THE ECOLOGICAL RESTORATION OF CANADIAN PEATLANDS: A HISTORY OF A SUSTAINABLE PARTNERSHIP BETWEEN THE HORTICULTURAL PEAT INDUSTRY AND ACADEMIA

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SUMMARY

In Canada, peatlands cover approximately 113.6 million hectares (**Fig. 1**). This represents 13% of the territory, and accounts for 90% of wetland ecosystems found across the country. Peatlands provide many ecosystem services benefiting humans such as carbon sequestration, and are one of the most cost-effective solutions to mitigate global warming effects. In North America, peatlands are exploited to extract peat from which the horticultural industry is the main consumer. However, this industrial activity requires peatlands drainage and vegetation removal which has adverse consequences on hydrology, biodiversity, and associated ecological service losses. Without human intervention, the degraded peatland may witness several decades of bare soils before a typical vegetation spontaneously recovers. In light of this situation, the Peatland Ecology Research Group (PERG) was created in 1992, mainly as a response to a workshop, organized by the Canadian Sphagnum Peat Moss Association (CSPMA), but involving all stakeholders across Canada interested in the management of after-used peatlands. PERG regroups peatland scientists from different Canadian universities and collaborates with provincial and federal agencies as well as the Canadian peat industry. They cooperate on projects aiming towards sustainable and integrated peatland management. For the past 30 years, PERG's research team has developed peatland restoration techniques and significantly contributed to improving knowledge about ecological recovery of these specific wetlands. This case study relates how the sustained cooperative and collaborative history of PERG and the Canadian peat industry over the past 30 years has been instrumental in developing a cost-efficient approach to restore degraded peatlands. The long-term partnership and ecological success are a result of the good corporate environmental vision of the industry since the beginning of the 1990s and the unique Canadian Research Council programmes to funding industry-university research projects.

***Keywords**:* technique of peatland restoration, restoration success, long-term collaboration, responsible management.

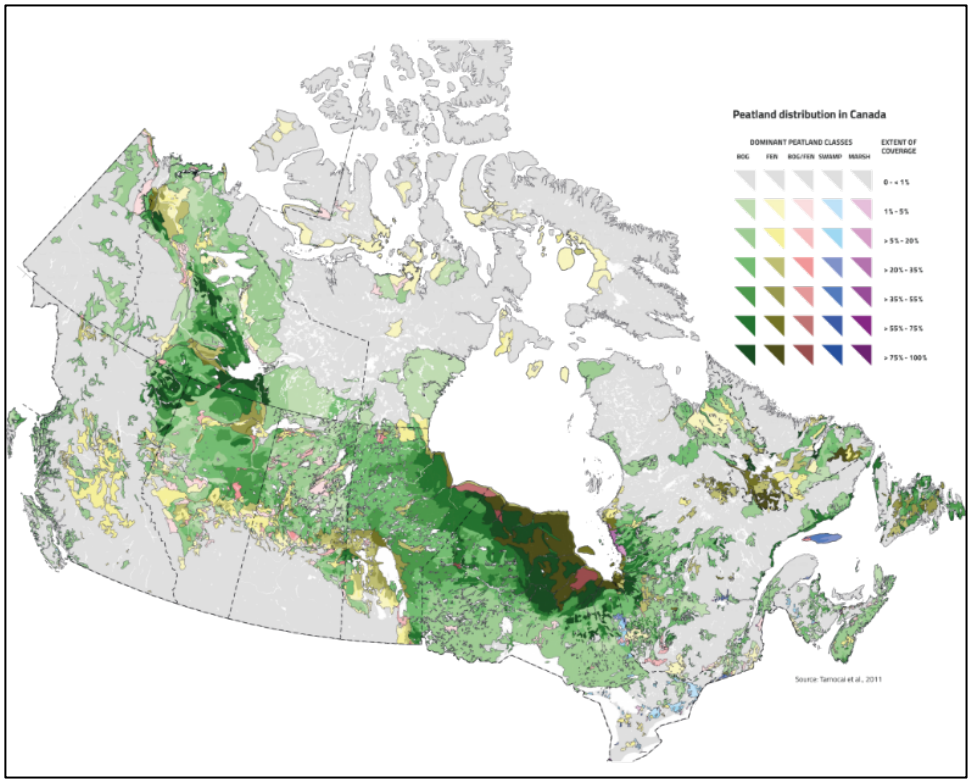


Figure 1. Peatland distribution in Canada (Tarnocai et al., 2011)

