Landscape Ecol
DOI 10.1007/s10980-007-9100-z

RESEARCH ARTICLE

The landscape history of Godmanchester (Quebec, Canada): two centuries of shifting relationships between anthropic and biophysical factors

Gérald Domon · André Bouchard

Received: 13 December 2005 / Accepted: 28 March 2007

Abstract Taking into consideration ecological aspects in land management requires an understanding of the processes and dynamics that create landscapes. To achieve this understanding demands that landscapes be studied as a biophysical and social reality, and that phenomena be analyzed within a historical perspective. Based on the research of a multidisciplinary team over the last 25 years, this paper proposes to reconstitute the landscape of Godmanchester (Quebec, Canada) from the pre-colonial period (1785) to today (2005). Using various methods and sources of data, seven stages of evolution were identified: (1) the pre-colonial period, (2) the first settlements, (3) the first agricultural developments, (4) the maximum development of agricultural activities, (5) the concentration of agricultural activities, (6) the intensification of agricultural activities, and (7) the importance of new amenities. First, these results allowed us to identify three sets of fundamental factors that are necessary to understanding the landscape changes, the geomorphological characteristics, the socio-economic demands, and the technological transformations. Second, the results highlight the key elements and the perspectives that are appropriate to their comprehension, in order to be able to direct the future evolution of the landscapes. This requires that transformations be analyzed from mid-term to long-term perspectives, that the consequences of the changes, as well as the opportunities that they generate, are well understood, and finally that relationships be drawn between the biophysical, anthropic, and technological factors responsible for these transformations. This paper concludes with the idea that the creation of landscapes occurs through actions brought about by social demands and by the adjustment of technologies according to the biophysical characteristics of the territories.

Keywords Landscape history · Landscape dynamics · Multidisciplinary research · North-Eastern North America · Land use changes · Resource management

G. Domon (✉)
Faculty of Environmental Design, University of Montreal, C.P. 6128, Succursale Centre-Ville, H3C 3J7 Montreal, Quebec, Canada
e-mail: gerald.domon@umontreal.ca

A. Bouchard
Plant Science Research Institute, Department of Biological Sciences, University of Montreal, 4101 Est rue Sherbrooke, H1X 2B2 Montreal, Quebec, Canada

Introduction

The emergence of landscape ecology has greatly improved our understanding of the analytical paths that could be the most useful for studying the ecological aspects of land use and landscape management (Dale and Haeuber 2001; Lin and Taylor 2002). Thus, although the research of pioneers (e.g., Hills 1961; Jurdant et al. 1977; Austin and Cocks 1978) emphasized the acquisition of information on ecological potentials and constraints, the research done along a landscape ecology perspective has shown the need for a real understanding of the dynamics and processes involved. Two essential conditions are required.

First, although the landscape has long been seen either exclusively as a biophysical reality (Palka 1995), or exclusively as a social and cultural reality (Meinig 1979; Jackson 1984), research has also emphasized the need to view the landscape simultaneously as a biophysical reality and as a social reality (Naveh and Liberman 1984; Tress and Tress 2001; Wu and Hobbs 2002). Emphasis is therefore placed on the reciprocal relationships between these systems (Brandt and Vejre 2004), the challenge residing at properly addressing this interface (Palang and Fry 2003).

Second, landscape research revealed the fundamentally dynamic nature of landscapes and, consequently, the need to position observed phenomena within a historical perspective (Palang and Fry 2003). The understanding of the processes and management of past traditional landscapes offers valuable knowledge for improved sustainable planning and management of future landscapes (Antrop 2005).

Although they appear theoretically evident today, these conditions still represent considerable methodological challenges. Thus, integrating social and ecological aspects remains one of the major concerns in landscape management and resource management (Haeuber and Dale 2001; Palang and Fry 2003). Difficulties are particularly due to the necessity of using methods originating from various disciplines, from quantitative to qualitative methods (Bürgi et al. 2004), and to the difficulty in integrating the resulting knowledge (Sooväli et al. 2003; Ruiz and Domon 2005).

As for historical knowledge, it is constantly facing limitations caused by the available sources of information, and particularly by the difficulty of reconstituting the past over long periods of time. Although the general availability of aerial photograph coverage, beginning in the late 1950s, has allowed us to keep abreast of the major trends of the last decades (e.g., Turner 1990; Simpson et al. 1994; Medley et al. 1995), it remains difficult to place them in a long-term context, and thus to evaluate the exact significance of landscape transformations. This difficulty seems particularly evident in North America where, in spite of certain major contributions (Andersen et al. 1996; Silbernagel et al. 1997; Russell and Bürgi 2004), the rapid pace of transformations and the large areas involved have had the effect of considerably limiting the documentation of occurring phenomena.

Over this backdrop, a multidisciplinary research team has worked, over the last 25 years, to reconstitute the landscape dynamics of the southern Quebec municipality of Godmanchester (Fig. 1). The interest of this study area is considerable since, because of the

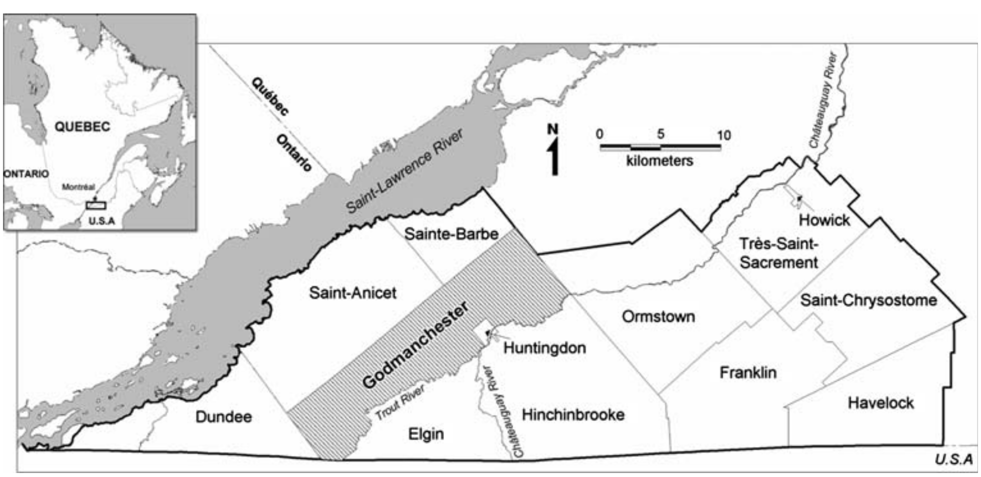

Fig. 1 Location map of Godmanchester and the other municipalities of the Haut-Saint-Laurent

geographical location and the historical conditions, colonization began relatively late, not much before 1800. With this set of conditions, the work of bringing the documentary sources available up to date has allowed us to reconstitute the pre-colonial vegetation and to measure the breadth of the transformations of the environment.

