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Dynamique des communautés végétales et impacts des perturbations humaines sur la végétation des tourbières

par

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Résumé

Ce mémoire visait à comprendre la dynamique temporelle et les patrons floristiques actuels de deux tourbières du sud-ouest du Québec (Small et Large Tea Field) et à identifier les facteurs anthropiques, environnementaux et spatiaux sous-jacents. Pour répondre aux objectifs, des inventaires floristiques anciens (1985) ont d'abord été comparés à des inventaires récents (2012) puis les patrons actuels et les facteurs sous-jacents ont été identifiés à l'aide d'analyses multi-variables. Mes résultats montrent d'abord qu'un boisement important s'est produit au cours des 30 dernières années dans les tourbières à l'étude, probablement en lien avec le drainage des terres agricoles avoisinantes, diminuant la hauteur de la nappe phréatique. Simultanément, les sphaignes ont proliférées dans le centre des sites s'expliquant par une recolonisation des secteurs ayant brûlés en 1983. D'autre part, mes analyses ont montré que les patrons floristiques actuels étaient surtout liés aux variables environnementales (pH et conductivité de l'eau, épaisseur des dépôts), bien que la variance associée aux activités humaines était aussi significative, notamment dans la tourbière Large (18.6%). Les patrons floristiques ainsi que les variables environnementales et anthropiques explicatives étaient aussi fortement structurés dans l'espace, notamment selon un gradient bordure-centre. Enfin, la diversité béta actuelle était surtout liée à la présence d'espèces non-tourbicoles ou exotiques. Globalement, cette étude a montré que les perturbations humaines passées et actuelles avaient un impact important sur la dynamique et la distribution de la végétation des tourbières Small et Large Tea Field.

Mots clés : Tourbière; Dynamique végétale; Perturbations anthropiques; Conditions environnementales; Boisement; Diversité béta; Partitionnement de la variation

Abstract

This study aimed to understand the temporal dynamics and the current floristic patterns in two peatlands of southwestern Quebec (Small and Large Tea Field), and to identify natural and anthropogenic drivers of the changes and patterns observed. To do so, past (1985) and recent (2012) floristic surveys were compared while current floristic patterns and underlying factors were identified using multivariate analyses. Firstly, results show that tree encroachment occurred over the last 30 years, likely due to drainage of surrounding farmlands lowering the water table level. Simultaneously, *Sphagnum* mosses have proliferated in the center of peatlands, probably explained by the recolonization of the areas burned in 1983. On the other hand, multivariate analysis showed that current floristic patterns were mainly related to environmental variables (water pH and conductivity, peat deposits thickness), although variance associated with human activities was also significant, especially in the Large peatland (18.6%). Floristic patterns as well as explanatory environmental and anthropogenic variables were highly structured in space, following a margin-expanse gradient. Finally, the current beta diversity was mainly related to the richness of native non-peatland and exotic species. Overall, this study showed that past and current human activities had a significant impact on vegetation dynamics and distribution of the Small and Large Tea Field peatlands.

Keywords: Peatland; Vegetation dynamics; Anthropogenic disturbance; Environmental factor; Tree encroachment; Beta diversity; Variation partitioning

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Chapitre 1 : Introduction générale

Les zones humides, auxquelles appartiennent notamment les tourbières, les marais et les marécages, sont des milieux intermédiaires entres les milieux terrestre et aquatique, se caractérisant par une nappe phréatique proche de la surface et par une forte productivité biologique (Barnaud & Fustec 2007). Ces écosystèmes couvrent 9% de la superficie mondiale des terres (Zedler & Kercher 2005) et fournissent divers services écologiques tels que l'amélioration de la qualité de l'eau, la régularisation des débits des cours d'eau, la séquestration du carbone et le support de la biodiversité (Gorham 1991; Charman 2002; Levison et al. 2013). Cependant, 50% de la superficie mondiale des zones humides ont été perdues au cours des derniers siècles et la plupart de celles encore présentes aujourd'hui sont dégradées (Moser et al. 1996; Zedler & Kercher 2005), principalement dues à l'urbanisation, l'agriculture et la sylviculture (Moser et al. 1996). Or, la modification des composantes de ces écosystèmes, et notamment celle de leurs communautés floristiques, peut constituer une menace sérieuse au maintien de leurs fonctions écosystémiques. Par exemple, la disparition des sphaignes et leur remplacement par des espèces vasculaires souvent associées au drainage des tourbières diminuent le taux d'accumulation de la matière organique et donc celui du carbone (Moore 2001). Dans ce contexte, ce mémoire visera à comprendre les facteurs responsables du façonnement des communautés floristiques des tourbières du sud du Québec, d'abord avec une perspective temporelle et ensuite avec une perspective spatiale. Dans les pages suivantes, une revue de littérature portant sur la dynamique des communautés végétales ainsi que sur les facteurs influençant la répartition de la végétation sera d'abord présentée afin de mettre en contexte le mémoire.

1.1 Dynamique des communautés végétales

1.1.1 Succession végétale

Les communautés végétales sont définies à la fois par la richesse et l'abondance des espèces ainsi que par leurs relations écologiques. Avec le temps, et surtout des conditions environnementales changeantes, les caractéristiques de la communauté évoluent. En effet, certains organismes vont apparaître alors que d'autres vont disparaître, ce qui entraine le changement de la communauté. On parle de succession pour désigner ces enchainements temporels, cycliques ou linéaires dans les écosystèmes (Gillet et al. 1991). Chaque transformation dynamique est caractérisée par quatre critères: l'origine des éléments qu'elle met en jeu (succession primaire ou secondaire), son sens (succession progressive ou régressive), sa cause (succession autogène ou allogène), et sa nature (changement d'espèces dominantes) (Decocq 1997).

Tout d'abord, on distingue la succession primaire de la succession secondaire par le fait que le développement de communauté végétale a lieu dans des habitats nouveaux dépourvus de végétation. La succession secondaire consiste pour sa part dans le retour à la végétation après une perturbation (Ricklefs & Miller 2005). On distingue également la succession régressive, où le biotope se dégrade et la communauté diminue sa biomasse et sa biodiversité, de la succession progressive, où la communauté devient stable et augmente sa biomasse (Walker et al. 1983). La succession peut aussi découler de modifications induites par les organismes eux-mêmes, il est alors question de succession autogène. L'évolution d'un étang vers une forêt impliquerait par exemple des processus de succession autogène selon la séquence suivante: en raison de la diminution du niveau de l'eau due à l'accumulation de matière organique, les arbres et arbustes tolérants l'immersion s'installent et assèchent au fur à mesure le milieu, qui deviendra en quelque temps une forêt terrestre. Les successions peuvent également provenir de modifications induites par des facteurs externes à la communauté (p.ex.: climat, feux, perturbations anthropiques), c’est la succession allogène. Dans la succession de l’étang vers un marais par exemple, de fortes précipitations et un mauvais drainage favoriseraient l’accumulation d’eau et ainsi la croissance d’une végétation hydrophile adaptée à ces conditions (Courchesne 2012). Ainsi, des changements graduels d’habitats et de communautés végétales se succèdent dans le temps pour atteindre un stade final le plus stable possible, appelé climax.

1.1.2 Succession végétale dans les tourbières

Dans les tourbières, la succession végétale à long terme est essentiellement liée aux variations climatiques et à des processus autogènes associés à la croissance verticale de la surface des tourbières, en lien avec l’accumulation continuelle des restes végétaux (Payette 1988). Dans les régions tempérées et boréales, le patron général de développement des tourbières s’effectue principalement en deux phases, soit une phase minérotrophe suivie d’une phase ombrotrophe. Cette succession, appelée ombrotrophication, peut se produire rapidement (entre 50 et 350 ans) ou être un phénomène graduel pouvant s’étendre sur environ 2000 ans (Kuhry et al. 1993). C’est un processus complexe pour lequel il y a encore beaucoup de débats sur les éléments déclencheurs, mais qui serait vraisemblablement associé à des changements climatiques et/ou hydrologiques et/ou au processus interne d’accumulation de la tourbe (Payette 1988; Hughes & Barber 2004; Robichaud & Bégin 2009). Par exemple, la mise en place de conditions climatiques fraîches et humides aurait induit l’ombrotrophication dans certaines tourbières (Robichaud & Bégin 2009), alors qu’elle serait plutôt associée à des périodes plus chaudes et sèches dans d’autres tourbières (Pajula 2000). L’ombrotrophication peut aussi être le résultat unique de l’accumulation progressive de la tourbe, engendrant l’élévation de la surface de la tourbière au-dessus de la nappe phréatique et permettant ainsi aux sphaignes de se développer et de devenir l'espèce dominante du milieu (Tremblay 2013). Peu importe le processus autogène ou allogène déclenchant l'ombrotrophication, cette succession est toujours caractérisée par la mise en place d'un couvert de sphaignes. Une fois présentes dans le milieu, les sphaignes forment un environnement défavorable pour de nombreuses plantes vasculaires en créant des conditions acides, pauvres en éléments nutritifs et anoxiques, favorisant ainsi leur propre maintien (van Breemen 1995). L'ombrotrophication peut néanmoins être inhibée et même inversée par l'apport d'eaux riches en nutriments dans la tourbière (Pajula 2000; Haraguchi & Nakazono 2011). Il est alors question de minérotrophication, c'est à dire le passage d'une tourbière ombrotrophe à une tourbière minérotrophe.

Certains changements environnementaux peuvent aussi engendrer des modifications dans la flore des tourbières sans toutefois en changer le statut trophique. Par exemple, l'augmentation de la dominance des arbres dans les tourbières est généralement associée à un réchauffement climatique et à des périodes de sécheresse (p.ex.: Weltzin et al. 2000; Breeuwer et al. 2009; Keuper et al. 2011 ; Heijmans et al. 2013). En effet, des températures plus élevées vont diminuer la hauteur de la nappe phréatique, augmenter la disponibilité des nutriments et allonger la saison de croissance, cela résultant en des conditions favorables de croissance pour les arbres (Heijmans et al. 2013). Cependant, le boisement des tourbières peut également être associé au drainage ou à l'accroissement des dépositions azotées (p.ex.: Pellerin & Lavoie 2003a; Linderholm & Leine 2004; Berg et al. 2009). Bien que ce phénomène n'implique pas de changement de statut trophique, il provoque néanmoins des bouleversements dans la diversité floristique des tourbières (Woziwoda & Kopec 2014). Néanmoins, Heijmans et al. (2013) ont avancé que ce phénomène pouvait être réversible dans le temps, mais cela reste à vérifier pour les paysages plus modifiés par l'homme.

1.2 Facteurs influençant la répartition de la végétation

1.2.1 Facteurs environnementaux

Dans les tourbières de l'hémisphère nord, les variations floristiques sont principalement associées à trois gradients écologiques, soit un gradient micro-topographique (Wheeler & Proctor 2000; Okland et al. 2001; Bragazza et al. 2005), un gradient bordure-centre (Malmer 1986; Okland et al. 2001) et un gradient chimique (Wheeler & Proctor 2000; Bragazza & Gerdol 2002; Bragazza et al. 2005).

Le gradient micro-topographique, principalement régi par la hauteur de la nappe phréatique, explique la répartition des espèces en fonction de la topographie de surface des tourbières. Il existe en effet une grande différence d'humidité entre les buttes (hummocks) et les dépressions (hollows) puisque la nappe phréatique ne suit pas la microtopographie de surface des tourbières (Andrus et al. 1983; Gignac 1992). La profondeur de la nappe phréatique, contrôlant alors le degré d'humidité de la tourbe affecte la ségrégation des espèces le long de ce gradient en lien avec la capacité des sphaignes à tolérer la dessiccation et à la capacité des plantes vasculaires à tolérer des conditions anoxiques (Bragazza & Gerdol 1996; Henkin et al. 2011). Ainsi, Okland (1990) a trouvé une relation très forte entre la distribution de la végétation et la hauteur moyenne de la nappe phréatique dans 800 parcelles d'une tourbière boréale. La profondeur de la nappe phréatique influence également le pH et la concentration en éléments nutritifs, ceux-ci étant plus élevés dans les dépressions que dans les buttes.