INTRODUCTION

Canada is home to a significant proportion of the world's peatlands (27%) and is the second most peatland covered country after Russia (Xu et al., 2017). In their natural state, and because of their unique hydrological function, peatlands provide a specific habitat for many species of flora and fauna. In addition, they provide many ecosystem services useful to human populations, in particular the sequestration of carbon in accumulated peat. By virtue of its structural qualities conducive to water retention, peat is a resource used as a growing medium. In North America, for example, peat is extracted from boreal and temperate peatlands, of which the horticultural industry is the main consumer. This industry has succeeded, in about 150 years, in propelling itself to the world rank of the horticultural peat market (CSPMA, 2014).

Peat extraction obviously has an impact on the environment. This industrial activity, which is carried out using giant vacuum machinery (**Fig. 2**), requires prior drainage and the removal of vegetation within the peatland, generating harmful consequences on hydrology, biogeochemistry, flora, fauna, and therefore on several ecosystem functions of this habitat on a variable time scale. After stopping the extraction operations, the harsh conditions generated by the disappearance of the acrotelm and the lowering of the water table cause modifications of the physicochemical properties of the peat, preventing a return of the plant communities typical of peatlands (Price and Whitehead, 2001; Price et al., 2003). Without human intervention, degraded peatlands can in some cases take several decades for characteristic vegetation – leading to the accumulation of peat – to re-establish spontaneously (Poulin et al., 2005; Graf et al., 2008).

Figure 2. Harvesting peat with giant vacuum machinery (Photo: Premier Tech Horticulture)

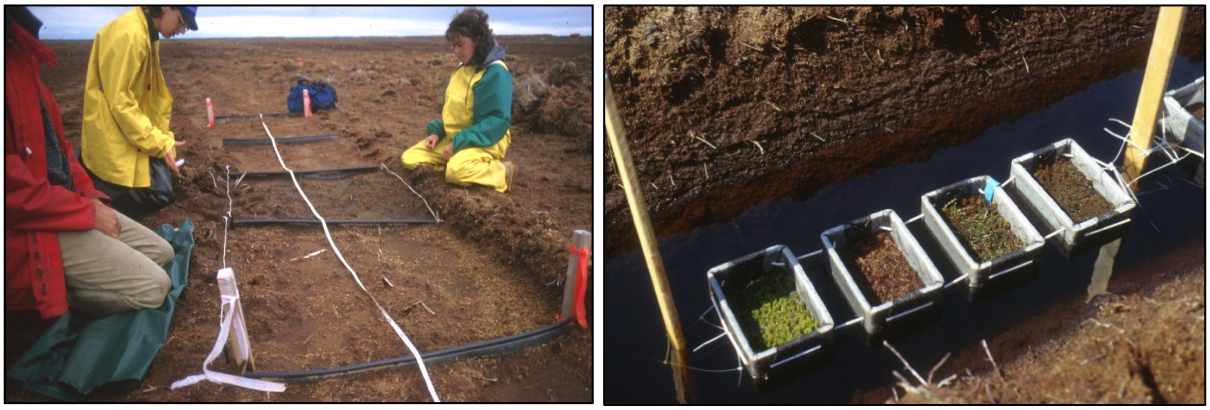
In response to this ecological problem, management methods for the responsible use of North American peatlands have been developed by a group of university researchers (Peatland Ecology Research Group), in association with the Canadian peat industry (Canadian Sphagnum Peat Moss Association and its members). Thus, an ecological restoration method, the "Moss Layer Transfer Technique" (MLTT), has been developed in the 1990s and has proven success in the reintroduction and establishment of bryophytes and vascular plants on ombrotrophic peatlands. This presentation aims to retrospectively describe the achievement of success in the rapid return (less than 15 years) of biodiversity components and ecosystem functions of peatlands restored with this method. In addition, a parallel is drawn to highlight the support for academic research by the Canadian horticultural peat industry and by governments that have made it possible to bring a significant contribution to the field of research in the ecology of peatland restoration.