Based on a synthesis of the different research projects done over the last 25 years, this paper proposes a reconstitution of the landscape dynamics of Godmanchester from the pre-colonial period (1785) to today (2005). Beyond a purely historical reconstitution, our goal, based on a concrete study area documented form various viewpoints, was to: (1) bring up to date the mechanisms by which anthropic and biophysical dimensions interact into shaping and transforming landscapes; and (2) identify, from this update, some implications for the shaping of their future. Beforehand, however, we present a brief overview of the characteristics of the study area and of the methodological framework.

Methods

Study area

Godmanchester, a rural municipality of 139 km^2, is located in the Haut-Saint-Laurent Regional County Municipality in the southernmost part of the province of Québec, Canada (Fig. 1). It belongs to the humid-cool temperate ecoclimatic region of Canada (Ecoregions Working Group 1989).

The Haut-Saint-Laurent Regional County Municipality lies on a bedrock of sandstone, dolomite and shale of the Potsdam and Beekmantown groups (Globensky 1981). Glacial recession left numerous moraine islets and ridges (maximum elevation 90 m) lying parallel to the St. Lawrence river (Bariteau 1988), whereas lowlands (maximum elevation 60 m) are covered with the nutrient-rich marine clay deposits of the post-glacial Champlain Sea. Two broad types of deposits are thus important on the territory of Godmanchester, the morainic deposits, creating stony soils, and marine clay deposits. To these two major types, we can also add a large biogenic (peaty) deposit in the north-eastern part of the study area (Fig. 2).

This area is part of the sugar maple-hickory zone (Grandtner 1966) of the deciduous forest region of the Great Lakes and St. Lawrence River area (Rowe 1972). Mesic forests are generally dominated by sugar maple (*Acer saccharum* Marsh.), accompanied by bitternut hickory (*Carya cordiformis* (Wang.) K. Koch), ironwood (*Ostrya virginiana* (Mill.) K. Koch) and basswood (*Tilia americana* L.). Red maple (*Acer rubrum* L.), trembling aspen (*Populus tremuloides* Michx.) and gray birch (*Betula populifolia* March) can be found on disturbed upland sites as well as on xeric sites with white pine (*Pinus strobus* L.) (Meilleur et al. 1994).

Located beside the small town of Huntingdon (2,666 inhabitants; Statistics Canada 2001 http://www.statcan.ca), Godmanchester remains today an essentially rural community whose population (1,528 inhabitants, or 11 inhabitants/km^2; Statistics Canada 2001) is dispersed along its rural roads.

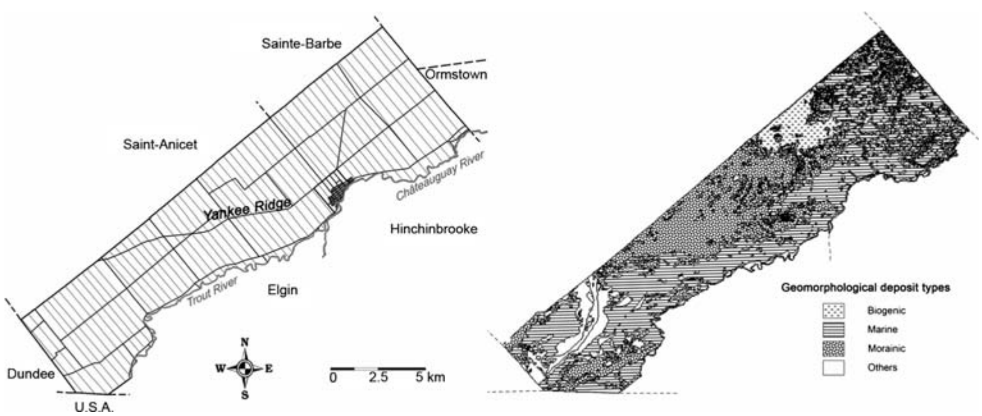

Fig. 2 Land registry map and geomorphology of Godmanchester

Methodological framework

Initially, the main objective of the research carried out in the Haut-Saint-Laurent region, where Godmanchester is located, was to produce the ecological classification and mapping of the territory in order to: (1) acquire a comprehension of the forest vegetation; and (2) serve as a basis for regional ecological planning (Bouchard et al. 1985). For this purpose, the first phase of the research gave the primary emphasis to geomorphological studies (Bariteau 1988; Delage 1997). Also during this first phase, forest vegetation was analyzed in detail (Meilleur et al. 1994).

This research rapidly revealed the breadth of the transformations of the natural forest cover and the complexity of the factors responsible for community composition and the configuration of the agro-forested landscapes (Bouchard and Domon 1997). Based on these first reports, later work was done within three research directions according to the distinct historical periods studied.

First, the study of nineteenth century transformations was based on two principal documentary sources: the wood sales recorded in notary deeds (Bouchard et al. 1989; Simard and Bouchard 1996), and the data from the Canadian censuses (1825–1871; Paquette and Domon 1997; Roy et al. 2002). Furthermore, the numerous testimonies recorded by Sellar (1888) have provided independent validation from our methods (Brisson and Bouchard 2004, 2006).

Second, the analysis and the treatment of information from aerial photographs (1958–1997) form the basis of the reconstitution of the land use dynamics for the twentieth century. As a first step, the relative influence that the geomorpholocial characteristics of the study area had on these dynamics has been studied (Pan et al. 1999, 2001; de Blois et al. 2001). This reconstitution was coupled with a systematic analysis of all the agricultural and forest policies and programmes likely to have an influence on the study area (Domon et al. 1993).

Finally, the current characteristics of the study area were analyzed, regarding the dynamics of vegetation (Meilleur et al. 1994; Brisson et al. 1994; de Blois et al. 2001, 2002; Brisson and Bouchard 2003; Schmucki et al. 2002) and the socio-economic characteristics (Domon et al. 1993; Paquette and Domon 1999, 2001a, b, 2003; Roy et al. 2005; Provost et al. 2006).

Detailed methodologies are presented in each of the cited papers.

Results

Two centuries of landscape changes in Godmanchester: a synthesis

As elsewhere, the agro-forested landscapes of Godmanchester are not the result of deliberate landscape policies, but rather of the dominant types of occupation and land uses (Fig. 3). In our specific case, three types of land use stand out as particularly significant: agricultural use, forestry use, and use for amenities.

Landscape dynamics and agricultural use

As in all of the Haut-Saint-Laurent region, colonization in Godmanchester was late. The first pioneers were Americans coming from New England, via the Chateauguay River (Fig. 1). Around 1795, some of these early immigrants settled in scattered locations on the lowlands near the present day site of Huntingdon (Fig. 3b). When Bouchette (1815, p. 262) visited the region just before the mid-1810s, he noticed that only squatters occupied certain isolated areas along the banks of the rivers (Roy et al. 2002).