La distribution des espèces vasculaires dans les tourbières, notamment celle des arbres et des arbustes est en partie régie par le gradient bordure-centre (Okland et al. 2001). Les facteurs associés à ce gradient sont multiples et varient généralement d'un site à l'autre (Wheeler & Proctor 2000; Bragazza et al. 2005). Néanmoins, la fluctuation annuelle de la hauteur de la nappe phréatique, plus grande en bordure qu'au centre de la tourbière, et une meilleure aération de la tourbe en bordure favorisant la croissance des arbres sont les deux facteurs les plus souvent cités (Bragazza et al. 2005). Les arbres, notamment présents en bordure réduisent alors le rayonnement accessible aux autres plantes et augmentent la litière au sol, ce qui est susceptibles de modifier la végétation en favorisant les espèces forestières (Okland et al. 2001). Le long du gradient bordure-centre, deux gradients secondaires importants quant à la ségrégation des espèces, notamment des bryophytes, peuvent également être observés: un gradient d'épaisseur de tourbe et d'ombre (Jeglum & He 1995; Whitehouse & Bayley 2005). En effet, l'épaisseur de tourbe ainsi que la luminosité sont significativement plus élevées dans les zones ouvertes présentes au centre des tourbières que dans les zones boisées de bordure où les espèces forestières remplacent les espèces tourbicoles (Whitehouse & Bayley 2005). Enfin, le gradient bordure-centre serait aussi associé au fait que les bordures sont souvent plus riches que le centre puisqu'elles reçoivent une eau riche en minéraux en raison de la proximité du sol minéral (Ingram 1967; Damman & Dowhan 1981). Ainsi, les espèces indicatrices de minérotrophie sont généralement plus abondantes en bordure qu'au centre de la tourbière (Sjors 1950; Damman & Dowhan 1981; Malmer 1986; Asada et al. 2003; Pellerin et al. 2009).

Finalement, le gradient chimique permet d'expliquer la répartition de la végétation entre les tourbières ombrotrophes (pauvres) et les tourbières minérotrophes (riches). Bien que ce gradient s'exprime à l'échelle régionale (entre les tourbières), il peut aussi s'observer à l'intérieur d'une même tourbière (Sjörs 1948; Tahvanainen et al. 2002). Ce gradient est étroitement lié au pH et à la conductivité (Andersen et al. 2011a) et suggèrent une séparation graduelle entre la végétation ombrotrophe et la végétation minérotrophe (Okland et al. 2001). Ainsi, les zones ombrotrophes dominées par les sphaignes et les éricacées ont un pH et une alcalinité plus faibles ($pH < 5.5$ et conductivité corrigée $< 80\ \mu S/cm^2$) que les zones minérotrophes, généralement caractérisées par les mousses brunes et les carex (Andersen et al. 2011a). Ce gradient est aussi associé à un gradient d'approvisionnement en éléments nutritifs (Bridgham et al. 1996). Par exemple, l'azote, le phosphore et le potassium sont présents en très petite quantité dans les tourbières ombrotrophes puisque le recyclage des éléments minéraux est ralenti par une faible décomposition des végétaux. Ainsi, uniquement les espèces adaptées pour survivre à une très faible disponibilité en éléments nutritifs (espèces ombrotrophes) peuvent survivre (Proctor 1995).

1.2.2 Perturbations

Les perturbations, qu'elles soient d'origine naturelle (feu, vent, épidémie d'insecte, etc.) ou d'origine anthropique (drainage, coupe forestière, urbanisation, etc.) peuvent aussi jouer un rôle prédominant dans la dynamique végétale des tourbières. Dans les zones perturbées, certaines espèces s'adapteront, tandis que d'autres apparaitront ou disparaitront, ce qui pourra provoquer un changement dans les communautés végétales. Dans les tourbières, la principale perturbation naturelle est le feu, tandis que les principales perturbations anthropiques sont le drainage, la coupe forestière, l'extraction de la tourbe, la pollution atmosphérique et les feux (Moore 2002; Pellerin & Lavoie 2003a; Poulin et al. 2004).

Les études portant sur le feu montrent que cette perturbation a habituellement peu de répercussions à long terme sur les communautés végétales des tourbières ombrotrophes. En effet, bien que les feux soient particulièrement dommageables pour les arbres (Chambers 1997), la flore d'origine se rétablit généralement en quelques décennies (Kuhry 1994; Robichaud 2000; Lavoie et al. 2001; Benscoter 2006; Magnan et al. 2012). Cela est souvent dû au fait que les feux dans les tourbières n'affectent généralement que les couches superficielles de tourbe en raison du fort niveau d'humidité (Magnan et al. 2012). Ainsi, la microtopographie du sol peut revenir à son état d'avant feu grâce à la régénération, les buttes peuvent devenir des dépressions dû à la combustion, ou bien les dépressions peuvent devenir des buttes par succession (Benscoter et al. 2005). Paradoxalement, les feux peuvent aussi avoir un impact positif sur les fonctions des tourbières (p.ex.: séquestration du carbone) en permettant aux tourbières forestières de retourner à un stade moins arboré, favorisant ainsi la croissance des sphaignes (Chambers 1997). En effet, suite au feu, la mousse *Polytrichum strictum* s'installe grâce à la remise en circulation des nutriments et colonise rapidement le milieu. Cette espèce, capable de tolérer un stress abiotique, va modifier l'environnement et faciliter la colonisation des sphaignes, qui deviendront par la suite l'espèce dominante (Groeneveld 2002; Benscoter et al. 2005).

À l'échelle mondiale, les activités humaines ont généralement un impact négatif sur les fonctions écologiques des tourbières (Moore 2002). Par exemple, le drainage peut avoir des effets désastreux sur le fonctionnement de la tourbière, car il peut affecter de manière permanente l'hydrologie du sol (Laine et al. 1995). Il a aussi été montré qu'à une distance inférieure à 60 m, un fossé de drainage a un impact sur le niveau de la nappe phréatique suffisamment important pour augmenter la croissance des arbres (Roy et al. 2000). Le drainage favorise ainsi l'abondance des arbres et des espèces tolérantes à l'ombre et diminue le recouvrement des sphaignes (Laine et al. 1995; Poulin et al. 1999; Frankl & Schmeidl 2000; Linderholm & Leine 2004; Pellerin et al. 2008). L'évolution de la tourbière vers une végétation forestière peut alors diminuer la diversité régionale, même si la diversité en espèces à chacun des sites est peu affectée (Laine et al. 1995). L'exploitation forestière modifie également les conditions hydrologiques mais cette fois-ci en augmentant la hauteur de la nappe phréatique et en réduisant la hauteur des buttes à cause de la compaction et de l'abrasion. Cela a alors pour effet d'augmenter l'abondance des arbustes intolérants à l'ombre, des herbacées et des sphaignes (Roy et al. 2000; Locky & Bayley 2007). Par ailleurs, les tourbières sont aussi sensibles à la pollution atmosphérique. Par exemple, une augmentation d'azote induit des changements importants dans la flore des tourbières, telle qu'une diminution du couvert de mousses et une augmentation du couvert des plantes vasculaires (Gunnarsson et al. 2002; Heijmans et al. 2002; Wiedermann et al. 2007; Sheppard et al. 2014). En effet, les espèces non vasculaires n'ont pas de cuticule permettant l'absorption des éléments nutritifs sur toute leur surface, ce qui les rend vulnérables lorsque leur niveau d'azote arrive à saturation (Bates 2002). L'azote en surplus va alors s'infiltrer dans l'eau et le sol, devenant ainsi accessible aux racines des plantes vasculaires, qui vont ensuite pouvoir dominer le milieu (Bubier et al. 2007).

1.2.3 Spatialité

La plupart des phénomènes écologiques sont structurés par des forces ayant des composantes spatiales. La distribution des espèces résulte d'une action combinée de forces externes (conditions environnementales, perturbations) et de forces internes (dynamique de la population). Or, ces deux types de forces génèrent une configuration spatiale dans la répartition des espèces ou des communautés (Legendre & Legendre 2012). Ainsi, deux sites proches géographiquement ont plus de chance d'avoir une végétation qui se ressemble que deux sites éloignés. Par exemple, plusieurs études ont montré qu'une partie importante de la variation de la végétation des tourbières était spatialement structurée (Tousignant et al. 2010; Andersen et al. 2011b). Alors que Tousignant et al. (2010) ont montré qu'il s'agissait du fait que les variables abiotiques étaient également structurées dans l'espace, Andersen et al. (2011b) ont constaté que cela était directement relié à la distribution de la végétation. En effet, les patrons spatiaux apparaitraient grâce aux espèces abondantes, couvrant de grandes superficies et ayant une distribution agrégée. En revanche, les espèces ayant un faible recouvrement ou étant peu fréquentes ne seraient pas susceptibles de contribuer à la répartition spatiale (Andersen et al. 2011b).

1.2.4. Influence relative des facteurs de contrôle

Un des grands défis des écologistes est de déterminer l'influence relative des facteurs qui régissent les patrons de végétation (facteurs abiotique, de perturbation et spatial). Pour cela, deux méthodes peuvent être utilisées: l'étude de l'évolution de la végétation ou bien l'étude de la végétation actuelle.

Tout d'abord, plusieurs études ont utilisé des techniques paléoécologiques ou historiques pour comprendre les facteurs responsables de la dynamique végétale (Lavoie & Richard 2000; Gunnarsson et al. 2002; Pellerin & Lavoie 2003a; Pellerin et al. 2008; Kapfer et al. 2011). Par exemple, dans une tourbière du sud de la Suède, Kapfer et al. (2011) ont ainsi constaté que le nombre total d'espèces présentes dans cette tourbière était resté constant durant 50 ans mais que la fréquence des espèces avait changé significativement en réponse à des changements environnementaux tels que la température, le pH, l'humidité du sol, la disponibilité en nutriments et en lumière. Par ailleurs, Pellerin et al. (2008) ont conclu que les changements des communautés végétales survenus durant trois décennies dans deux tourbières du Québec étaient dus à l'action conjointe des activités humaines et d'une période de sècheresse. Pour leur part, Pellerin et Lavoie (2003a) ont suggéré qu'une interaction entre un climat sec, du drainage et des périodes de feux semblaient être les principaux facteurs responsables de la succession végétale contemporaine survenue dans plusieurs tourbières ombrotrophes.

À l'inverse, peu d'études ont tenté de quantifier l'influence relative des facteurs régissant les patrons de végétation en utilisant les communautés végétales actuelles. Dans une tourbière tempérée, les variables environnementales (notamment la distance à la bordure et la hauteur de la nappe phréatique) expliquent 30% de la variation de la composition floristique (Pellerin et al. 2009). De même, Tousignant et al. (2010) ont estimé que les conditions abiotiques avaient une influence prédominante sur la composition en espèces des tourbières de Lanoraie. Cependant, bien que les perturbations anthropiques des tourbières de Lanoraie expliquaient une faible fraction de la variation de la végétation (8.2%) comparée aux variables abiotiques (25.2%), l'analyse multivariée montrait que ces deux facteurs étaient liés à la distribution de certaines plantes, notamment celle des arbres et des arbustes. Toutefois, il est a prendre en considération que les activité humaines auraient tendance à modifier les conditions environnementales plutôt que d'avoir un impact direct sur les communauté végétales (Girard et al. 2002).

1.3 Objectifs de l'étude

L'objectif général de cette étude est de comprendre les facteurs responsables du façonnement des communautés végétales de deux tourbières du sud du Québec soumises à de fortes pressions anthropiques. L'étude se fera tout d'abord avec une approche temporelle et ensuite grâce à une perspective spatiale.

Les objectifs spécifiques du mémoire sont de :

1) Reconstituer la dynamique récente (30 ans) des communautés végétales.
2) Identifier les principales perturbations naturelles et anthropiques présentes sur les sites et explorer leur influence potentielle sur cette dynamique.
3) Analyser l'importance relative des conditions environnementales, des perturbations anthropiques et des composantes spatiales sur la distribution de la végétation actuelle.

Les résultats obtenus permettront d'évaluer l'impact des différentes perturbations sur les communautés végétales des tourbières et de proposer des avenues pour protéger à long terme cet écosystème.