DISCUSSION

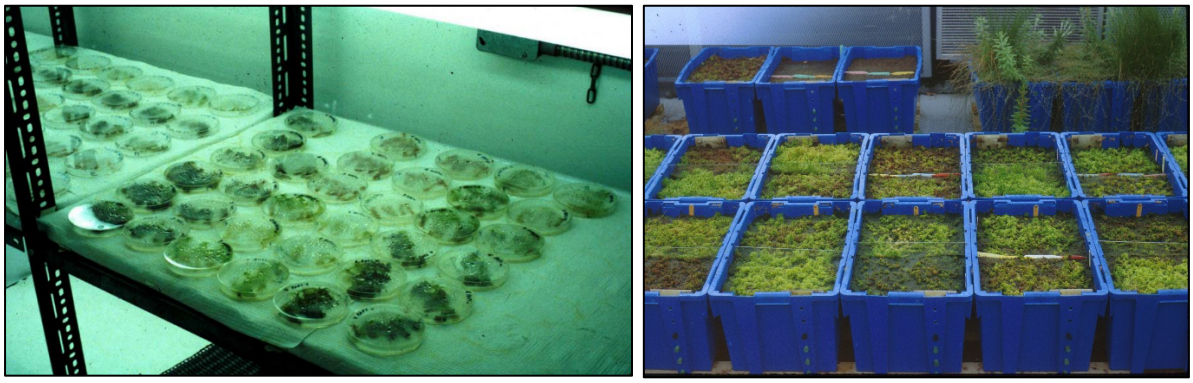
1) The 1990s: Genesis and consolidation of a collaboration

In the early 1990s, Canada has about 75 companies primarily engaged in peat extraction for horticultural purposes. The year 1992 marks a turning point in the management of peatlands by the horticultural peat industry. In February, a workshop bringing together all the actors revolving around the peat environment is organized with the aim of finding a consensus on the sustainable management of this resource. Unanimously, peatland restoration is chosen from among the post-extraction peatland reclamation options. In that same year, Line Rochefort of Université Laval (Quebec, Canada) created the Peatland Ecology Research Group (PERG). This group is the result of a concerted effort between different actors bringing together university scientists from various disciplines (vegetation, fauna, hydrology, geochemistry), the Canadian peat industry, as well as federal and provincial government agencies. Consequently, various grants will allow Line Rochefort and its collaborators to set up several research projects, in particular on the characterization of peat and the restoration of degraded peatlands.

Post-extraction peatlands located in Quebec (Sainte-Marguerite-Marie peatland) and New Brunswick (Maisonnette and Lamèque peatlands) become the first experimental stations for preliminary tests on peatland restoration. At these sites, several aspects are studied, such as the state of the post-extraction substrate (including peat chemistry and its microtopography), various small-scale *Sphagnum* reintroduction trials (**Fig. 3a and b**), various ways to rewet or conserve moisture at the sites, plant and animal species present. At the same time, tests are being carried out in the laboratory and in the greenhouse at Université Laval to better understand the biology of *Sphagnum* mosses, in particular on the survival, regeneration and colonization capacity of *Sphagnum* diaspores and fragments, in Petri dishes and on peat, depending on various conditions of humidity, fertilization, light, etc. (**Fig. 4a and b**).



Figures 3a and b. Small-scale field experiments with the aim of testing different techniques for reintroducing mosses typical of peatlands on bare peat or in water (Photos: S. Campeau)



Figures 4a and b. Laboratory and greenhouse experiments aiming at evaluating various factors on the growth of Sphagnum *mosses (particularly their resistance to desiccation) (Photos: PERG and S. Boudreau)*

The results of this research are first reflected in the form of the restoration of 150 ha at the Sainte-Marguerite bog in 1994, using ecological engineering techniques specific to the acid and oligotrophic conditions of the residual peat found in this area. Subsequently, a first Peatland restoration guide for peat managers is published in 1997 (Quinty and Rochefort, 1997). It describes what was at that time called "The Canadian Approach to Peatland Restoration."