At the beginning of the 1820s, some of the early American pioneers began to venture away from the rivers toward the morainic ridge. In fact, the census of 1825 revealed that, in the mid-1820s, many of Yankee Ridge's lots were occupied and used for agricultural production before all of those bordering the rivers were settled. Using the census manuscripts, it has been possible to categorize the lots occupied between 1825 and 1842, as well as to evaluate to what degree the patterns of land occupancy were a reflection of local geomorphological deposits (marine, morainic, biogenic). The results of this reveal two main trends. First, a close relationship exists between the lots occupied in 1825 and 1831 and those where morainic deposits predominate (Fig. 3c). Second, unoccupied lots tend to be associated with marine and biogenic deposits, although there was a gradual reduction in the strength of the relationship

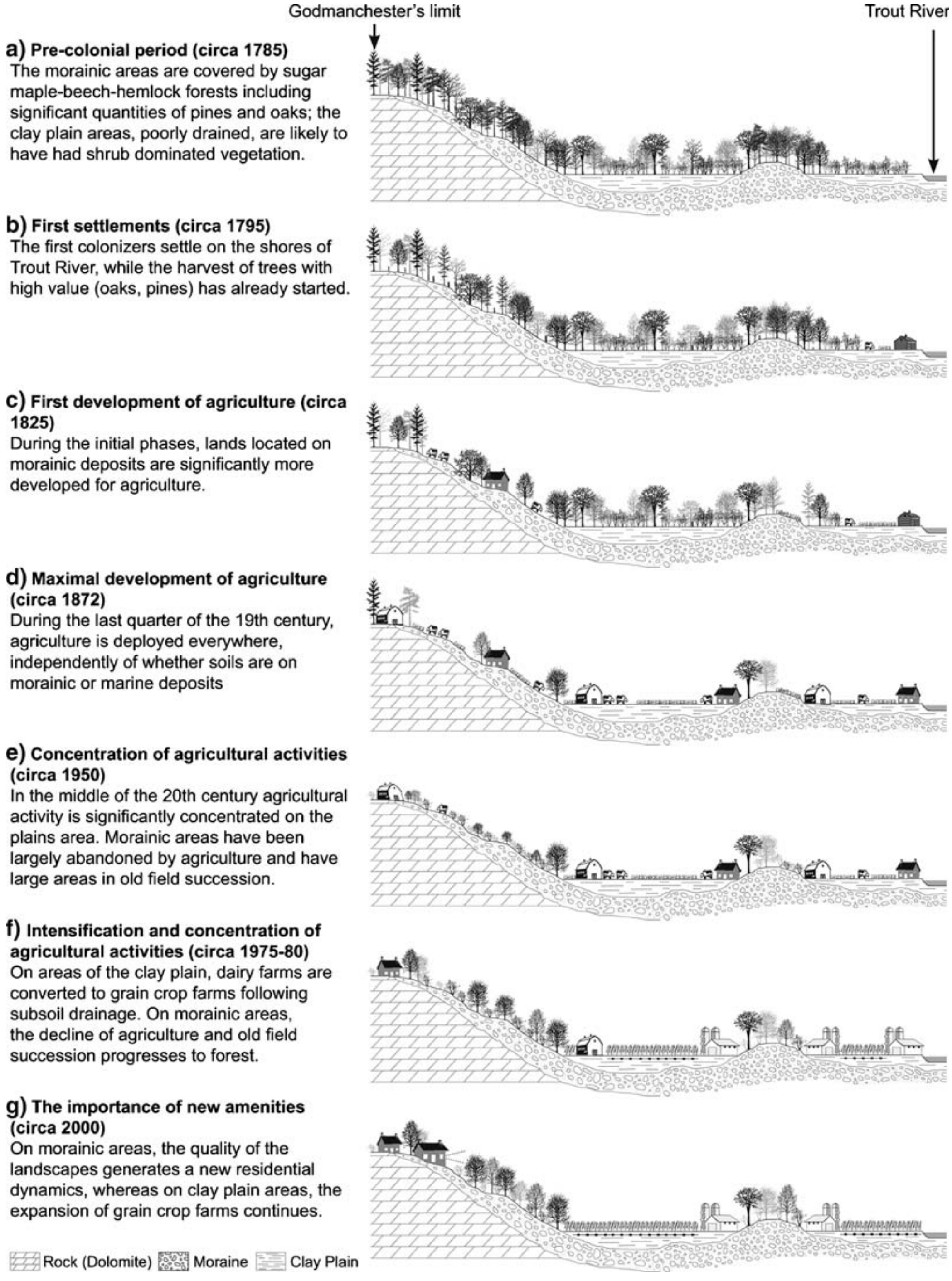

Fig. 3 Schematic illustration of landscape dynamics from the pre-colonial period (1785) to today (2000)

with marine deposits from 1825 to 1842. This result suggests that the earlier trend to avoid moist, clay-based soils was significant, but decreased up until 1842 (Roy et al. 2002).

The study of nominative censuses pointed out the considerable expansion of improved areas in the second half of the nineteenth century (Fig. 3d). From 16.4% of the total area of Godmanchester in 1842, improved areas increased to 58.0% in 1871, culminating with 83.1% in 1891. Overall, regression analysis suggests that, during the period considered (1842–1871), the variation in the proportion of morainic and marine deposits has had marginal influence on observed improved areas per lot. Therefore, in the nineteenth century, the improvement of soils for cultivation expanded very rapidly on either the morainic or the marine deposits (Paquette and Domon 1997). During all of the nineteenth century, the conditions at the colonization front of new territories seem to have been such, that no matter what the quality of the soils was for agriculture, they were nevertheless cultivated.

While improved areas increased during all of the nineteenth century, they started to decline in the Haut-Saint-Laurent, as in all of Quebec, beginning in the 1930s (Boudreau et al. 1997). However, detailed mapping of the land use in Godmanchester, derived from the aerial photographs available (1957–1993), reveals that agricultural abandonment did not occur at the same pace everywhere. Agricultural abandonment was much more concentrated on the morainic deposits, the fields on marine (clay) deposits being clearly advantaged agriculturally (Fig. 3e). Thus, in 1958, 88% of marine deposits were improved for agriculture, compared to only 36% of morainic and biogenic deposits (Pan et al. 1999). This relative advantage of clay soils over marine deposits is not only reflected in the relative importance of cultivated areas, but also in a higher land value. Indeed, the analysis of transactions (scales, wills, judgements, donations, exchanges, etc.) done for the Godmanchester territory between 1958 and 1997 reveals that in 1958 the land value per hectare was significantly higher for lands over marine deposits (Provost et al. 2006; and see Landscape dynamics and amenities below).

The relative advantage of lands on marine deposits, significant from the middle of the twentieth century, increased considerably with the agricultural policies established in the 1970s (Fig. 3f). Following the spectacular growth in dairy production (2,862 l/head/year in 1966 to 4,386 in 1986) and the levelling off of demand, considerable efforts were made to convert dairy farms into grain farms (primarily corn) everywhere that the climate allowed. Whereas poor drainage was the main limiting factor for growing long season grain crops, the general application of subsoil drainage, coupled with grants for building storage structures and systems to stabilize the income of the producers, led to a remarkable increase in areas in corn production. This production increased, for the whole of Quebec, from 43,000 ha in 1971 to more than 228,000 ha in 1986, and for the Huntingdon county within which is located Godmanchester, from 1,000 ha to 8,700 ha over the same period (Domon et al. 1993). Analysis of the five temporal land use layers (1958, 1965, 1973, 1983, 1993) confirms the strong relationship between land use types and geomorphological deposit types occurring in the second part of the twentieth century (Pan et al. 1999). In 1993, cultivated lands occupied 86% of all marine clay deposits found in Godmanchester, whereas they were down to only 25% of the areas of morainic deposits.