1.4 Organisation du mémoire

Le corps du mémoire est constitué de quatre chapitres dont deux rédigés sous forme d'articles scientifiques. Le second chapitre présente la dynamique temporelle récente des communautés végétales de tourbières soumises à des pressions anthropiques. Le troisième chapitre présente l'importance relative des facteurs qui ont conduit à la végétation actuelle des tourbières. Enfin, le quatrième chapitre présente une conclusion générale au mémoire.

Le chapitre 2 a été soumis pour publication dans Applied Vegetation Science tandis que le chapitre 3 sera soumis ultérieurement pour publication. Les auteurs sont, en ordre, Salomé Pasquet, Stéphanie Pellerin et Monique Poulin. Le premier auteur a effectué l'échantillonnage sur le terrain, le traitement et l'analyse des données, ainsi que la rédaction du présent mémoire. Stéphanie Pellerin a élaboré et supervisé le projet de recherche, ainsi que corrigé et commenté les manuscrits. Monique Poulin a également corrigé et commenté les manuscrits.

Chapitre 2: Three decades of vegetation dynamics in peatlands isolated in an agricultural landscape

2.1 Introduction

Although peatlands cover extensive areas at boreal and temperate latitudes, they are threatened locally in inhabited regions by human activities such as peat extraction, tree plantation, agriculture and urban sprawl (Poulin et al. 2004; Lindholm & Heikkilä 2012). However, the wide array of functions and ecosystem services they provide should favor social acceptance of their conservation. For instance, owing to their plant accumulation processes, peatlands contain around 30% of global soil carbon stock (Gorham 1991). They also constitute fresh water reserves and help regulate regional hydrologic fluxes (Levison et al. 2013). Furthermore, they support specialized flora adapted to harsh prevailing conditions, notably acidic and water logged soils. In temperate regions, their flora contrasts sharply with surrounding environments and contributes to increased regional diversity (Ingerpuu et al. 2001). The maintenance of the above functions and services are nevertheless at risk when peatland plant communities are altered. With intensification of the human footprint on ecosystems, it becomes crucial to increase our understanding of the factors that regulate floral composition and structure in peatlands.

Ecological factors driving vegetation patterns in pristine peatlands have been investigated in several studies since the 1950s (e.g., Sjörs 1950; Malmer 1986; Belland & Vitt 1995; Bragazza et al. 2005). Results have established that floristic variation in peatlands is mainly controlled by three ecological gradients: acidity–alkalinity, availability of nutrients and water table depth. A margin-expanse gradient is also frequently described, even though the ecological factors underlying it are complex and vary from site to site (Wheeler & Proctor 2001; Bragazza et al. 2005). Locally, secondary gradients such as peat thickness or shading are also important, especially for bryophytes (e.g., Jeglum & He 1995; Whitehouse & Bayley 2005). More recently, some studies have shown that anthropogenic forces that directly or indirectly impact peatlands may override these natural gradients and drive peatland floristic patterns and dynamics (e.g., Feléchoux et al. 2000; Pellerin & Lavoie 2003a; Toursignant et al. 2010).

The main anthropogenic disturbance in peatlands is drainage, which usually enhances shrub and tree encroachment, hampers *Sphagnum* growth and facilitates the establishment of generalist or non-peatland species (Laine et al. 1995; Minkkinen et al. 1999). Some studies have also shown that climate warming (Weltzin et al. 2000; Breeuwer et al. 2009) and nitrogen input from atmospheric pollution (Berendse et al. 2001; Gunnarsson et al. 2004) may have adverse impacts on peatland vegetation, mostly on *Sphagnum* species. Knowledge about the impact of such anthropogenic disturbances has mostly been gained through observational studies (comparing disturbed with undisturbed sites) or short-term experiments (< 10 years). Although these studies have provided important clues regarding expected changes, they have generally been unable to capture the long-term trends of community succession that follow environmental changes. Nevertheless, some studies have met this challenge by using historical vegetation surveys conducted 30-80 years ago as baselines from which to make explicit predictions concerning temporal change that can then be tested using contemporary surveys (e.g., Backéus 1972; Gunnarsson et al. 2002; Pellerin et al. 2008; Hájková et al. 2012).

It is recognized that re-visiting permanently marked plots for studying vegetation changes lead to accurate assessments. In contrast, the use of legacy data from historical surveys with imprecise locations is challenging and can lead to biased estimation of changes. Nonetheless, it is now accepted that such studies can provide valid results, especially when inferences are based on average changes observed across sample plots, rather than on changes within individual plots (Vellend et al. 2013; Chytrý et al. 2014). In this regard, Kapfer et al. (2011) reported compositional changes over 50 years in a *Sphagnum*-dominated peatland by referring to species' optimum value for different environmental gradients. They showed an increase in frequency of occurrence of species with low indicator values for light and moisture and a high indicator value for nutrients. These changes were related to an increase in air temperature and atmospheric nitrogen supply. Similarly, a study by Pellerin et al. (2008) based on unmarked plots showed significant changes in plant composition, mainly an increase of shrub and tree cover, in two southern boreal bogs over a 32-year period. For the present study, vegetation surveys carried out in 1984-85 in two peatlands located in a landscape highly transformed by humans, were used as a baseline. We specifically aimed to (1) determine changes in plant composition between the initial survey in 1984-85 and our 2012 study, (2) identify disturbances located on and surrounding the sites and explore their potential impact on the vegetation changes, and (3) analyse the impact of recent tree encroachment on peatland flora. We hypothesized that drainage is the dominant driver of the vegetation changes, and predicted an increase of non-peatland and exotic species richness at the cost of typical peatland species.

2.2 Study sites

The Small and the Large Tea Field peatlands are located in southwestern Québec, Canada (Figure 1). They are isolated in an agricultural landscape occupied mainly by maize and dairy farms and large garden markets on organic soils. Both sites rest on rich marine clay deposits of the Champlain Sea at an altitude of 50 m at sea level. Their mean peat thickness is 267 cm (Stdev: 11 cm; min: 10 cm; max: 519 cm; Pasquet unpublished data). The mean annual temperature (1965-2012) at the nearest meteorological station (10 km) is about 6 °C and mean annual precipitation is 990 mm, 16% of which falls as snow (Environment Canada 2013). Average readings registered for both climatic variables were lower during the 10-year period prior to the first sampling (1974-84; 6.5 °C, 968 mm) than in the 10-year period preceding our resampling (2002-12; 7.6 °C, 1073 mm). Wet nitrogen depositions have only been monitored since 1988 in the area (NAtChem 2013). The Tea Field peatlands are located in a region with some of the highest levels of wet N deposition in eastern North America (Turunen et al. 2004), with an average of 0.7 g N m^{-2} $year^{-1}$ between 1988 and 2005 (most recent data available).

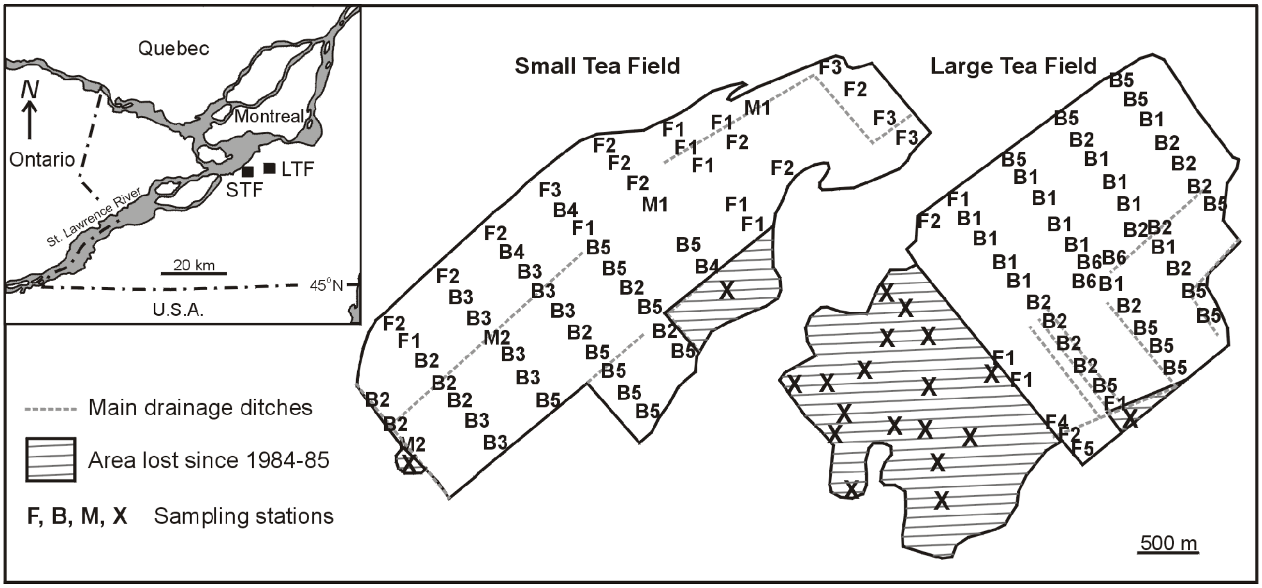


Figure 1. Location of the peatlands studied (southwestern Québec, Canada), and of the sampling plots within the peatlands. Plots are differentiated according to their membership in the plant communities defined in 1984-85 (See Table 1 for the name of each community, B = bog, F = fen and M = marsh). Sampling stations indicated by an X were not sampled in 2012 as they were located in areas that have been lost to agriculture. STF: Small Tea Field; LTF: Large Tea Field.

Since the beginning of European settlement in the region (early 19th century), about 70% of these peatlands' original area has been lost, mainly to agriculture. According to the historical study of Jean and Bouchard (1987), in 1863, the two peatlands were still connected, and occupied an area of 5075 ha. Fifty years later (1912), they had been disconnected and covered a total area of 3828 ha. Large areas at the margins of the bogs were already drained and cultivated (Anrep 1917). In 1936, the total area of the bogs was estimated at about 3000 ha (McKibbin & Stobbe 1936), and around 40% of their surface was in culture or in pasture while drainage ditches were all over the place. McKibbin and Stobbe (1936) also indicated that frequent fires, mostly human ignited, has greatly reduced the thickness of peat layers in several areas. The last known fire occurred in 1983 in the Large Tea Field (Jean & Bouchard 1987). In 1984, at the time of the first vegetation inventory, the total area of the two peatlands was estimated at 1600 ha. Agriculture was again the main cause of the lost. By 2012, it had been reduced to 1115 ha, representing a further loss of 485 ha (S. Pasquet, unpubl. data). Historic human activities not only reduced the surface of the two bogs, they also had major impacts on their plant communities. Macrofossil and pollen analyzes carried out in these two peatlands (Laframboise 1987) showed that the pre-colonial vegetation was very different from the current vegetation, particularly due to the expansion of agriculture (drainage, clearing, pasture) and repeated fires. For instance, spruce nearly disappeared from the peatland (no spruce were found in 1984-85 and only one spruce sapling was found in 2012), while this species used to be abundant on the two bogs according to Anrep (1917) and McKibbin and Stobbe (1936). Using notary deeds, Bouchard et al. (1989) demonstrated that spruces were selectively lumbered in the region between 1849 and 1957. However, since 2009, 820 ha have been set aside as a conservation preserve by Nature Conservancy-Québec.

Although the area of the Tea Field peatlands has shrunk dramatically since colonization, few human activities have taken place directly in the remaining portion of the peatlands. Some tree cutting is underway at their margins, and a large all-terrain vehicle track intersects the Large Tea Field. Man-made drainage ditches (between one and three meters) also run through the peatlands, especially in the southern part of the Large Tea Field and in the central section of the Small Tea Field (Figure 1). The main ditch in the latter is intersected by seven beaver dams, however, and is thus likely ineffective for drainage. Finally, a human-ignited fire in 1983 affected most of the area of both peatlands, except the margins of the Large Tea Field and the northeastern section of the Small Tea Field.

