Resource Management Service, 1987).

34 William Glen was the project manager for all but the 1980 inventories, and, within the resources available, the classification used in each of the inventories was comparable.

35 Glen, *Prince Edward Island 1935/1936 Forest Cover Type Mapping*, 4.

36 Variables such as tree species or agricultural land use are different in some inventories, due to the quality of the photographs and availability of resources. For example, a range of crop types and land uses were identified in 2000, but in 1980 and earlier years all contiguous areas of cleared land were included in a single polygon.

37 Don W. Thomson, *Men and Meridians: The History of Surveying and Mapping in Canada, vol. 1, Prior to 1867* (Ottawa: Queen's Printer, 1966).

38 Elsbeth Heaman, *The Inglorious Arts of Peace: Exhibitions in Canadian Society during the Nineteenth Century* (Toronto: University of Toronto Press, 1999), 160.

39 Robert Chalmers, "Report on the surface geology of eastern New Brunswick, north-western Nova Scotia and a portion of Prince Edward Island," *Annual Report*, Geological Survey of Canada, 8 (1895): Part M; Douglas G. Sobey, *Early Descriptions of the Forests of Prince Edward Island: A Source-Book, vol. II, The British and Post-Confederation Periods – 1758–c.1900* (Charlottetown: 2006), Part B: The Extracts, 222.

40 Clark, *Three Centuries and the Island*, 19; F. A. Stilgenbauer, *The Geography of Prince Edward Island*, PhD dissertation, University of Michigan, Ann Arbor, 1929; O. L. Loucks, "A Forest Classification for the Maritime Provinces," *Proceedings of the Nova Scotia Institute of Science* 25 (1962): 85–167.

41 Stephen J. Pyne, *Awful Splendour: A Fire History of Canada* (Vancouver: UBC Press, 2007), 223; Bernhard E. Fernow, *Forest Conditions of Nova Scotia* (Ottawa: Commission of Conservation, Canada, and Department of Crown Lands, Nova Scotia, 1912), 2–5.

42 Williams relied on a rather general interpretation of "improved land" for his early estimates, and according to Ramankutty there were flaws in some of the census statistics on which his estimates for forest areas were based. N. Ramankutty and J. A. Foley, "Characterizing Patterns of Global Land Use: An Analysis of Global Croplands Data," *Global Biogeochemical Cycles* 12 (1998): 667–85.

43 "Snapshot of Canadian agriculture," http://www.statcan.gc.ca/ca-ra2006/articles/snapshot-portrait-eng.htm, (accessed May 2013).

44 N. Ramankutty, J. A. Foley, and N. J. Olejniczak, "Land-Use Change and Global Food Production," in Ademola K. Braimoh and Paul L. G. Vlek, eds., *Land Use and Soil Resources* (Dordrecht: Springer, 2008), 28.

45 Canada, *Census of Agriculture*, 1986, xvi; Donald C. E. Robinson, Werner A. Kurz, and Christine Pinkham, *Estimating the Carbon Losses from Deforestation in Canada*, prepared for the National Climate Change Secretariat, Canadian Forest Service (Vancouver: ESSA Technologies, 1999), 4, Table 2.1; G. Kornelis Van Kooten, "Bioeconomic Evaluation of Government Agricultural Programs on Wetlands Conversion," *Land Economics* 69, no. 1 (1993): 29; P. Sellers and M. Wellisch, *Greenhouse Gas Contribution of Canada's Land-Use Change and Forestry Activities: 1990–2010*, final draft, prepared by MWA Consultants for Environment Canada, July 1998.

46 For the 1930 and 1940 upper-end estimates, we added the percentage of reverting land (6.7 per cent of cleared land) to our interpolated figures, and for 1955 and 1960, we used the amount of reverting land in 1958 (3 per cent of cleared land).

47 V. Smil, "China's Agricultural Land," *The China Quarterly* 158 (June 1999): 414, 417; Frederick W. Crook, "Underreporting of China's Cultivated Land Area: Implications for World's Agricultural Trade," *China Situation and Outlook Series* (Washington, D.C.: Department of Agriculture, 1993): 33–39; Stefan Siebert, Felix T. Portmann, and Petra Döll, "Global Patterns of Cropland Use Intensity," *Remote Sensing* 2 (2010): 1639; Ramankutty et al., "Land-Use Change and Global Food Production," 24.