The agricultural dynamics has had at least three consequences for the landscape characteristics of Godmanchester. First of all, at the level of the fine structure of the landscape, the intensification of agricultural practices was reflected, from 1965 to 1993, by a notable decrease in the number of patches (16%), by an increase in their average size (20%), and a decrease in edge length (4.6%) (Pan et al. 1999). Afterwards, the general application of subsoil drainage and the pressures for increasing grain crop areas led to a significant decrease in wetlands. Within the study area, the relative importance of areas with biogenic deposits that were transformed to agricultural use has tripled from 1973 to 1993, increasing from 7.2% to 24.6% (Pan et al. 1999). Nearby, just north of Godmanchester, significant parts of two extensive bogs, remnants of the pre-colonial vegetation (Large Tea Field, 900 ha; Small Tea Field, 800 ha in St. Anicet; Fig. 1) were drained, burnt and cultivated (Domon et al. 1993; Bouchard and Jean 2001). Also, the agricultural dynamics has strongly influenced the structure and the characteristics of the hedgerow network. On morainic deposits, agricultural abandonment has caused the hedgerows to become integrated with abandoned farmland scrub and expanding wooded areas, their density dropping from 25.3 m/ha in 1979 to 22.7 m/ha in 1997 (Schmucki et al. 2002). This situation is in stark contrast with that of the marine clay deposits. After decreasing during the period of intensification of agricultural practices, the density of hedgerows has shown a marked increase between 1979 (14.3 m/ha) and 1997 (23.8 m/ha). However, this increase was masking the presence of a clearly higher proportion of shrubby hedgerows (79% in 1992), most likely associated with modifications to drainage networks, as well as to a much lower degree of connectivity per hectare than in the 1950s and the 1960s (Schmucki et al. 2002).

Landscape dynamics and forest use

The exploitation of the forest species, and consequently the transformation of the original forest cover (Fig. 3a), started around 1795, a few decades before the first settlers came to establish permanent residence. To their great astonishment, the first settlers would encounter a diminished nature, as evidenced among others, by the story recorded by R. Sellar from Mrs. Robert Forbe who recalls her arrival in Godmanchester in the fall of 1828 in these words:

> When we came to our lot, which was all under bush except a bit by the river strewn by decaying pinelogs left by the lumberman, oh but we were disappointed; it was so different from the glowing descriptions of the bush we had believed while in Scotland. My father-in-law, an old man, was so stunned by the change, that he was never himself again (Sellar 1888, p. 427).

Wood sales recorded in notary deeds allowed us to determine the quantities, the prices and the species involved in nineteenth century transactions between 1795 and 1900 (Simard and Bouchard 1996). These showed clearly that the nineteenth century forest exploitation was intensive but concentrated within a restricted period. From the first transaction recorded in 1799, the volume sold increased in a drastic way to reach 38,965 m^3 in the decade from 1820 to 1830. After this very active period, the volumes declined rapidly, and the sales had nearly stopped by 1870. During this period, from early 1800 to 1870, there was a definite sequence of species sold. Oaks (mostly *Quercus macrocarpa*) dominated the transactions of the first decade, followed by pines (mostly white pine, *Pinus strobus*) with large quantities sold especially between 1820 and 1840, Sugar maple (*Acer saccharum*), yellow birch (*Betula alleghaniensis*) and American beech (*Fagus grandifolia*) were often sold together, mainly between 1820 and 1840. Beginning in 1850, other species, such as hemlock (*Tsuga canadensis*), were commercially exploited, although the logging activities were already in decline. In all cases, it appears that every one of these species was exploited until the resource was depleted, because sales of their wood stopped even though prices remained high (Simard and Bouchard 1996).

The historical reconstitution of the two centuries of occupation of the territory of Godmanchester suggests that the forest was always a residual agricultural space. Thus, its constant and rapid decrease all through the nineteenth century resulted essentially from the expansion of improved areas for agricultural purposes (Paquette and Domon 1997). From the middle of the twentieth century, its recovery on morainic areas is directly associated with the constraints they present with respect to the mechanization of agricultural practices (Domon et al. 1993; Pan et al. 1999). Finally, the new wave of decrease in wooded areas on the clay plains observed from the mid-1970s is directly associated with the agricultural policies aimed at increasing areas in grain production (Domon et al. 1993; Pan et al. 1999). Also, a survey conducted among woodlot owners was to reveal that forest management and improvement activities remained marginal, since only 6% had done reforestation activities within a 5-year period preceding the survey, and that only 7% had had revenues from wood sales during the same period (Domon et al. 1993). Even more significant, when a parcel of land, chosen on account of its proximity to the main house, was pointed out to them, the first reason respondents mentioned in order to explain why the parcel had remained wooded was the poor agricultural characteristics of the study area. Indeed, nearly half of them stated that the soil was not good enough to put in crops, whereas over a third believed that cultivating the land would be too costly for what it might yield (Domon et al. 1993).

The forest vegetation of Godmanchester bears the deep imprint of these various historical factors. In order to better understand the composition of the current forest communities of the territory, the vegetation composition were analyzed in relation to three sets of variables: (1) environmental (surface deposits; soil texture and drainage; stoniness; elevation, slope, etc.); (2) historical (trajectory of land use form 1958 to 1997; importance of grazing; minimum age of the tree community); and (3) spatial context (nature, proximity and heterogeneity of adjacent land). Analysis confirmed the dominant effect of historical factors on vegetation patterns. Land use history overrides environmental and contextual control for tree composition (de Blois et al. 2001). As elsewhere in North America (Foster 1992; White and Mladenoff 1994; Fuller et al. 1998) within uncultivated patches, human influences have therefore replaced natural catastrophic events as the main ecological disturbance, obscuring abiotic relationships with tree species.

In addition, the comparison of the volumes of wood and the species of trees sold in the nineteenth century, as recorded in notary deeds, with the current composition of the woodlots confirms the magnitude of the transformations of the forest cover, and allows us to better perceive its impoverishment. The vegetation lots where the wood volumes were harvested were re-sampled (Brisson and Bouchard 2003) in order to compare the composition of species sold in the nineteenth century with the current forest composition of the same areas. The results reveal three particularly significant elements. First, certain forest community types (those where sugar maple had beech and yellow birch as co-dominants) are nowadays totally absent from the study area (Brisson and Bouchard 2003). Second, certain species (beech, yellow birch, spruce, larch) have totally disappeared from lots where they were originally abundant. Finally, the composition of the regeneration of the current forest communities is such that there are no signs of a return to the original composition, similar to that of the only protected pre-colonial forest, Muir's Forest (Brisson et al. 1994). Thus, it appears that some changes in the composition of forest communities may be irreversible.