The Tea Field peatlands are characterized by a mosaic of ombrotrophic (bog) and minerotrophic (fen) plant communities with some patches of marshes. In 1984-85, Jean & Bouchard (1987) distinguished sixteen plant communities (Table 1; Figure 1). Six bog communities (B1–B6; Table 1) were identified, mainly in the central portion of both peatlands (Figure 1). Eight fen communities (F1–F8) were also identified (Table 1), mostly at the margins of both sites (Figure 1). Finally, two marsh communities (M1-M2) were found in the Small Tea Field, mainly near beaver dams. Three of the 16 communities identified in 1984-85 (F6–F8) were entirely situated in areas that have since been lost to agriculture.

Table 1. Plant species communities in the Large and Small Tea Field peatlands, southwestern Québec (Canada). The number of plots (N. plots) and the mean number of species per plot (Mean N. species) in each community in 1984-85 and 2012 are also indicated, as well as the Sørensen dissimilarity index. NA: not analysed

		N. plots		Mean N. Species		
Code	**Communities**	**1984**	**2012**	**1984**	**2012**	**Sørensen Index**
B1	*Chamaedaphne calyculata* dwarf-shrubland	14	14	10.9	12.6	0.51
B2	*Betula populifolia* - *Eriophorum vaginatum* dwarf-shrubland	20	20	8.4	12,7	0.53
B3	*Betula populifolia* - *Oclemena nemoralis* dwarf-shrubland	9	9	14.2	15.1	0.46
B4	*Betula populifolia* - *Spiraea latifolia* dwarf-shrubland	8	3	14.9	15.7	0.51
B5	*Betula populifolia* - *Chamerion angustifolium* burnt land	21	21	14.2	14.3	0.28
B6	*Chamerion angustifolium* burnt land	3	3	10.3	14.0	0.90
F1	*Betula populifolia* - *Populus tremuloides* – *Rubus hispidus* woodland	14	12	18.6	21.1	0.43
F2	*Populus tremuloides* - *Alnus incana* – *Rubus idaeus* woodland	17	11	18.6	22.6	0.39
F3	*Populus tremuloides* - *Phragmatis australis* woodland	4	4	17.8	20.0	0.56
F4	*Salix petiolaris* shrubland	1	1	21.0	34.0	NA
F5	*Salix amygdaloides* shrubland	1	1	22.0	37.1	NA
F6	*Cornus stolonifera* dwarf-shrubland	5	0		NA	NA
F7	*Acer rubrum* shrubland	2	0		NA	NA
F8	*Salix alba* woodland	1	0		NA	NA
M1	*Typha latifolia* – *Calamagrostis canadensis* marsh	5	2	11.0	15.5	0.64
M2	*Salix petiolaris* – *Lythrum salicaria* marsh	2	2	13.0	14.0	0.61
	Tea Field Peatlands : Total	127	103	14.0	16.2	0.35

2.3 Methods

2.3.1 Field Sampling

The vegetation of the two peatlands was first surveyed using 127 sampling plots (5 × 5 m) during the summers of 1984 and 1985 (Jean & Bouchard 1987). Most of the plots were located every 200 m along north-south transects spaced 500 m apart (Figure 1). Three supplemental plots were set up to capture smaller plant communities, while the plots in the southwestern part of the Large Tea Field were established randomly (Figure 1). Each sampling plot was set up in a homogeneous portion of the plant community. The percent cover of each plant species in each plot was estimated according to seven classes: (1) <1%, (2) 1-5%, (3) 6-10%, (4) 11-25%, (5) 26-50%, (6) 51-75%, (7) >75%. The total percent cover of burned surface and open surface water was estimated visually by projecting their horizontal coverage on the 5 x 5 m plot. The pH of the peat deposit was measured from a sample extracted ten cm below the soil surface. Samples were kept frozen in the lab until analysis. The soil pH was measured both years using a dilute Calcium Chloride ($CaCl_2$) solution.

In 1984-85, Jean and Bouchard (1987) noted the precise position of all but four plots on a map, along with the limits of the 16 vegetation communities. In our study, we digitized, registered in space and integrated this map in Quantum GIS 1.7.4 software (QGIS), then retrieved the geographic coordinates of each plot. During the summer of 2012, we revisited 103 of the 127 sampling plots. The 24 remaining plots were either not located on the map (the four mentioned above) or were located in sectors lost to agriculture (Figure 1). In addition to geographical coordinates, we used all reported information available (e.g., position in relation to drainage ditches or roads) to determine the location of the plots. Considering the abundance of human benchmarks in the studied area, we estimated that the 2012 plots were located within 50 m of the original plots. This sampling error should have had only a minor impact on the trends in change over time in the vegetation of these sites (Pellerin et al. 2008). All plots were sampled using the same methods as in 1984-85.

Woody plant encroachment

To assess woody plant encroachment in the two bogs, we used grey-scale aerial photographs from 1983 and 1999 (1: 15 000) as well as Google Earth's Digital Globe satellite imagery from 2010. Aerial photographs were selected based on cloud free conditions and absence of distortion. The 1983 photos were digitized and registered in space using QGIS to be comparable with the 2010 satellite imagery. In QGIS, woody areas were manually delineated on each 1983 aerial photo and 2010 satellite image based on color and texture. Woody areas were those with more than 35% coverage of tall tree (> 2 m). Automatic methods, such as thresholding, were not suitable due to high variability in the background color of the photos. Visual interpretation of vegetation structure was, however, confirmed by stereoscopic viewing of 1983 and 1999 aerial photographs (the 1999 photos were the most recent available).

Mapping of anthropogenic disturbances

All anthropogenic disturbances located within or bordering the Tea Field peatlands were identified using georeferenced aerial photographs and satellite images. Then the perimeters of each disturbed surfaces (agricultural land, tree cutting areas, roads, all-terrain vehicle trail, drainage ditches) were delineated in QGIS. The percentage of disturbed surfaces and ditch density (m/ha) within a radius of 100 m from each sampling plot was then calculated. The efficiency of a drainage ditch in a peatland depends on several factors (e.g., peat composition and structure, ditch depth and direction), but its impact on vegetation is rarely apparent at distances exceeding 100 m (e.g., Poulin et al. 1999; Roy et al. 2000).

2.3.2 Taxonomic verification

We carefully verified plant lists, standardized all species nomenclature to conform to VasCan (Brouillet 2012), bryophytes to Faubert (2012) and lichens to PLANTS database (USDA & NRCS 2013) and corrected any past misidentification using herbarium specimens (Marie-Victorin Herbarium). When no herbarium specimen was available, we changed identification when there was clear evidence of error, for instance, when a species does not occur (historically or presently) in the study area (e.g., *Aronia pyrifolia* instead of *A. melanocarpa*). We grouped all species from taxonomically difficult groups at the genus level (e.g., *Brachythecium*, *Carex*, *Rubus*, *Salix*, *Sphagnum*), as they were usually not well distinguished in 1984-85. Likewise, we grouped all subspecies at the species level, because subspecies were rarely identified in 1984-85. For lichens, we retained only the four most common species (*Cladina mitis*, *C. rangiferina*, *Cladonia cristatella*, *C. multiformis*), which accounted for > 90% of total lichen cover and were easy to identify in the field. All vascular taxa were then classified as native peatland, native non-peatland or exotic species, using information in Dubé et al. (2011) and Lavoie et al. (2012).

2.3.3 Data analyses

Data in the 1984-85 study were only available at the community level and included: (1) a list of species, (2) the number of plots in which each species occurred, (3) the mean number of species per plot, (4) the mean cover of each species, (5) the mean peat pH, and (6) the covers of burned and open water surfaces. Prior to analyses, each plot sampled in 2012 was assigned to one of the 1984-85 plant communities using the 1984-85 map. In subsequent analyses, we omitted all data from communities situated entirely in sectors that had been transformed into agricultural fields (F6–F8) or with a single sampling plot in 2012 (F4, F5).

To determine the extent of changes in species composition for the peatlands and for each community from 1984-85 to 2012, we calculated the Sørenen dissimilarity index (Kolef et al. 2003), using the list of species from both years. We also identified the species with the greatest changes in frequency of occurrence between 1984-85 and 2012, by comparing the proportion of plots occupied by each species in each sampling period. For this comparison, we used only species occurring in at least 5 plots in both years or in a least 10 plots in one of the years for a total of 65 species analysed. Significant changes in frequency of occurrence were determined using Chi-square goodness-of-fit tests.

Species with significant cover changes were identified at the community level because, as mentioned above, the 1984-85 dataset reported only the mean cover value for each species, leaving the variance unknown. Therefore, a one-sample t-test with 95% degree of confidence was used to test whether the 1984-85 mean (treated as a constant) was included in 2012 confidence interval. Species cover was evaluated using the mid-point of each class for each community in both periods. For these analyses, only communities with at least 5 sampling plots in 2012 and species with more than 10% of mean cover in a specific community in at least one of the sampling periods were used. A similar method was used to identify changes in mean peat pH, mean open water cover and percentage of disturbed surfaces and ditch density within a radius of 100 m from each sampling plot.

Finally, using only the 2012 data, we analyzed the impact of tree encroachment on the flora of the peatlands. We first sorted the 2012 plots into three classes of habitats: (1) plots that were already forested in 1984-85 (old forest), (2) plots that became forested between 1983 and 2010 (new forest) and (3) plots that had never been forested in the time span of the study (open site). To evaluate whether the three habitat types could be segregated on the basis of plant species composition, we performed a linear discriminant analysis (LDA) using cover data of all vascular and non-vascular species found in more than 10 sampling plots (54 species). Indicator species of each habitat group were then identified by the IndVal method (Dufrêne & Legendre 1997). Lastly, the number of peatland and non-peatland vascular species (including exotic species) per habitat was compared with the help of repeated-measures ANOVA. The repeated aspect of the ANOVA was necessary because the richness of one habitat group was not independent of the richness of the other. Richness of species was evaluated using all vascular species found in 2012 (224 species; Appendix S1, supporting information). Assumptions of normality and homogeneity of variances were met. Post-hoc multiple comparisons were performed using Tuckey HSD in JMP 10.0.0 (SAS Institute, Cary, North Carolina, USA). Univariate statistical analyses and multivariate analyses were performed in version 2.15.1 of the R environment (R Core Team, Vienna, Austria).

2.4. Results

2.4.1 Floristic richness and composition changes

In the eleven plant communities studied, a total of 190 taxa (159 vascular and 31 nonvascular) were sampled in 1984-85 (114 plots), and 177 taxa (150 vascular and 27 nonvascular) in 2012 (101 plots) (Appendix 1). Considering the smaller number of plots sampled in 2012, the overall richness per unit area appears to have increased, an inference in part supported by the higher mean number of species per plot in all communities (Table 1). Regardless of richness trend, there was a 35% floristic dissimilarity between 1984-85 and 2012 (Table 1); 70 species were observed only in 1984-85 and 57 species only in 2012. Most lost and new species were herbs (63 and 65% respectively). Although most were rare (≤ 5 plots) and occupied small surfaces (mean cover ≤ 10%), three lost species (*Typha angustifolia*, *T. latifolia*, *Epilobium ciliatum* subsp. *glandulosum*) and four newly found ones (*Phalaris arundinacea*, *Ilex verticillata*, *Gaylussacia baccata*, *Cornus racemosa*) were dominant or subdominant (mean cover > 20%) in some of the communities in which they occurred. In both studies, the vascular flora was primarily composed of non-peatland species (65% of the flora in 1984-85 and 63% in 2012; including exotic species), and the proportion of exotic species remained low (< 10%) (Appendix 1). At the community level, the floristic dissimilarity between the two sampling periods ranged from 28 to 90% (Table 1). Species turnover was particularly high in the two marsh communities (M1, M2), as well as in the *Chamerion angustifolium* burnt land (B6), but these communities were also represented by the fewest number of plots that could induce pseudo-turnover due to reduced sampling.

Among the 65 species tested for changes in frequency, 21 showed a significant increase (Figure 2), including two exotic species (*Phragmites australis*, *Rhamnus cathartica*), several non-vascular species (e.g., *Sphagnum* spp., *Aulacomnium palustre*, *Pleurozium schreberi*) and ericaceous shrubs typical of peatlands (*Kalmia angustifolia*, *Rhododendron canadense*, *Vaccinium* spp. *Gaylussacia baccata*). In contrast, nine species were found to have decreased significantly in frequency (Figure 2), in particular, *Chamerion angustifolium*. Most of the species occurring less frequently today than in 1984-85 were non-peatland herbaceous species.