From the mid-1990s, several elements made it possible to consolidate a long-term partnership between PERG researchers and their partners of the Canadian peat industry. Scientific conferences and Technology transfer workshops are organized almost every year in order to present the latest developments made within the framework of research projects in peatland restoration and management. A newsletter and a website informs PERG's partners and collaborators about the fieldwork carried out by researchers and their students, and they provide summaries of research publications.

In 1996, Line Rochefort and three other PERG researchers obtain a major Cooperative Research and Development (CRD) grant from the Natural Sciences and Engineering Research Council of Canada (NSERC), in partnership with various Canadian peat-producing companies. The four-year grant focuses on the integrated management of peatlands in eastern Canada. This CRD grant marks the start of long-term funding in the form of various grants from NSERC in partnership with the Canadian peat industry. These grants aim to create mutually beneficial collaborations between Canadian universities and partners from the public or private sectors, leading to breakthroughs that translate into economic, social or environmental benefits for Canada and Canadians. Research funding is shared between industrial partners and NSERC, by matching funds.

2) 1999 and 2000: The Bois-des-Bel restored peatland, an emblematic experimental station

In the fall of 1999 and in the winter of 2000, an area of 8.4 ha of the Bois-des-Bel peatland, in eastern Quebec, is restored using the restoration method for ombrotrophic peatlands developed by the PERG a few years earlier (**Fig. 5a and b**). Part (3.1 ha) of the bog is selected to act as an unrestored control area. In order to assess the success of restoration operations, a database is created: 755 vegetation sampling points, combined with 57 listening points for birdsong, all georeferenced in a geographic information system. Thus, the Bois-des-Bel peatland is given the title of a true open-air experimental site, constituting an essential pillar for the constant improvement of peatland restoration methods.


Figures 5a and b. Restoration of the Bois-des-Bel peatland in December 1999: during and after the spreading of protective mulch (Photos: Manon Croft)

3) The 2000s and 2010s: The rise of peatland restoration research in Canada

In 2003, six years after its first publication, the Peatland restoration guide is given a facelift with the publication of a second edition (Quinty and Rochefort, 2003). The content is greatly enhanced with a more detailed approach to the steps of peatland restoration with what is now called the "Moss Layer Transfer Technique" (MLTT) developed in partnership with the peat industry. These steps include:

A. Planning of restoration and various operations, based on site conditions, established objectives, as well as the reference ecosystem serving as a model for restoration;
B. Site preparation (modification of the topographic profile, creation of dikes or basins, scraping of the peat surface; **Fig. 6a and b**);
C. Harvesting plant material (plants or diaspores) at the donor site (**Fig. 7a and b**);
D. Spreading of diaspores and plant fragments on the site to be restored (**Fig. 8a**);
E. Spreading protective mulch (**Fig. 8b**);
F. Phosphate fertilization (**Fig. 9a**);
G Blocking drainage ditches (**Fig. 9b**).

Steps B to G are done using machinery. Other topics are also addressed in this new edition of the guide, including the creation of ponds and the restoration of ecosystem functions through restoration monitoring.


Figures 6a and b. Site preparation: removal of surface crust and modification of the topographic profile (Photos: PERG)

Figures 7a and b. Harvesting plant material (plants or diaspores) at the donor site (Photos: PERG)

Figures 8a and b. On the left: spreading of diaspores and plant fragments (Photo: Manon Croft). On the right: spreading protective mulch (Photo: PERG)

Figures 9a and b. On the left: phosphate fertilization. On the right: blocking drainage ditches (Photos: PERG)