While our results clearly demonstrate that some natural forest communities have totally disappeared from the study area, they also suggest that some unusual communities have been favored by past human activities. For instance, although sugar maple is clearly the most successful tree species to colonize the mesic sites of till (morainic) surface deposits, large nearly monospecific stands of white cedar are found in similar habitats. These constitute contrasting coniferous islands within an otherwise deciduous forest or agricultural landscape. Our results suggest that cattle grazing has played a significant role in the appearance of white cedar stands on mesic sites, whereas competition processes and landscape patterns possibly contributed to the maintenance of relatively persistent white cedar stands in the landscape (de Blois and Bouchard 1995).

Landscape dynamics and amenities

While previous results strongly suggest that Godmanchester's landscape dynamics have been strongly related to agricultural activities, there are some indications that agriculture is no longer the sole determinant. Indeed, census data show that even though residents engaged in agriculture have substantially decreased in numbers over the years, the total population of the municipality has not significantly declined (Paquette and Domon 1999). An analysis of the land value per m^2 reveals that although the comparative advantage of marine deposits for agriculture in the second half of the twentieth century produced a significantly higher value on marine deposits and farm abandonment on morainic deposits, the latter deposits have become more in demand beginning in the late 1980s. Thus, starting in 1987, a decrease occurs in the correlation between land sale price and the geomorphological index; the value of the land located on morainic deposits increasing faster than that of those located on marine deposits (Provost et al. 2006). This increase could be explained by possible new land uses on morainic deposits, one of which would be residential use (Fig. 3g). Research done in a township neighboring Godmanchester in the Haut-Saint-Laurent (township of Havelock) on residential settlement patterns reveals the importance of the arrival of neo-rural residents, and the fact that these new residents do not spread uniformly throughout the different landscape contexts (Paquette and Domon 2001a, b, 2003; Paquette et al. 2005). In order to better understand the residential dynamics and its effect on the territory, residential lots of Havelock were visited and characterized according to three broad groups of factors: (1) socio-demographic characteristics and residential history of the residents (birth place, former place of residence, profession, age, etc.); (2) visual characteristics of the lot (depth of field of view, breadth of field of view, visual access to the road, etc.); and (3) landscape trajectory (land use evolution between 1968 and 1997, transformation of the buildings, etc.). Analyses of these data showed that some widely recognized socio-demographic characteristics associated with rural migration movements are significantly correlated to specific landscape contexts. Urban background, professional occupation and age group (45–64) are highly associated with ‘Woodlot-closed view’ (landscape with a natural or semi-natural wooded appearance) and ‘Upper hillside-panoramic view’ (open landscape with panoramic views), two types of landscapes that are particularly typical of the wooded morainic areas with a more accentuated topography (Paquette and Domon 2001a, b, 2003). Thus, because specific landscape attributes seem to sustain selective rural migration flows and act distinctively on the overall re-composition context, landscape may now be a ‘resource’ that contributes to the redistribution of populations and rural development.

To better grasp the motivations behind the decision to move in, and the selection of residence location of these neo-rural inhabitants, interviews were conducted using the biographical approach (Ni Laoire 2000). Three motivations clearly stand out: the desire to benefit from a domestic space with a greater guarantee of tranquility; the intention of living in a more ‘natural’ environment; and, finally, the wish to acquire an area to do outdoor projects and activities (gardening, forest management, etc.) (Roy et al. 2005). Although their aptitude for agricultural use was initially the reason that the very first residents settled on morainic areas, nowadays they offer a set of amenities (‘nature’, space, tranquility, etc.) that are attracting a new population, that in turn is likely to promote new landscape dynamics. Indeed, as an example, in 2004, a non-profit organization has purchased part of the territory of Godmanchester in order to create a reserve for the purpose of preserving landscapes and natural environments in perpetuity (Latreille, personal communication).

Discussion

The research results highlight the speed and the continuous nature of the transformations of the landscapes of Godmanchester. In less than two centuries, large parts of the territory went from forests to farmland, before returning again to forests. Even where this return to forest has not occurred, the landscapes have been undergoing constant and profound transformations, particularly by changing from an agriculture centred on dairy production with crop rotation to a corn monoculture requiring: strict control over drainage conditions, and generating a decrease in the relative importance of isolated woodlots and wetlands; modifications to the characteristics of hedgerow networks; changes in the configuration (size, shape) of patches, etc. It is also significant that all of the study area was at one time or other under the direct control of human activity. It is also certain that, although the neo-rurals of today attribute high value to the ‘natural’ character of the forests of the morainic areas, the composition of these forests is very different from the natural pre-colonial forests. The nature and the intensity of the changes we recorded are of course not unique to Godmanchester because they correspond in many ways to observations made elsewhere. Thus, the major phenomena that have affected the morainic areas are similar, in their broad strokes, to those described by Russel and Bürgi (2004) in their case studies on certain sites in Pennsylvania and in the State of New York. In this way, Godmanchester seems representative of the phenomena which have marked eastern North America. Furthermore, having been settled very late, the transformations have occurred in a kind of ‘fast motion film’ of the changes that have come about elsewhere, in Europe particularly, on a much longer time span (Renard 1991).

Landscape dynamics or the shifting relationships between anthropic and biophysical factors

Our research reveals that, in order to understand the changes and the manner in which they spread over the study area, it is essential to take into account three of their main properties.

First, changes rarely occur in a uniform way on territories: they remain closely associated to the geomorpholocial characteristics of the territories. For example, the spatial configuration of the spread of intensive crops as well as that of abandoned farmland cannot be understood without knowledge of the nature and distribution of surface deposits. In the study area, two broad sets of conditions (clay plain and moraine) have strongly produced distinct dynamics, each undergoing profound changes. Highly prized for agriculture at the beginning of colonization, lands on morainic deposits were widely abandoned during the twentieth century, before they eventually became sought after for a new residential trend near the end of the twentieth century. As for the lands on marine deposits, although they were significantly less occupied and cultivated during the first decades of the colonization, they clearly became more sought after for agriculture during the whole of the twentieth century, their agricultural potential increasing even more with the policies instigated during the 1970s aimed at increasing the areas in grain crops. The significant shift of agricultural activities on the territory of Godmanchester illustrates clearly that the potential of soils for a given activity remains relative, and that it evolves to the point of even reversing itself over time. Thus, in the absence of the technical means to control drainage and the help of machinery, at the beginning of the nineteenth century agriculture was more concentrated on the stony and well-drained soils of the Ridge. With the advent of machinery and the widespread use of drainage techniques, the poorly drained clay soils of the plain would become, at the end of the twentieth century, the most interesting from an agricultural point of view. Morainic areas are mostly composed today of large areas of old abandoned fields reclaimed by forest, awaiting a vocation, and whose composition still reflects past agricultural use (pasture versus fodder crops; Benjamin et al. 2005).