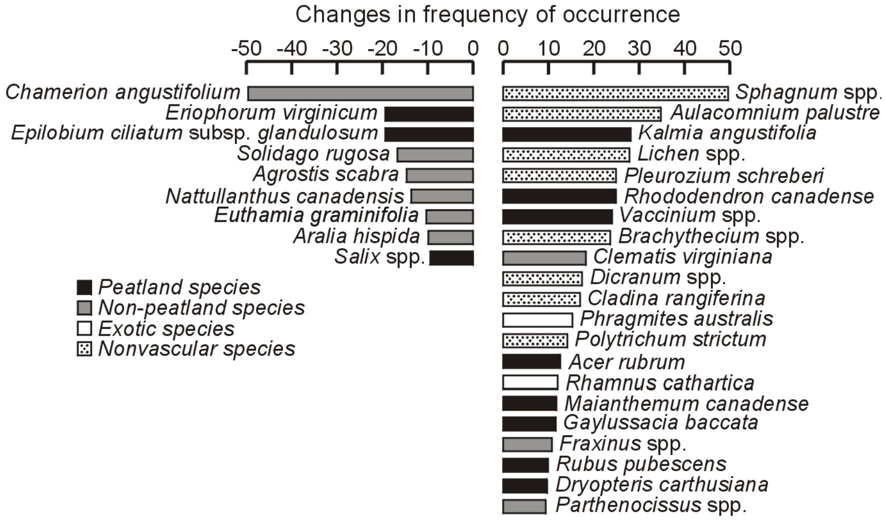


Figure 2. Significant changes (Chi-square goodness-of-fit tests; $p \leq 0.05$) in species' frequency of occurrence (number of plots) from 1984-85 to 2012. Changes in frequencies were calculated by subtracting the frequencies in 1984-85 from frequencies in 2012. On the left side are species with lower frequency in 2012 than in 1984-85, and on the right side, species with higher frequency in 2012 than in 1984-85. Only species occurring in at least 5 plots in both years or in at least 10 plots in one of the years were considered (65 species).

Mean plant cover changes

The mean cover of 11 taxa differed significantly between 1984-85 and 2012, and in either one or several of the six communities with more than five sampling plots (Figure 3). Seven of these species were peatland species (e.g., *Vaccinium* spp., *Sphagnum* spp., *Oclemena nemoralis*), and four were non-peatland species (*Chamerion angustifolium*, *Rubus* spp., *Pteridium aquilinum*, *Populus tremuloides*). All species with a greater mean cover in 2012 than in 1984-85 were peatland species occurring in ombrotrophic communities. In contrast, four of the eight species with a lower mean cover in 2012 were non-peatland species found in minerotrophic communities. The mean cover of *Sphagnum* spp. increased significantly in the four ombrotrophic communities, and even tripled in one of these (see B1, Figure 3). The trajectory of *Betula populifolia*'s mean cover between the two time periods diverged among communities, being two times higher in two bog communities and three times lower in a fen community.

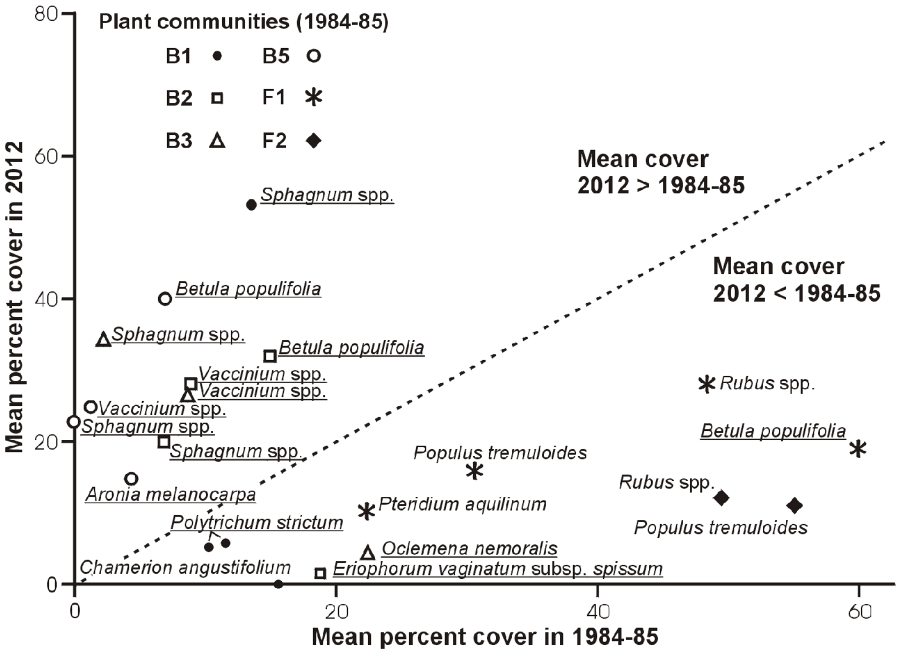


Figure 3. Changes in species mean cover between surveys in 1984-85 and 2012. Only species with significant mean cover change are presented, and this, for each community analysed. See Table 1 for the name of each community. Underlined indicates native peatland species.

2.4.2 Tree encroachment and species composition and richness

Analyses of aerial photographs and satellite images indicated that widespread forest expansion occurred in both peatlands (Figure 4). During the period studied, the percentage of the area occupied by forest increased from 26 to 51%, which represents an overall gain of 280 ha of forest habitat (Table 1). Tree encroachment was particularly noticeable at the margins of the sites (Figure 4). *Betula populifolia* (observed in 82% of the plots in 2012), *Populus tremuloides* (37%) and *Acer rubrum* (31%) accounted for most of the increase in forest cover.

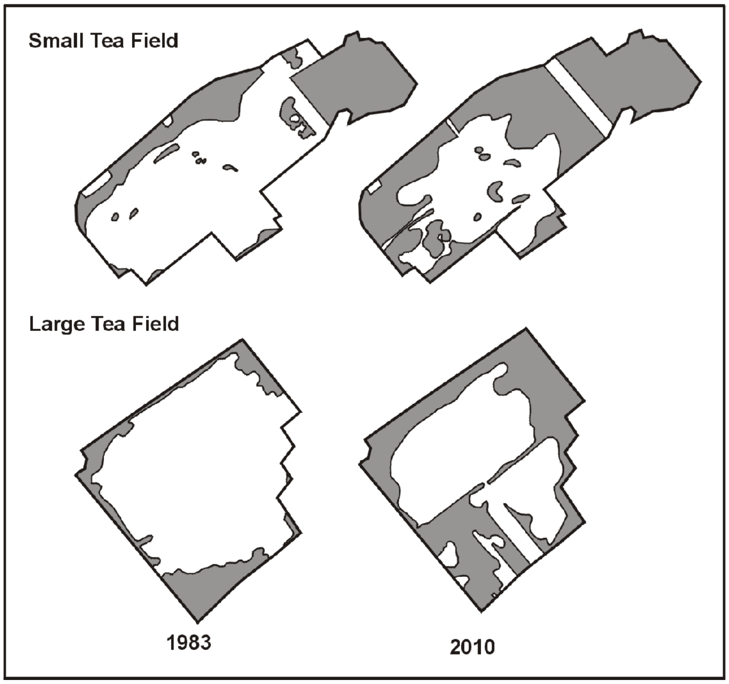


Figure 4. Spatio-temporal evolution of the forest cover (grey sector) of the Small and Large Tea Field peatlands, reconstructed using aerial photographs (1983 and 1999) and satellite imagery (2010).

The LDA correctly classified 97% of the sampling sites in the appropriate group: 100%, 94% and 98% of old forest, new forest and open habitats respectively. Open habitats and old forests were the most distinct groups (Figure 5). Twenty-three species were found to be indicators of old forests, one of new forests and 17 of open habitats (Table 2). All indicator species of new forest and open habitats were peatland species, while most of the indicator species of old forests (15 species) were non-peatland or exotic species (*Phragmites australis*, *Rhamnus cathartica*). Although not exotic, three invasive vines in southern Québec (*Clematis virginiana*, *Pathenocissus inserta*, *Vitis riparia*) were also indicators of old forests (Table 2). Plots located in old forests had significantly more non-peatland species than peatland species (Figure 6). In contrast, we found two times more peatland than non peatland species in new forest and 15 times more in open habitats.

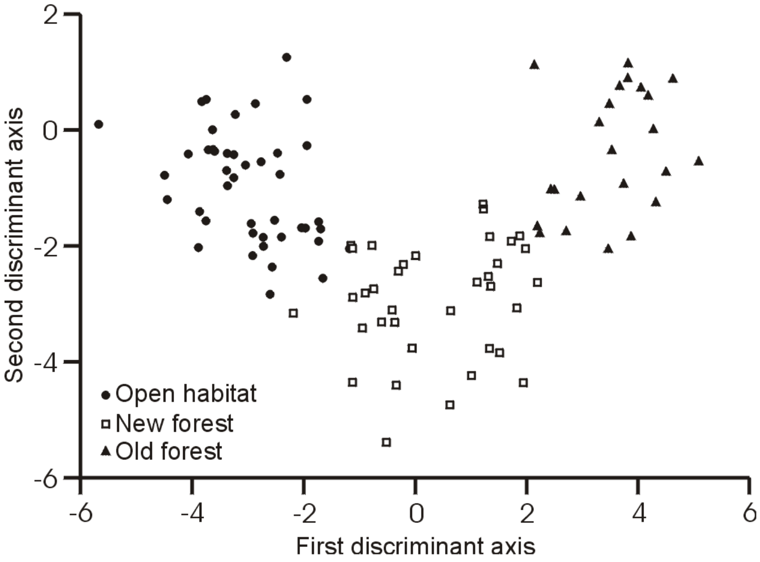


Figure 5. Linear Discriminant Analysis (LDA) of the three habitat categories made on species abundance in 2012 survey. Old forests are those that were already present in 1984-85 and new forests are those that developed between 1984-85 and 2012. Open habitats are peatland area that remained treeless. LDA correctly classified 100% of the old forest plots, 94% of the new forest plots and 98% of the open habitat plots.

Table 2. Indicator species of old forests, new forests and open habitats. Old forests are those that were already present in 1984-85 and new forests are those that developed between 1984-85 and 2012. Open habitats are peatland areas that remained treeless. Indicator value (IV) is also shown. Only species with p-value < 0.05 are presented. † indicates non-peatland species.

Species	**IV**		**IV**
Old forests			
Acer rubrum	0.43	*Maianthemum canadense*	0.23
Alnus incana subsp. rugosa	0.33	*Onoclea sensibilis*	0.42
Brachythecium rutabulum†	0.13	*Parthenocissus inserta*†	0.39
Brachythecium salebrosum†	0.15	*Populus tremuloides*†	0.26
Callicladium haldanianum	0.14	*Rhamnus cathartica*†	0.39
Clematis virginiana†	0.48	*Rubus idaeus*†	0.51
Cornus stolonifera	0.37	*Rubus hispidus*†	0.30
Doellingeria umbellata†	0.14	*Rubus pubescens*	0.33
Dryopteris carthusiana	0.22	*Solidago gigantea*†	0.34
Fraxinus pennsylvanica†	0.25	*Solidago rugosa*†	0.18
Impatiens capensis†	0.17	*Vitis riparia*†	0.40
Lythrum salicaria†	0.15		
New forests			
Betula populifolia	0.37		
Open habitats			
Aulacomnium palustre	0.26	*Polytrichum strictum*	0.67
Chamaedaphne calyculata	0.38	*Rhododendron canadense*	0.54
Cladina rangiferina	0.26	*Sphagnum capillifolium*	0.64
Cladonia cristatella	0.26	*Sphagnum magellanicum*	0.19
Eriophorum vaginatum subsp. *spissum*	0.46	*Sphagnum papillosum*	0.32
Kalmia angustifolia	0.57	*Sphagnum rubellum*	0.53
Ilex mucronata	0.39	*Vaccinium angustifolium*	0.48
Oclemena nemoralis	0.15	*Vaccinium corymbosum*	0.33

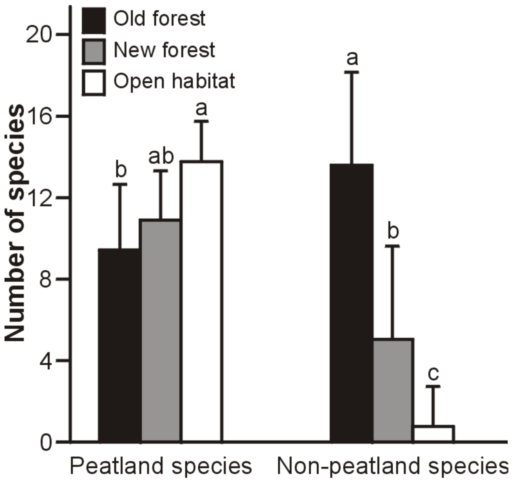


Figure 6. Mean number of peatland and non-peatland (including exotic) species in each habitat type (ANOVA habitat*species: *F* = 56.77, *P* <0.0001). Bars indicate standard deviation. Different letters indicate a significant difference at α = 0.05 within each habitat type as determined by a Tukey's test.