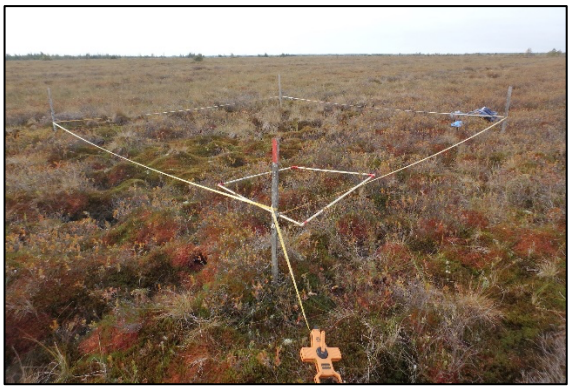
The funding of PERG research by NSERC and by the peat industry partners continues during the years 2000 and 2010. From 2003 to 2018, it is carried out in the form of three five-year terms of the Industrial Research Chair in Peatland Management granted to Line Rochefort. The repeated terms of this Chair demonstrate the real interest of the peat industry in responsible peatland management in Canada. The various projects are supported by several collaborating researchers with complementary expertise (plant ecology, hydrology, biogeochemistry, fauna, and biological invasions). At the same time, an increasing number of post-extraction peatlands are restored each year by peat industry partners in various Canadian provinces: Quebec, New Brunswick, Manitoba, Saskatchewan, and Alberta.

Obtaining the Chair and additional grants make it possible to undertake various research projects with increasingly diverse objectives, such as:

- the expansion of knowledge on the ecological restoration of peatlands dominated by *Sphagnum* mosses (bogs) and the evaluation of the restoration success, by monitoring the long-term evolution of the restored ombrotrophic

peatland of Bois-des-Bel and monitoring the return of plant communities in restored peatlands (through regular inventories of all restored sites in Canada; **Fig. 10 a and b**);

- the evaluation of the return of ecosystem functions of restored peatlands, such as hydrology and carbon sequestration (through greenhouse gas exchange measurements; **Fig. 11**);
- the development of techniques for restoring fens, which have characteristics different from bogs (for this purpose, new large-scale experimental sites are created: Bic – Saint-Fabien in Quebec, Elma North, Moss Spur and South Julius in Manitoba, Evansburg in Alberta);
- the development of new restoration approaches for specific environments, such as salted coastal bogs, peatland margins (laggs), peatland pools (**Fig. 12**);
- the reclamation of peatlands that cannot be restored, including the production of berries (e.g., cloudberry) or tree planting;
- the cultivation of *Sphagnum* mosses (*Sphagnum* farming) as a renewable resource, which can be used directly for the development of growth substrates or as donor material for the restoration of peatlands.



Figures 10a and b. Monitoring of vegetation. On the right: at the Bois-des-Bel peatland ten years after restoration (Photos: PERG and Line Rochefort)

Figure 11. Measurement of greenhouse gas exchanges at the Bic – Saint-Fabien peatland (Photo: Vicky Bérubé)

Collaboration between the peat industry and PERG researchers continues throughout the 2020s, under a grant from NSERC. The research undertaken fills some gaps in specific fields of research. In addition, in order to maintain the co-evolutionary approach favoured by the peatland restoration guide, an update of the latter is carried out in 2019 and 2020 (Quinty et al., 2019, 2020a, b, c). The fine-tuning of peatland restoration methods will help improve the ecological value of restored ecosystems over the next few years.

Figure 12. Planting of vascular species on the edge of a pool created in the Bic – Saint-Fabien peatland (Photo: Flor Salvador)

4) The success of the ecological restoration of peatlands by the MLTT

Since its development in the late 1990s, the Moss Layer Transfer Technique has enabled the Canadian peat industry to restore an ever-increasing number of peatlands (mostly *Sphagnum* peatlands) in the country. Specifically, 44 peatland sites have been restored nationally, including 31 in eastern Canada (Quebec and New Brunswick; **Fig. 13**), as well as 13 in western Canada (Manitoba, Saskatchewan and Alberta; **Fig. 14**).