Second, no matter how determining they are, the biophysical characteristics never operate on their own: landscape transformations are always the expression of a socio-economic demand for a specific resource. The historical harvesting sequence of forest species illustrates particularly well the influence of demand on landscape transformation. Thus, oak timber was harvested first to respond to the urgent needs for naval construction, then pine timber to answer the needs for residential construction in the Montreal region, and, finally, the exploitation of hemlock timber coinciding with the beginning of the construction of the great rail networks of western North America (Simard and Bouchard 1996). Also, in the 1970s, grain crops (mainly corn) grew rapidly after demand for dairy products levelled off, which before that had been the traditional production in the study area. Furthermore, the new trends observed for the morainic areas seem very closely associated with a new social demand towards the qualitative aspects of the territory.

If the biophysical characteristics of a territory and the social demand for the goods it provides are two major determinants of landscape dynamics, the historical reconstitution of Godmanchester illustrates rather well the determining role of a third factor that acts as a kind of mediator of the first two. The technological transformations stand out indeed as being at the origin of the shifts between anthropic and biophysical relationships and, thus, at the origin of landscape transformations. Even though the goal of increasing the area of grain crops was announced in the 1960s (Domon et al. 1993), its implementation was thwarted by the absence of short growing season varieties and of appropriate drainage infrastructures to lower soil moisture and provide for earlier sowing. The problem was solved by the development of corn varieties which could do well in short growing seasons, combined with the widespread use of subsoil drainage installations which, at the end of the 1970s, lifted the threshold limiting the production potential of lands on marine deposits. This led to the spectacular expansion in total areas under grain crop cultivation, and to a profound transformation of agricultural landscapes. Similarly, the new values attributed to wooded lots and the wide landscapes of the morainic areas seem inseparable from certain improvements, even breakthroughs, of a technical and technological nature: improvements of the transportation infrastructure (road network, telecommunication developments allowing work at home, etc.) (Paquette and Domon 2003).

Thus, although it is increasingly admitted that ‘‘human aspects and dimensions have to be treated as an intrinsic part of landscape processes and functions’’ (Naveh 2004), the role of technology in the relationships between the social factors and the biophysical factors remains to be better understood, and better measured. The dynamic reconstitution of the landscapes of Godmanchester suggests that technologies act sometimes to impede, sometimes to expedite transformations in the relationships between biophysical and anthropic factors.

Some implications for the shaping of landscapes

The transformations of landscapes are thus the expression of the dynamics of the relationships between socio-economic demands for resources and the biophysical characteristics, as adjusted or influenced by technology. Because technological innovations are constant and unpredictable, we cannot, as mentioned by Naveh (2000), predict the future of our landscapes. Therefore, instead of trying to predict the characteristics of future landscapes, should we not instead try to guide their development and shaping? For this, and as shown by the reconstitution of the historical landscape dynamics of Godmanchester, it seems necessary to operate on at least three complementary aspects.

First, it is important to continue to document the transformations of landscapes and their consequences. Thus, in the Haut-Saint-Laurent at least, residents tend to greatly underestimate the breath of the changes that have occurred in the surrounding landscapes and, even more importantly, to bias their view of the nature of these changes in order to make them more in agreement with their actions and values (e.g., Benjamin K., Domon G. and Bouchard A., in preparation). Although during the last 20 years several researchers have worked (Turner 1990; Hietala-Koivu 1999, etc.) at documenting the recent dynamics (ca. 1950–2000) and illustrating certain similarities at the international scale (homogenization of landscapes, farm abandonment in areas not suitable for intensive agriculture, etc.), interpreting these dynamics within a mid-term to long-term perspective still remains to be done, which will allow us to address their relative importance. Thus, the scope of certain recent or ongoing transformations (i.e., arrival of new residents, forest cutting) remains very puny when compared to the scope of certain transformations that have occurred over the long-term (i.e., transformation of the soil drainage regime on the clay plain).

The consequence of the changes deserve special attention because they are numerous, complex and sometimes unexpected. In the Haut-Saint-Laurent, for example, agricultural abandonment on morainic areas did not only have negative impacts, to which it is generally associated (i.e., decline in the traditional agricultural landscapes). As indicated by the research on the dynamics of new residential arrivals, in a context where the amenities of the 'natural' environment are nowadays highly valued by a new population of urban origin, this abandonment has, in fact, generated a set of new opportunities, particularly with respect to ecological restoration and the conservation of wooded areas.

Conclusion

The capacity to act on the shaping of future landscapes assumes not only a knowledge of the ongoing dynamics but also a real understanding of these transformations. The reconstitution of the historical dynamics of the landscapes of Godmanchester shows clearly that the isolated analysis of each of its components (biophysical, anthropic, technological) cannot ensure such an understanding. In the light of the research done so far, the transformation of the landscapes stands out as the end product of each of these components and of the complex and dynamic relationships among them. In this way, the research on landscape dynamics must not only allow the documentation of the changes and their consequences but also, as this paper attempts to do, explain them by identifying the relationships between the biophysical, anthropic and technological factors.

Finally, beyond the indispensable comprehension of the ongoing dynamics, the shaping of landscapes must happen through actions aimed at influencing, or modifying certain trends. More specifically, the research carried out in the Haut-Saint-Laurent suggests that, at least in the case of agro-forested areas, this inflection of trends could be achieved by following two complementary avenues. On the one hand, it would involve influencing social demand through the programmes and policies for the exploitation of agricultural and forest resources through which it is expressed. For example, in the Haut-Saint-Laurent, the conversion of dairy farms into grain farms resulted from the specific request of agricultural producers concerned with finding new markets. This demand, which was reflected by policies and general programmes, could have been adjusted in order to take into account some of their most negative consequences: cutting down of wooded areas, simplification of the hedgerow networks, etc. On the other hand, it would also require the adjustment of the deployment of technologies in order to take into account the specific characteristics of the territories considered. Thus, in our study area, some of the worst consequences of the recent transformations are due to the fact that the subsoil drainage occurred indiscriminately, without accounting for local specific characteristics and, particularly, the presence of wetlands of high ecological value.

The landscape dynamics of Godmanchester has been, over the last two centuries, the non-deliberate result of the relationships between biophysical, anthropic and technological components. This dynamic has created a set of irreversible consequences: some forest communities are nowadays totally absent; some tree species are no longer present on the lots where they were once abundant; some wetlands were destroyed and cultivated; and so on. Under these circumstances, we must not only succeed in shaping the landscapes that we would like to have, but we must also leave future generations a sufficient range of opportunities, in order for them to also be able to design the landscapes that they would like.