2.4.3 Environmental changes

The 1983 fire affected more than 50% of the surface of 6 out of the 11 communities studied (Table 3). The percentage of fire-disturbed area was particularly high (between 44 to 88%) in ombrotrophic dwarf shrublands (B1 to B6) and in the *Typha latifolia – Calamagrostis canadensis* marsh (Table 3). In 1984-85, the mean cover of open surface water was low (less than 5%) in most of the communities, but very high (87.5%) in the two marsh communities (Table 3). In 2012, we found no area of open surface water in any of the sampling plots, even upon revisiting the site during a wetter period (May 2013). In 1984-85, the mean peat surface pH ranged from 2.9 to 5.9, and from 2.7 to 5.2 in 2012 (Table 3). It was significantly lower in 2012 than in 1984-85 in four ombrotrophic communities (B1, B4–B6), one minerotrophic community (F3) and one marsh (M2). No significant difference was found in ditch density within a radius of 100 m from a sampling plot (Table 3). The proportion of disturbed area within a radius of 100 m from a sampling plot was significantly higher in 2012 than in 1984-85 over the entire peatland area as well as in three of the ombrotrophic communities (B2, B5, B6; Table 3).

Table 3. Percentage of fire disturbed area in 1984-85 (Fire), mean percent cover of open surface water (OW), mean pH (pH), mean ditch density (DD, m/ha) and mean percent disturbed area (PD). $_{84}$ = 1984-85 data; $_{12}$ = 2012 data; CI$_{95\,\%}$ = Confidence intervals. Bold indicates significant changes. See Table 1 for the name of each community.

	Fire	**OW$_{84}$**	**OW$_{12}$**	**pH$_{84}$**	**pH$_{12}$ (CI$_{95\,\%}$)**	**DD$_{84}$ (CI$_{95\,\%}$)**	**DD$_{12}$ (CI$_{95\,\%}$)**	**PD$_{84}$ (CI$_{95\,\%}$)**	**PD$_{12}$ (CI$_{95\,\%}$)**
Peatlands						10 (6-14)	17 (11-23)	**2 (1-3)**	**6 (4-8)**
B1	52.5	**0.5**	**0**	2.9	**2.7 (2.7-2.8)**	2 (0-7)	2 (0-7)	0 (0-0)	0 (0-0)
B2	61.9	**0.5**	**0**	2.9	3.0 (2.8-3.2)	15 (4-26)	35 (8-52)	**1 (0-1)**	**7 (3-11)**
B3	87.5	**1.3**	**0**	3.2	3.2 (2.8-3.5)	7 (0-20)	7 (0-20)	0 (0-1)	1 (0-2)
B4	44.0	**5.1**	**0**	3.2	**3.0 (2.9-3.1)**	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
B5	81.6	**0.5**	**0**	3.2	**2.8 (2.7-2.9)**	4 (0-11)	18 (5-32)	**0 (0-1)**	**8 (2-15)**
B6	87.5	**1.3**	**0**	3.3	**2.8 (2.6-2.9)**	36 (1-71)	36 (1-71)	**2 (1-2)**	**6 (4-8)**
F1	23.9	**0.5**	**0**	3.6	3.5 (2.9-4.0)	12 (0-28)	12 (0-28)	6 (2-11)	12 (7-16)
F2	0.5	**0.7**	**0**	4.5	4.5 (3.9-5.1)	4 (0-13)	4 (0-13)	4 (0-9)	4 (0-9)
F3	0.5	**3.0**	**0**	5.9	**5.2 (4.8-5.5)**	13 (0-39)	13 (0-39)	3 (0-7)	3 (0-7)
M1	52.7	**68.5**	**0**	4.4	4.8 (3.2-6.4)	53 (48-57)	53 (48-57)	3 (3-3)	12 (0-25)
M2	0.5	**87.5**	**0**	5.6	**5.1 (4.9-5.2)**	31 (0-91)	31 (0-91)	2 (0-6)	2 (0-6)

2.5 Discussion

Our study shows that disturbed peatlands are dynamic ecosystems where vegetation communities can experience substantial changes in less than three decades. For instance, we found noteworthy species turnover. Yet, contrary to our expectations, non-peatland and exotic species richness did not increase at the cost of typical peatland species, as their proportions remained fairly similar. There was however not much room to increase, since non-peatland and exotic species already represented more than 60% of peatland richness in 1984-85. Our study also showed that most species whose mean cover or frequency increased over time were typical peatland species (e.g., *Sphagnum*, *Vaccinium*), whereas most of the species with a lower mean cover or frequency today were non-peatland species (e.g., *Chamerion angustifolium*). Another important change was a noticeable increase in forest cover. Indeed, the percentage of the total peatland area covered by woodlands doubled in 27 years.

Rapid human-induced vegetation changes have recently been documented in several boreal and temperate peatlands in Europe (e.g., Frankl & Schmeidl 2000; Freléchoux et al. 2000; Linderholm & Leine, 2004) and North America (e.g., Pellerin & Lavoie 2003ab; Berg et al. 2009). Human-induced drainage and eutrophication, fire, climate change and natural succession are the main factors usually pinpointed to explain these changes, due to their influence on water and nutrient availability. In the peatlands studied, most forest expansion occurred at site margins, which suggests a gradual drying of the interface between the peatlands and the agricultural landscape, likely due to extensive drainage of the surrounding agricultural fields for maize production. Considering that plants respond rather slowly to drying, this process may even have begun prior to the original sampling. Man-made ditches in the peatlands may also have favored drying, although the main ditch was maybe ineffective due to beaver dams and that density observed was quite low, and much lower than the level usually recommended (>200 m/ha) to spur tree growth in peatlands (Roy et al. 2000). In a recent study, Kapfer et al. (2011) suggested that a mean annual temperature increase of 0.7ºC over a 50-year period may have been sufficient to induce drier surface conditions in a nearly pristine peatland of southern Sweden and favor an increase in the frequency of indicator species for low moisture levels, such as *Betula pubescens*. The mean annual temperature increase in the study area was 1.1 ºC. However, mean precipitation increased over the same time period, thereby likely compensating for the increase in temperature (Feddema et al. 2005). High levels of nitrogen deposition have frequently been suggested to explained vascular plant abundance or biomass increase in peatlands (e.g., Gunnarsson et al. 2002; Kapfer et al. 2011; Hájková et al. 2012), but the results of experimental studies are not straightforward (Bubier et al. 2007; Sheppard et al. 2014). Nitrogen deposition levels have been quite high in the area of the Tea Field peatlands (0.7 g N m^{-2} $year^{-1}$) over the last 30 years, and likely high enough to have facilitated forest development once seedlings established at the margins as well as establishment of non-peatland species.

While drainage and increased nutrient availability are good explanatory factors for the forest expansion at the broad peatland level, they are inconsistent with other changes observed at the finer-scale, notably, increases in *Sphagnum* cover and frequency. We thus postulate that short-term post-fire succession is also an important driver of the changes observed, especially in the ombrotrophic communities. According to Benscoter & Vitt (2008), the post-fire succession trajectory in ombrotrophic peatlands is divided into three stages, progressing from short term (< 10 years) dominance of true mosses such as *Polytrichum strictum*, to persistent dominance of *Sphagnum* mosses (20-80 years) and finally to partial replacement of *Sphagnum* by feathermoss (e.g., *Pleurozium schreberi*). The observed decrease in the cover of *Polytrichum strictum* coupled with the increased cover of *Sphagnum* suggests that the Tea Field peatlands are presently in the second phase of Benscoter & Vitt's (2008) peatland post-fire succession model. In fact, *Polytrichum strictum* is a pioneer species well adapted to growing on bare ground after a fire (Maltby et al. 1990) and known to facilitate the growth of *Sphagnum* mosses (Groeneveld & Rochefort 2005). Following *Sphagnum* establishment, it is, however, generally outcompeted (Li & Vitt 1995). *Sphagnum* expansion in studied peatlands may in turn explain the lower mean pH observed in 2012 in most of the communities as *Sphagnum* as the ability to create acidic conditions (van Breemen 1995). Other indices, such as the increase of *Betula populifolia* cover and the virtual disappearance of *Chamerion angustifolium* (fireweed), also point to significant fire related changes. *Betula populifolia* is a shade-intolerant pioneer well adapted to rapid post-fire regeneration (Flinn & Wein 1987) and favored by drainage, while the cover of *Chamerion angustifolium* usually peaks a few years after a fire, and then declines to pre-fire levels within 20 years (Pavek 1992).

Whatever the underlying causes of the changes observed in the flora of these two peatlands, they are likely to induce profound modifications in ecosystem functioning. Despite the increase in *Sphagnum* cover in the central portion of both sites, the observed plant succession toward a globally more forested system may have created conditions that hamper peat accumulation, notably through the decrease in *Sphagnum* growth that can be expected under forest cover, due to litter accumulation and dry, shady conditions (Eppinga et al. 2009). Such changes could further facilitate tree and shrub growth (Heijmans et al. 2013). In our study, old forests were characterized mostly by non-peatland species, including some of the most invasive species (e.g., *Rhamnus cathartica*, *Lythrum salicaria*) in northeastern America, further indication of the deleterious impact of the tree encroachment process on peatland integrity. The fact that we found a single indicator species associated to new forest indicates that this habitat is transitional, between open habitat and old forests. Episodes of tree growth in peatlands followed by

Sphagnum-dominated periods have been documented frequently in paleoecological studies (e.g., Chambers 1997). Still, these recurrent changes occurred at a time when climate was the main driver of plant succession. Recent modeling studies and field work also suggest that *Sphagnum*-dominated peatlands are resilient to drought events and tree expansion (Gunnarsson & Flodin 2007; Heijmans et al. 2013). However, these studies were conducted on nearly pristine sites and did not take human disturbances other than climate warming into account. In the peatlands reported on here, the human footprint is probably too extensive to allow treed state reversal without direct interventions such as ditch blocking or tree cutting. The integrity of these peatlands, designated conservation sites in 2009, will thus not be preserved without active management. The broader implication is that peatland conservation, mainly bog conservation, in highly modified landscapes cannot be disengaged from restoration.

Chapitre 3: Relative influence of abiotic and anthropogenic factors on vegetation of two peatlands.

3.1 Introduction

The structure and functioning of the world's ecosystems have changed more rapidly in the second half of the twentieth century than at any time in human history (Millenium Ecosystem Assessment 2005). Human induced disturbances lead to important short and long-term changes in ecosystem dynamics, which have prompted ecologists to investigate the relative importance of anthropogenic and natural sources of variation in ecosystem structure and processes (Cushman & Wallin 2002; de Blois et al. 2002; King et al. 2004; Kaniewski 2007). Among others, wetlands are the most threatened habitat worldwide (Millenium Ecosystem Assessment 2005), and their plant dynamics is becoming a central question for insuring the persistence of the wide array of ecosystem services they provide. In particular, peatlands are recognized to be of great importance for contributing to fresh water reserve and regulation of regional hydrologic fluxes (Levison et al. 2013), storing great quantities of atmospheric carbon (Gorham 1991), preserving paleoenvironmental records (Barber 1993) and supporting a specialized flora adapted to harsh prevailing conditions (Charman 2002). These ecosystem services are in direct link with natural variation in peatland plant assemblages and their long-term supply will depend in part on peatland resilience when becoming isolated in humanly modified landscapes.