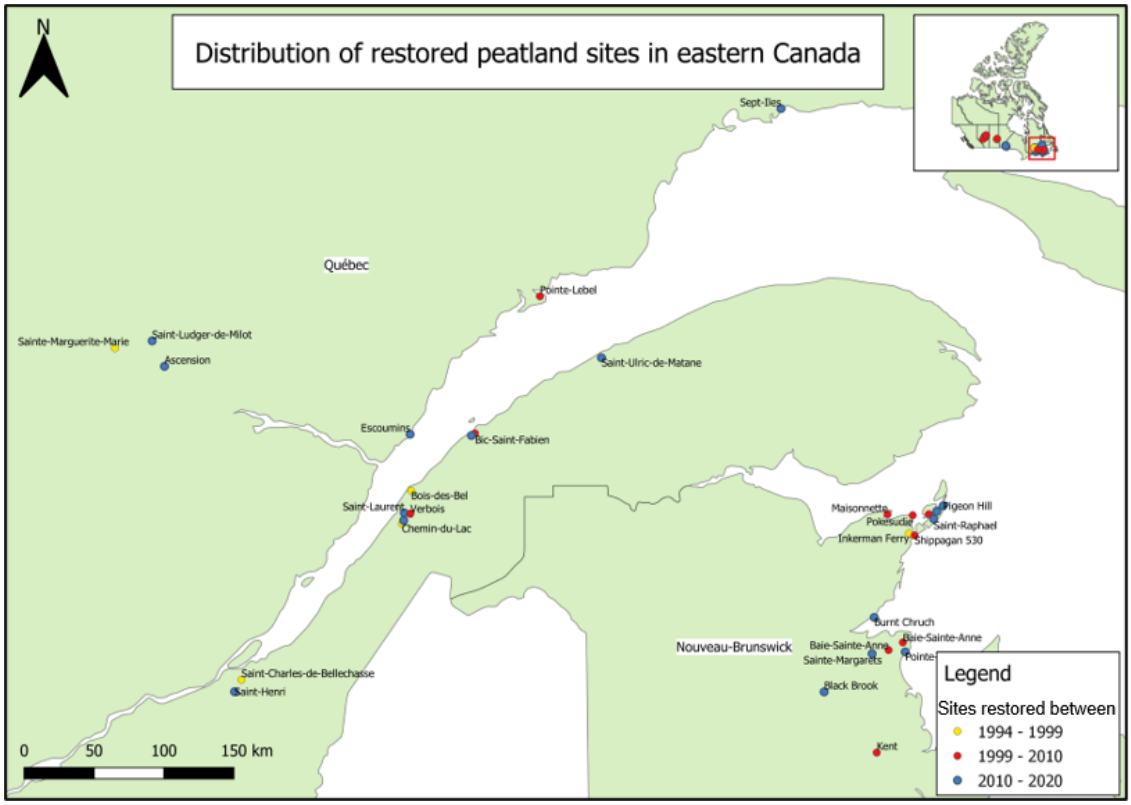


Figure 13. Distribution of restored sites in eastern Canada (Illustration: Gwendal Breton)