Historical studies, like those conducted in Godmanchester, could be helpful for reaching that goal. In the first place, they not only allow us to identify landscape elements that have completely disappeared but also those that are the most at stake given the actual dynamics. Also, they show that, at least in an agroforested context, programs and policies, particularly those that promote dissemination on new technologies, have been and still are amongst the main driving forces of landscape changes. Finally, in order to shape the future landscapes, such studies allow us to identify objectives for those programs and policies. In Haut-Saint-Laurent, for instance, those studies revealed that programs and policies should consider forested areas not as ''natural areas to be protected'' but instead as forested communities to be reconstructed. Moreover, they allow us to identify the main scenarios for such a reconstruction: restoration of initial forest composition, abundance maximization of some tree species of great economical value (oak, walnut, etc.), maximization of amenities for neo-rurals, etc.

In sum, such studies not only inform us on what the past has been, but also give us a good idea of what the future could be.

Acknowledgements This synthesis paper is based on the dedicated work of our research group, especially the graduate students who are well represented in the references. We are especially grateful to Dr. Danielle Marceau for her inestimable contribution during the last years of this project, to the two anonymous referees for their very constructive comments and to Julie Ruiz for the figures. During the last 25 years, this interdisciplinary research program has been supported by grants from the Natural Sciences and Engineering Research Council of Canada to André Bouchard, from the Social Sciences and Humanities Research Council of Canada to Gérald Domon, and also by a team grant from the Fonds québécois pour la recherche sur la nature et les technologies (FQRNT).

References

Andersen OB, Crow TR, Lietz SM, Stearns F (1996) Transformations of a landscape in the upper mid-west, USA: the history of the lower St. Croix river valley, 1830 to present. Landscape Urban Plan 35:247–267

Antrop M (2005) Why landscapes of the past are important for the future. Landscape Urban Plan 70:21–34

Austin MP, Cocks KD (eds) (1978) Land use on the South Coast of New South Wales, vol 4, CSIRO, Melbourne, Australia

Bariteau L (1988) La cartographie géomorphologique au 1:20 000 de modelés polygéniques: un exemple des basses terres du Saint-Laurent. MSc thesis, Université de Montréal, Montréal, Québec, Canada

Benjamin K, Domon G, Bouchard A (2005) Vegetation composition and succession of abandoned farmland: effects of ecological, historical and spatial factors. Landscape Ecol 20:627–647

Bouchard A, Bergeron Y, Camiré C, Gangloff P, Gariépy M (1985) Proposotion d'une méthodologie d'inventaire et de cartographie écologique: le cas de la M.R.C. du Haut-Saint-Laurent. Cahiers de géographie du Québec 29:79–85

Bouchard A, Dyrda S, Bergeron Y, Meilleur A (1989) The use of notary deeds to estimate the changes in the composition of 19th century forests in Haut-Saint-Laurent, Québec. Can J For Res 19:1146–1150

Bouchard A, Domon G (1997) The transformation of the natural landscapes of the Haut Saint-Laurent (Québec) and its implication on future resources management. Landscape Urban Plan 37:99–107

Bouchard A, Jean J (2001) Historique d'un paysage de tourbière profondément transformé par l'homme. In: Payette S, Rochefort L (eds) Écologie des tourbières du Québec-Labrador. Les Presses de l'Université Laval, Québec, Canada, pp 389–398

Bouchette J (1815) Description topographique de la province du Bas-Canada. Faden, London, UK

Boudreau C, Courville S, Séguin N (1997) Le territoire: atlas historique du Québec. Les Presses de l'université Laval, Québec, Canada

Brandt J, Vejre H (2004) Multifunctional landscapes, vol I, Theory, values and history. WIT press, Southampton, Boston, UK

Brisson J, Bergeron Y, Bouchard A, Leduc A (1994) Beech-maple dynamics in an old-growth forest in southern Québec, Canada. Ecoscience 1:40–46

Brisson J, Bouchard A (2003) Human activities caused major changes in tree species composition in southern Quebec, Canada. Ecoscience 10:236–246

Brisson J, Bouchard A (2004) The Haut-Saint-Laurent wilderness at the time of settlement based on Sellar's history. Part I: Wildlife. Châteauguay Valley Hist Soc Annu J 37:25–31

Brisson J, Bouchard A (2006) The Haut Saint-Laurent wilderwess at the time of settlement based on Seellar's history. Part III: Forests and Wetlands. Châteauguay Valley Hist Soc Annu J 39:29–45

Bürgi M, Hersperger AM, Schneeberger N (2004) Driving forces of landscape change—current and new directions. Landscape Ecol 19:857–868

Dale VH, Haeuber RA (2001) Applying ecological principles to land management. Springer, New York Berlin Heidelberg

de Blois S, Bouchard A (1995) Dynamics of Thuja occidentalis in an agricultural landscape of Southern Quebec. J Veget Sci 6:531–542

de Blois S, Domon G, Bouchard A (2001) Environmental, historical, and contextual determinants of vegetation cover: a landscape perspective. Landscape Ecol 16:421–436

de Blois S, Domon G, Bouchard A (2002) Factors affecting plant species distribution in Hedgerows of Southern Quebec. Biol Conserv 10:355–367

Delage M. (1997) Façonnement et métamorphose du modelé drumlinoïde par deux écoulements glaciaires successifs dans la région de Huntingdon (sud du Québec). PhD thesis, University of Montréal, Montréal, Québec, Canada

Domon G, Bouchard A, Gariépy M (1993) The dynamics of the forest landscape of Haut-Saint-Laurent (Québec, Canada): interactions between biophysical factors, perceptions and policy. Landscape Urban Plan 25:53–74

Ecoregions Working Group (1989) Ecoclimatic regions of Canada, first approximation. Ecoregions working group of the Canada Committee on ecological land classification. Ecological land classification series, No. 23, Sustainable development branch, Canadian Wildlife Service, Conservation and Protection, Environment Canada, Ottawa, Ontario, Canada, 119 pp

Foster DR (1992) Land-use history (1730–1990) and vegetation dynamics in Central New-England, USA. J Ecol 80:753–772

Fuller TL, Foster DR, McLachlan TS, Drake N (1998) Impact of human activity on regional forest composition and dynamics in central New England. Ecosystems 1:76–95

Globensky Y (1981) Région de Huntingdon. Rapport géologique 198. Ministère de l'Énergie et des Ressources, Gouvernement du Québec, Montréal, Québec, Canada

Grandtner MM (1966) La végétation forestière du Québec méridional. Presses de l'Université Laval, Québec, Canada

Haeuber RA, Dale VH (2001) New directions in land management: incorporation of ecological principles. In: Dale VH, Haeuber RA (eds) Applying ecological principles to land management. Springer, New York Berlin Heidelberg, pp 316–330

Hietala-Koivu R (1999) Agricultural landscapes change: a case study in Yläne, southwest Finland. Landscape Urban Plan 46:103–108

Hills GA (1961) The Ecological basis for Land use planning. Ontario Department of Lands and Forests Research Report No. 46

Jackson JB (1984) Discovering the vernacular landscape. Yale University Press, New Haven, USA

Jurdant M, Bélair JL, Gerardin V, Ducruc J-P (1977) L'inventaire du Capital-Nature. Série de la classification écologique No. 2. Ministère des Approvisionnements et Services, Ottawa, Ontario, Canada, 202 pp