48 The first "Agriculture Quality Check" performed by the Dominion Bureau of Statistics was in 1956, although it only investigated total farm area and not the condition of farm land. Canada, *Census of Canada 1956, Agriculture*, Bulletin 2–11 (Ottawa: Edmond Cloutier, Queen's Printer, 1957), xii; Canada, *1961 Census of Canada, vol. 5, Agriculture*, Bulletin 5.1 (Ottawa: Roger Duhamel, Queen's Printer, 1963), Table 4, xviii; Don W. Thomson, *Skyview Canada: A Story of Aerial Photography in Canada* (Ottawa: R.B.W. Ltd., 1975), 167.

49 The 1951 and 1956 censuses defined farms differently, incorporating more farms into the total, and as a result they made the drop from 1955 to 1960 appear more drastic. Canada, *Eighth Census of Canada, 1941, vol. VIII, Agriculture*, Part I (Ottawa: Edmond Cloutier, King's Printer, 1947), xx; Canada, *1961 Census of Canada, vol. 5*, vii.

50 According to the 1961 Census, "a farm is defined as an agricultural holding of one acre or more with sales of agricultural products during the past 12 months of $50 or more." Canada, *1961 Census of Canada: Agriculture, Bulletin 5.1–1* (Ottawa: Roger Duhamel, Queen's Printer, June 1963), Table 1, vi–vii.

51 Smil, "China's Agricultural Land," 417.

52 Prince Edward Island, *Journal of the Legislative Assembly of the Province of Prince Edward Island*, 1915, 109, "Collectable;" J. E. Lattimer, *Taxation in Prince Edward Island, A Report* (Charlottetown: Department of Reconstruction, 1945), 28.

53 L. M. Montgomery, *Jane of Lantern Hill* (Toronto: McClelland & Stewart, 1937), chap. 34.

54 Ramankutty et al., "Prevailing Myths," 503.

55 In some cases the agricultural production data in the census did not stop at subdivision boundaries, either. At least two townships in Prince Edward Island (Lot 65 and Lot 6) contained properties where the house, and therefore head of household, was in one subdivision and large portions of the property belonged to the adjacent subdivision. It appears in this case that the farm land and its products were entirely attributed to the subdivision containing the house.

56 Kris Inwood and Jim Irwin, "Land, Income and Regional Inequality: New Estimates of Provincial Incomes and Growth in Canada, 1871–1891," *Acadiensis* 31, no. 2 (2002): 157–58; Julian Gwyn, "Golden Age or Bronze Moment? Wealth and Poverty in Nova Scotia: the 1850s and 1860s," *Canadian Papers in Rural History* 8 (1992): 195–230.

57 Robinson et al., *Estimating the Carbon Losses*, 6, Table 2.2.

58 D. G. Sobey and W. M. Glen, *The Forest Vegetation of the Prince Edward Island National Park and the Adjacent Watershed Area Prior to European Settlement as Revealed from a Search and Analysis of the Historical and Archival Literature*, Phase 2; Analysis and Discussion (Contracted Report for Prince Edward Island National Park, 2002).

59 *Atlas of Province of Prince Edward Island, Canada and the World, 1927* (Toronto: Cummins Map Co., 1928).

60 It should be noted that the reverting section in 1958 included a significant strip of the neighbouring property's farm land. By 2000, the neighbouring farm had re-cleared the encroaching forest along the property lines, indicating the dynamic processes of reversion and clearing along parcel edges.

61 Jeremy Atack, "Farm and Farm-Making Costs Revisited," *Agricultural History* 56 (October 1982): 673.

62 McInnis, "Perspectives on Ontario Agriculture," 103.

63 Marina Fischer-Kowalski and Helmut Haberl, eds., *Socioecological Transitions and Global Change: Trajectories of Social Metabolism and Land Use* (Cheltenham: Edward Elgar, 2007).

64 Liu and Tian, "China's Land Cover and Land Use Change from 1700 to 2005."