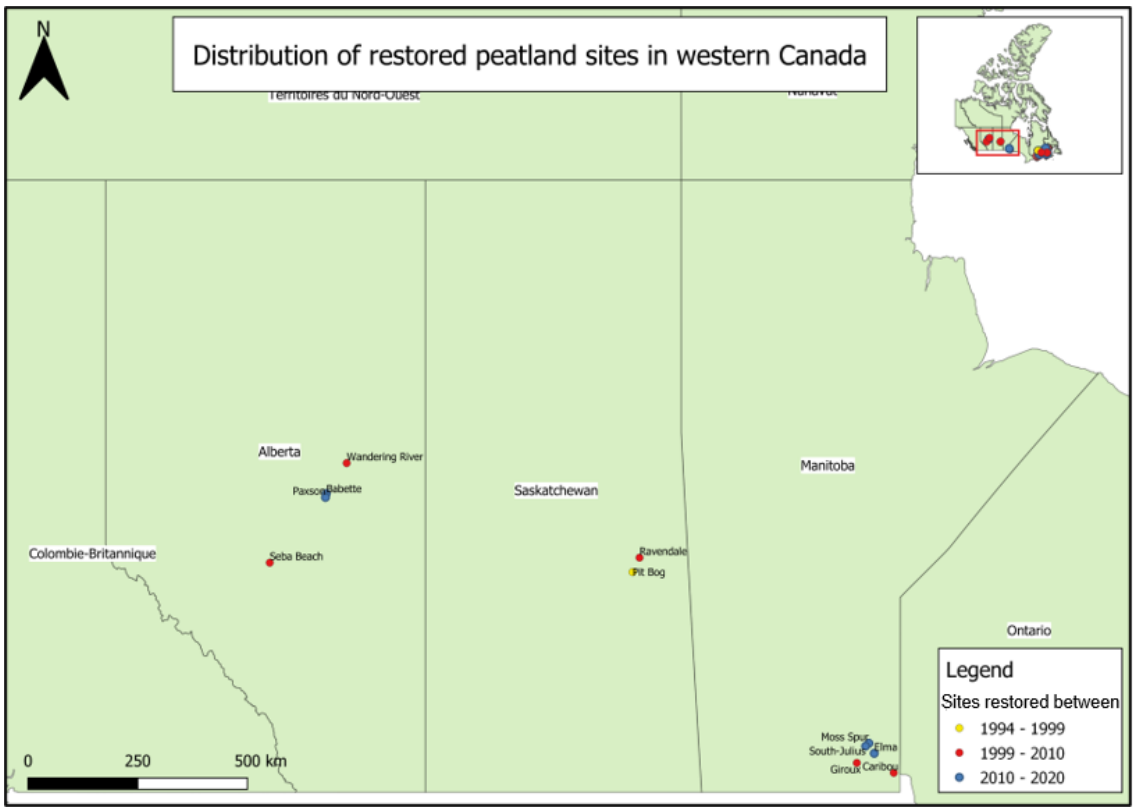


Figure 14. Distribution of restored sites in western Canada (Illustration: Gwendal Breton)

Through monitoring of these peatlands, it was possible to demonstrate that this large-scale mechanized technique of restoration has been shown to be successful in the reintroduction and establishment of bryophytes (*Sphagnum* and *Polytrichum*) and vascular plants for ombrotrophic peatlands within five years after restoration (González et al., 2013, 2014). PERG has assessed that it facilitates the return of 82% of the biodiversity of vascular plants (Hugron et al., 2020). The technique is effective for reestablishing hydrological attributes (Taylor et al. 2016). It also leads to a return of peat accumulation and to restore the carbon sink function (Strack and Zuback, 2013; Nugent et al, 2018). The work of González and Rochefort (2019) led to the creation of a statistical tool to define the success of the application of MLTT on degraded peatlands. The main advantage of this tool is that it uses simple indicators based on the vegetation layer; it can also be used throughout Canada.

PERG's successes in peatland restoration have led governments in various provinces in Canada to modify their policies on wetlands and peatlands. Some now require restoration measures for disturbances in these environments (New Brunswick, Quebec, Manitoba and Alberta). Several large-scale peatland restoration projects are also being carried out in other countries with the MLTT.

CONCLUSION

Peat extraction is an important commercial and industrial activity in Canada and must be conducted responsibly. As peatlands provide many useful ecosystem services to human populations, in particular carbon sequestration, their restoration is one of the most cost-effective solutions to mitigate the effects of global warming (Griscom et al., 2017; Nugent et al. 2019).

It is through the long-term, sustained and joint funding of university research by the Canadian government and the peat industry that such results have been achieved in ecological restoration of peatlands in the country. This is a unique opportunity to demonstrate how a partnership between academia and industry can create synergy to help advance knowledge on both practical and fundamental sides.

Continued research into peatland restoration guarantees greater success in restoration efforts from coast to coast in Canada. It helps inform governments to develop better laws, regulations, policies and programs for responsible peatland management across the country. It also provides verifiable evidence that the Canadian peat industry is complying with international conventions as proof of its investment in good corporate citizenship.

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