Floristic variations in peatlands of the northern hemisphere are mainly controlled by three ecological gradients: water table depth (Wheeler & Proctor 2000; Okland et al. 2001; Bragazza et al. 2005), margin-expanse (Malmer 1986; Okland et al. 2001) and acidity-alkalinity (Wheeler & Proctor 2000; Bragazza & Gerdol 2002; Bragazza et al. 2005). The water table depth, controlling the moisture content of peat substrate, affects mainly species segregation along the hummock-hollow microtopography in relation to the ability of *Sphagnum* species to tolerate dessication and to the ability of vascular plant species to tolerate anoxic conditions (Bragazza & Gerdol 1996; Henkin et al. 2011). The margin-expanse gradient is more complex to define since factors underlying vegetation changes along this gradient differ between sites (Wheeler & Proctor 2000; Okland et al. 2001). However, it seems to be mostly related to peat aeration favoring tree growth at the margin, which in turn reduces radiation and increases litterfall (Okland et al. 2001; Bragazza et al. 2005). The margins are also often richer than the expanse because they receive mineral enriched water from the uplands and are closer to the mineral soil (Damman and Dowhan 1981; Ingram 1967). The alkalinity-acidity gradient is related to a decrease in pH and conductivity values as well as to phosphorus, ammonium and calcium concentrations in water from fen to bogs (Andersen et al. 2011a). Along this gradient, vegetation shifts from communities dominated by brown mosses and sedges in fens to communities dominated by *Sphagnum* mosses and ericaceous shrubs in bogs (Wheeler & Proctor 2000; Okland et al. 2001). Finally, secondary gradients such as peat thickness or shading may also be important, especially for bryophytes (Jeglum & He 1995; Whitehouse & Bayley 2005).

Currently, some studies have shown that anthropogenic disturbances acting at different temporal and spatial scale could overcome these natural gradients and drive part of peatland floristic patterns and dynamics (e.g., Freléchoux et al. 2000; Pellerin & Lavoie 2003a; Tousignant et al. 2010). Drainage is the main anthropogenic disturbance occurring in peatlands. Although drainage may have imperceptible short-term effect on plant communities, it can have tremendous effects on the long-term vegetation of the peatland (Laine et al. 1995). By increasing peat substrate' aeration, peat physicochemical properties are altered (increase of oxygen diffusion), which will accelerate its decomposition rate and thus reduce carbon sequestration (Gorham 1991; Tuittila et al. 1999; Silins & Rothwell 1999; Andersen et al. 2010). Also, water table drawdown following drainage can modify species distribution, favoring shrub and tree encroachment (e.g., Linderholm & Leine 2004; Kapfer et al. 2011; Berg et al. 2009). Other studies have also shown that climate warming (Weltzin et al. 2000; Breeuwer et al. 2009) and nitrogen input from atmospheric pollution (Berendse et al. 2001; Gunnarsson et al. 2004) may have adverse impacts on peatland vegetation, mostly on *Sphagnum* species (Gunnarsson et al. 2002; Heijmans et al. 2002; Wiedermann et al. 2007). For example, in two nitrogen deposition experiments in Swedish peatlands, the total biomass production of *Sphagnum* species decreased significantly after a 10 $g.m^{-2}.yr^{-1}$ N supply (Gunnarson & Rydin 2000). The above factors will play in synergy and vegetation is unlikely to remain stable with further increase of anthropogenic activities.

To tease apart the relative impact of abiotic, anthropogenic and spatial factors on vegetation distribution, multivariate analyses are very useful (e.g., Lachance & Lavoie 2004; Pellerin et al. 2009; Tousignant et al. 2010). On the other hand, to determine the ecological value of natural habitats, diversity indices are effective additional tools (Magurran 2004). Species composition is an important aspect of biodiversity (Debinski & Humphrey 1997) but compositional changes along environmental gradients are complex and may vary from one region to another depending on the range of site variability considered and the diversity indices used (Keddy & Fraser 1999). In Duck Mountain peatlands, Canada, Locky & Bayley (2006) found that high alpha diversity (species richness) was related to high habitat heterogeneity and moderate environmental variables (pH and alkalinity), whereas low alpha diversity was associated to environmental extremes. Likewise, in North American peatlands, gamma diversity (landscape species diversity) of fens (with high habitat heterogeneity) was higher than that of bogs (with low habitat heterogeneity) (Bedford et al. 1999). However, Vitt & Chee (1990) observed that moderate-rich fens in Alberta had greater species diversity than extreme-rich fens, contrary to Vitt et al. (1995). Beta diversity (compositional change) of vascular plants has also been shown to be higher than that of bryophytes (Locky & Balyey 2006), but studies including both groups of plant remain scarce. Anthropogenic disturbance such as drainage can increase species diversity globally at a site, notably through increase of forest and ruderal species (Vasander et al. 1997; Lachance & Lavoie 2004). On the contrary, nutrient loading, due to eutrophication, resulted in reductions in species diversity of both vascular plants and bryophytes, especially in an area adjacent to a farm field (Drexler & Bedford 2002). Diversity indices should thus be partitioned for meaningful groups of plants in order to estimate the changes in ecological value of a site after disturbances. In some regions of the world, peatlands are becoming very isolated in humanly modified landscapes and their vegetation may be greatly impacted. Studies combining multivariate analysis with diversity indices for both vascular and bryophyte layers remain scarce, but largely needed to predict the faith of peatlands in such context. Our specific objectives were 1) to analyse the relationship between species diversity and disturbances in two peatlands isolated in an agricultural landscape and 2) to determine the importance of environmental drivers on vegetation, more specifically the exclusive and combined contribution of abiotic conditions, anthropogenic disturbances and spatial variation on plant species assemblages.

3.2 Methods

3.2.1 Study area and sites

The Small and the Large Tea Field peatlands, spaced approximately by 3 km, are located in southwestern Quebec (Canada) and cover respectively an area of 640 ha and 475 ha (Figure 1). Both sites rest on rich marine clay deposits of the Champlain Sea, at an altitude of 50 m above sea level. Study sites are located in the bioclimatic domain of sugar maple grove with bitternut hickory (Grandtner 1966; Saucier et al. 2009), the warmest region of the province. The mean annual temperature (1965-2013) at the nearest meteorological station (10 km), is about 6 °C, with an average of -7.3 °C for January (coldest month) and of 22.6 °C for July (warmest month). The mean annual precipitation is 990 mm, 16 % of which falls as snow (Environment Canada 2013). The two study peatlands are isolated in an agricultural landscape occupied mainly by maize and dairy farms as well as intensive garden markets on organic soils.

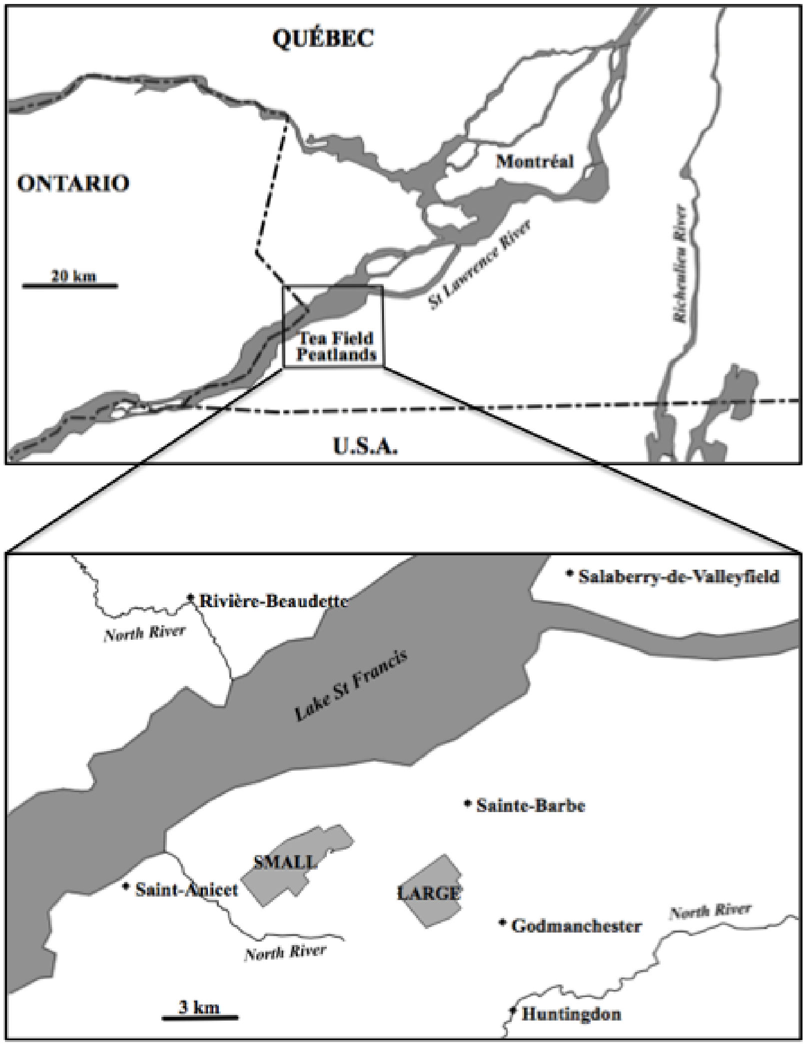


Figure 1. Location of the Tea Field peatlands, southern Quebec, Canada. The Small Tea Field currently covers 640 ha and the Large Tea Field covers 475 ha.

Since the beginning of European settlement in the region (early 19th century), about 70% of the original area of the two peatlands has been lost, mainly to agriculture. In 1863, the two peatlands were still connected and occupied an area of about 5075 ha (Jean & Bouchard 1987).

Fifty years later (1912), they were disconnected and covered a total area of about 3828 ha (Anrep 1917). In 1984, the total area of the two peatlands was estimated at 1600 ha (Jean & Bouchard 1987). In 2012, it was 1115 ha, which represents a further loss of 485 ha. Since 2009, 820 ha have been set apart as conservation preserve by Nature Conservancy-Québec.

Although the Tea Field peatlands area has declined meaningfully since the colonization, few human activities have directly affected the remaining portion of the peatlands. Some tree cutting is occurring at the margins of the peatlands and a large all-terrain vehicle track is intersecting the Large Tea Field. Man-made drainage ditches are also running through the peatlands' area especially in the southern part of the Large Tea Field and in the central section of the Small Tea Field (Figure 2). The main ditch in the latter is however intersected by seven beaver dams, and is thus likely to be ineffective. Finally, a human ignited fire occurred in 1983 and affected most of the area of both peatlands, except the margins of the Large Tea Field and the northeastern section of the Small Tea Field.

3.2.2. Sampling and data collection

Vegetation

From June 4 to August 7, 2012, vegetation was sampled within 102 plots (5 x 5 m) located every 200 m along north-south transects spaced by 500 m. A total of 55 plots were sampled in the Small Tea Field and 47 plots in the Large Tea field. The percent coverage of each plant species in each plot was estimated using seven classes: (1) <1%, (2) 1-5%, (3) 6-10%, (4) 11-25%, (5) 26-50%, (6) 51-75%, (7) >75%. The total percent coverage of each vegetation layer (canopy tree > 10 m, lower tree 5-10 m, high shrub 2.5-5 m, lower shrub < 2.5 m, herb, moss, litter and bare peat) was then visually estimated by the projection of their horizontal coverage on the

5 x 5 m plots, except for tree cover that was estimated in a ~200 m^2 circular plot. Finally, tree basal area was calculated using the number of stems selected with a 2-factor prism.