Liu J, Taylor WW (2002) Integrating landscape ecology into natural resource management. Cambridge University Press, Cambridge

Medley KE, Okey WB Barrett GW, Lucas MF, Renwick WH (1995) Landscape change with agricultural intensification in a rural watershed, southwester Ohio, U.S.A. Landscape Ecol 10:161–176

Meilleur A, Bouchard A, Bergeron Y (1994) The relation between geomorphology and forest community types of the Haut-Saint-Laurent, Québec. Vegetatio 111:173–192

Meinig DW (1979) The interpretation of ordinary landscapes. Oxford University Press, New York

Naveh Z, Lieberman AS (1984) Landscape ecology, theory and application. Springer, München Berlin Heidelberg

Naveh Z (2000) What is holistic Landscape ecology? A conceptual introduction. Landscape Urban Plan 50:7–26

Naveh Z (2004) The importance of multifunctional, self-organizing biosphere landscapes for the future of our total human ecosystem—a new paradigm for transdisciplinary landscape ecology. In: Brandt J, Veijre H (eds) Multifunctional landscapes, vol I, Theory, Values and History. WIT Press, Ashurst, Southampton, UK, pp 33–62

Ni Laoire C (2000) Conceptualising Irish rural youth migration: a biographical approach. Intl J Popu Geogr 6:229–243

Palang H, Fry G (2003) Landscape interfaces. In: Palang H, G. Fry (eds) Landscape interfaces, cultural heritage in changing landscapes. Kluwer, Dordrecht, The Netherlands, pp. 1–13

Palka EJ (1995) Coming to Grips with the concept of Landscape. Landscape J 14:63–73

Pan D, Domon G, deBlois S, Bouchard A (1999) Temporal (1958–1993) and spatial patterns of land use changes in Haut-Saint-Laurent (Quebec, Canada) and their relation to landscape physical attributes. Landscape Ecol 14:35–52

Pan D, Domon G, Marceau D, Bouchard A (2001) Spatial pattern of coniferous and deciduous forest patches in an agricultural landscape: the influence of land use and physical attributes. Landscape Ecol 16:99–110

Paquette S, Domon G (1997) The transformation of the agroforestry landscape in nineteenth century: a case study. Landscape Urban Plan 37:197–209

Paquette S, Domon G (1999) Agricultural trajectories (1961–1991), resulting agricultural profiles and current sociodemographic profiles of rural communities in southern Quebec (Canada): a typological outline. J Rural Stud 15:279–295

Paquette S, Domon G (2001a) Rural domestic landscape changes: a survey of the residential practices of local and migrant population. Landscape Res 27:367–395

Paquette S, Domon G (2001b) Trends in rural landscapes development and sociodemographic recomposition in Southern Quebec (Canada). Landscape Urban Plan 55:215–238

Paquette S, Domon G (2003) Changing ruralities, changing landscapes: exploring social recomposition using a multi-scale approach. J Rural Stud 19:425–444

Paquette S, Domon G, Roy L (2005) De l'agricole...au paysage. Anciennes et nouvelles frontières socio-spatiales dans la recomposition des espaces ruraux du sud du Québec. In: Arlaud S, Jean Y, Royoux D (eds) Rural/urbain: nouveaux liens, nouvelles frontiers. Presses Universitaires de Rennes, Rennes, France, pp 213–224

Provost E, Ménard A, Frihida A, Domon D, Marceau DJ (2006) Fluctuations in land values in a rural municipality in southern Quebec, Canada. Can Geogr-Géogr Can 50:450–464

Renard J (1991) Réflexions, méthodes d'approche et perspectives de recherche relatives à l'avenir des espaces agricoles dans l'ouest de la France. In: Chevalier J, Jean B, Klein JL (eds) De la Loire au St-Laurent. GRIDEQ, Rimouski, Québec, Canada, pp 199–215

Rowe JS (1972) Les régions forestières du Canada. Service des forêts. Environnement Canada, Ottawa, Canada

Roy L, Domon G, Paquette S (2002) Settlement patterns, environmental factors and ethnic background on the south-western Quebec (Canada) frontier: the Godmanchester township (1793–1842). Can Geogr 46:144–159

Roy L, Paquette S, Domon G (2005) Le rural comme territoire d'appartenances multiples: l'exemple des motifs de migrations résidentielles dans le sud du Québec. Recherches Sociographiques XLVI(1):35–65

Ruiz J, Domon G (2005) Integrating physical and human dynamics in landscape trajectories: exemplified at the Aulnages watershed (Québec, Canada). In: Tress B, Tress G, Fry G, Opdam P (eds) From landscape research to landscape planning: Aspects of integration, education and application. Springer, Wageningen UR Frontis Series, Dordrecht, The Netherlands, pp 67–81

Russell EWB, Bürgi M (2004) Ecological Aspects of multifunctional landscapes in historical perspective. In: Brandt J, Vejre H (eds) Multifunctional landscapes: theory, value and history. WIT Press, Southampton, UK, pp 97–113

Sellar R (1888) The History of the County of Huntigdon and the seignories of Chateauguay and Beauharnois from the first settlement to the year (1838) The Huntingdon Gleaner. Huntingdon, Québec, Canada

Schmucki R, deBlois S, Domon G, Bouchard A (2002) Spatial and temporal dynamics of hedgerows in three agricultural landscapes of southern Quebec, Canada. Environ Manag 30:651–664

Silbernagel J, Martin SR, Gale MR, Chen J (1997) Prehistoric, historic, and present settlement patterns related to ecological hierarchy in the Eastern Upper Peninsula of Michigan, U.S.A. Landscape Ecol 12:223–240

Simard H, Bouchard A (1996) The precolonial 19th century forest of the Upper St.-Lawrence Region of Quebec: a record of its exploitation and transformation through notary deeds of wood sales. Can J For Res 26:1670–1676

Simpson JW, Boerner REJ, DeMers MN, Berns LA (1994) Forty-eight years of landscape change on two contiguous Ohio Landscapes. Landscape Ecol 9:261–270

Sooväli H, Palang H, Kaur E, Peil T, Vermandere I (2003) Combining approaches in landscape research, the case of Saaremaa, Estonia. In: Palang H, Fry G (eds) Landscape interfaces, cultural heritage in changing landscapes. Kluwer, Dordrecht, The Netherlands, pp 357–374

Tress B, Tress G (2001) Capitalising on multiplicity: a transdisciplinary systems approach to landscape research. Landscape Urban Plan 57:143–157

Turner MG (1990) Landscape changes in nine rural counties in Georgia. Photogram Eng Remote Sensing 56:379–386

White MA, Mladenoff DJ (1994) Old growth forest landscape transitions from pre-European settlement to present. Landscape Ecol 9:191–205

Wu J, Hobbs R (2002) Key issues and research priorities in landscape ecology: an idiosyncratic synthesis. Landscape Ecol 17:355–365