Abiotic variables and spatial components

At each sampling plot, the peat deposit thickness was measured manually using metal probes inserted in the peat profile. Water table depth was measured in May 2013 and was estimated relative to the peat surface from a manually excavated hole at each plot after the level has stabilized. The water pH and conductivity were then measured in the field using a portable pH-conductivity meter (Hanna Instruments). Conductivity values were adjusted to 25 °C and corrected for the concentration of hydrogen ions (Sjors 1950). To take into account the spatial structure of the vegetation data and on the explicative variables, a spatial matrix was generated with the geographical coordinates (X, Y) of each sampling plot.

Anthropogenic disturbances

Four measurements were used to calculate a disturbance index inspired from the Anthropogenic Activity Index proposed by Ervin et al. (2006). This index is a rapid assessment method that assigns a score of human disturbance severity to each plot from selected metrics (Table 1). In our case, the sum of each of the four metric scores provided a composite disturbance score ranging from 0 (least disturbed) to 12 (most disturbed).

Table 1. Description of the four metrics used to calculate the disturbance index for each sampling plot. The sum of each metric score provides a composite site disturbance score ranging from 0 to 12.

	Scores
Metric 1. Hydrological alteration (distance to the closest drainage ditch)	
Ditch located at more than 100 m from the sampling plot	0
Ditch located at 51 to 100 m from the sampling plot	1
Ditch located at 21 to 50 m from the sampling plot	2
Ditch located at less than 20 m from the sampling plot	3
Metric 2. Drainage ditch density (100 m buffer around the plot)	
No drainage density in the buffer	0
Drainage density between 0 and 40 m/ha	1
Drainage density between 41 and 80 m/ha	2
Drainage density superior to 81 m/ha	3
Metric 3. Landscape disturbance (500 m buffer around the plot)	
100 % of peatland area	0
75 % and more of peatland area	1
Less than 75 % of peatland area + 15 % and more of forest area	2
Less than 75 % of peatland area + 15 % and more of agricultural area	3
Metric 4. Local disturbance (100 m buffer around the plot)	
No disturbance in the buffer	0
Between 1 and 10 % of the buffer is disturbed	1
Between 11 and 50 % of the buffer is disturbed	2
51 % and more of the buffer is disturbed	3
Disturbance index	12

Anthropogenic disturbance variables were identified using 1:15 000 aerial photographs (2009) and Google earth's DigitalGlobe satellite imagery (2004, 2010) and digitized in Quantum GIS 1.7.4 software (Quantum GIS Development Team, 2011). The perimeters of disturbed surfaces (agricultural fields, wood cutting areas, roads, all-terrain vehicle trail, housing) and drainage ditches located inside or bordering the peatlands were firstly digitized for both peatlands. The percentage of disturbed surfaces within a radius of 100 and 500 m from each sampling plot was then calculated and considered as local and landscape disturbances, respectively (Table 1). Drainage ditch density (m/ha) within a radius of 100 m from each sampling plot was also calculated as well as the distance to the closest drainage ditch.

3.2.3 Data analysis

Both peatlands were analyzed separately. Vegetation matrix was not transformed because the data are expressed in species abundance class (Braun-Blanquet), which already amounts to a logarithmic transformation (Legendre & Legendre 2012).

Prior to analyses, rare species (found in less than four plots and sum of percent cover across all plots <10%) were removed from the database. All remaining species were classified with regard to growth form (tree, shrub, forb or bryophyte). As well, vascular species were sorted into three mutually exclusive groups (1) native peatland species, (2) native non-peatland species, and (3) exotic species (Appendix 2). Species habitat preference follows Dubé et al. (2011) as well as an unpublished database including inventory data of 7280 sampling plots in peatlands of Québec (S. Pellerin, unpublished data). Species origin status follows Lavoie et al. (2012).

Diversity and species richness

The local contribution of beta diversity (LCBD) was calculated for each plot to estimate the degree of specificity of plots in terms of community composition (Legendre & De Caceres 2013).

A multiple regression analysis was then conducted to determine the factors influencing the LCBD. Co-linearity between explanatory variables (Table 2) was previously tested (VIF coefficients ranged between 1.1 and 3.7 for the Small Tea Field and between 1.9 and 3.8 for the Large). Spearman's correlation was also used to evaluate the relationship between beta diversity and species richness, and more precisely to designate group of species with a high degree of uniqueness of sampling plots. These analyses were performed with beta.div.R function and stats package in version 2.15.1 of the R language (R Core Team 2012). "Distance to the closest edge" variable was log-transformed because it did not follow a normal distribution.

Plant species assemblage and relative influence of variables on species composition

We first identified plant species assemblages using a time-constrained clustering with the Ward's method (Legendre & Legendre 2012). The cross validation criterion was used to determine the number of groups.

We also explored the influence of environmental factors on plant species assemblage with redundancy analysis (RDA), where axes were constrained by abiotic, anthropogenic disturbance and spatial variables. Co-linearity between explanatory variables (Table 2) was previously tested (VIF coefficients ranged between 1.2 and 3.6 for the Small Tea Field and between 1.7 and 3.9 for the Large). The significance of the model was assessed using a permutation test with 999 randomized runs. The resulting graph has been fitted with a frame type 2 in order to preserve the correlation between descriptors (Legendre & Legendre 2012). In addition, a variance partitioning was performed to discriminate between the relative influence of abiotic, anthropogenic disturbance and spatial variables (Borcard et al. 1992). The significance of the adjusted bimultivariate redundancy statistic (R^2_a; Peres-Neto et al. 2006) was tested using permutation analysis with 999 randomized runs (Legendre & Legendre 2012). These analyses were performed using const.clust and vegan packages of the R language (R Core Team 2012).

Table 2. Environmental variables sampled in the 102 sampling plots and their abbreviation.

Variables	Abbreviations
Anthropogenic variables	
Disturbance index (0-12) see Table 1	Disturbance_Index
Distance to the edge (m)	Dist_Edge
Local contribution of beta diversity	LCBD
Abiotic variables	
Tree basal area (m^2/ha)	Basal_Area
Peat thickness (cm)	Peat
Water table level (cm)	Water_Level
Water pH	W_pH
Water corrected conductivity (µS/cm^2)	W_Conductivity
Coordinates	
Latitude	X
Longitude	Y

3.3 Results

Mean water pH was low in both peatlands indicating ombrotrophic conditions (Table 3), although minerotrophic areas with pH above 6 were found at the margins of the sites. Mean water corrected conductivity was high in both peatlands (Table 3) and indicated minerotrophic conditions, but means were influenced by extreme values from marginal plots as about 50% of the plots in both peatlands had a conductivity level associated to bog conditions (< 80 µS/cm^2; Andersen et al. 2011a). Water level ranged between 0 to about -95 cm in both sites with averages between -25 and -35 for both peatlands (Table 3). The peat deposit was on average thicker in the Large than in the Small Tea Field (Table 3). The mean percentage of disturbed surfaces within a radius of 100 m varied from 0 to 33% in the Small and from 0 to 52% in the Large Tea Field (Table 3). Finally, the mean drainage ditch density within a radius of 100 m remained low in both peatlands (below 10 m/ha), with highest values reaching 64 m/ha and 100 m/ha in the Small and Large Tea Field respectively (Table 3).

Table 3. Mean of some explanatory variables in the Small and Large Tea Field peatlands. Values in parentheses indicate: the standard deviation; the minimum value - the maximum value.

	Small Tea Field	Large Tea Field
Disturbance index	3.1 (0.4; 0-10)	3.6 (0.4; 0-11)
Local disturbance (%)	5 (1; 0-33)	7 (2; 0-52)
Drainage ditch density (m/ha)	10 (3; 0-64)	25 (5; 0-100)
Peat thickness (cm)	218 (13; 14-519)	325 (15; 10-493)
Water table level (cm)	25 (2.5; 0-95)	35 (3; 0-98)
Water pH	4.6 (0.1; 3.4-6.3)	4.3 (0.1; 3.6-6.5)
Water corrected conductivity ($\mu S/cm^2$)	104 (17; 0-492)	108 (16; 7-566)

A total of 224 taxa (173 vascular and 51 non vascular) were recorded in the 102 sampling plots. Among these species, 63 were considered native peatland species, 77 native non-peatland species and 17 exotic species. The number of species was higher in the Small (184 species in 55 plots) than in the Large (148 species in 47 plots) Tea Field, especially for forb species (97 vs. 76) and native non-peatland species (66 vs. 47) (Table 4; Appendix 2). However, the mean number of species per plot was fairly the same in each peatland (18.5 species per plot in the Small and 16.5 in the Large). Overall, *Betula populifolia*, *Aronia melanocarpa*, *Rhododendron canadense* and *Vaccinium* spp. were the vascular species with the highest frequency (found in more than 50% of plots) whereas *Polytrichum strictum* and *Sphagnum capillifolium* were the most frequent non-vascular species (found in more than 45% of plots; Appendix 2).

Table 4. Number of species sampled in Tea Field peatlands and more precisely in the Small and Large Tea Field peatlands.

	Tea Field	Small Tea Field	Large Tea Field
Number of species	224	184	148
Number of trees	19	15	12
Number of shrubs	32	29	26
Number of forbs	122	97	76
Number of bryophytes	51	43	34
Number of native peatland species	63	52	48
Number of native non-peatland species	77	66	47
Number of exotic species	17	13	11

3.3.1 Beta diversity patterns and drivers

Abiotic and anthropogenic disturbance factors together explained 31% and 18% of the variation in beta diversity in the Small and the Large Tea Field, respectively (Table 5). Plots contributing most to the beta diversity were mainly located at the margins of the peatlands, especially in the Small Tea Field (Figure 2). The degree of uniqueness of sampling plots (LCBD) was significantly higher in plots with high water pH (Table 5). For both peatlands, degree of uniqueness of sampling plots was globally related to high species richness (Table 6). This was especially true when considering only herb richness. On the contrary, the degree of uniqueness of sampling plots was higher for areas poor in bryophyte species (Table 6). Both native non-peatland and exotic species played a significant role in beta diversity, contributing to increase the degree of uniqueness of sampling plots (Table 6).

Table 5. Multiple regression analysis between the local contribution of beta diversity and explanatory variables in the two study peatlands. (‘***’ p<0,001 ; ‘**’ p<0,01 ; ‘*’ p<0,05 ; ‘.’ p<0,1).

Explanatory variables	Estimate	Standard error	t value	P value
Small Tea Field: adjusted R^2=0.31 (p-value=0.0008)				
(Intercept)	9.86e-03	7.47e-03	1.32	0.193
Distance to the closest edge	-1.68e-03	1.04e-03	-1.62	0.113
Disturbance index	-3.83e-04	3.27e-04	-1.17	0.248
Tree basal area	-5.42e-05	1.09e-04	-0.50	0.620
Peat thickness	5.76e-06	9.50e-06	0.61	0.548
Water table level	-1.68e-05	4.01e-05	-0.42	0.677
Water pH	3.78e-03	1.15e-03	3.30	0.002 **
Water corrected conductivity	8.06e-06	8.91e-06	0.90	0.370
Large Tea Field: adjusted R^2=0.18 (p-value=0.038)				
(Intercept)	6.18e-03	2.07e-02	0.30	0.767
Distance to the closest edge	-1.50e-03	1.81e-03	-0.83	0.413
Disturbance index	1.66e-04	4.77e-04	0.35	0.730
Tree basal area	-4.55e-05	2.48e-04	-0.18	0.856
Peat thickness	-4.57e-06	1.90e-05	-0.24	0.811
Water table level	-1.16e-04	7.68e-05	-1.51	0.138
Water pH	6.67e-03	3.36e-03	1.98	0.054 .
Water corrected conductivity	2.45e-06	1.69e-05	0.14	0.885

Table 6. Spearman correlation between LCBD and richness of different groups of plant species at the Small and Large Tea Field peatlands. (‘***’ p<0,001 ; ‘**’ p<0,01 ; ‘*’ p<0,05).

	LCBD	
	Small Tea Field	Large Tea Field
Richness		
Total species	0.320^{*}	0.434^{**}
Trees	0.281^{*}	0.139
Shrubs	-0.263	0.253
Forbs	0.696^{***}	0.563^{***}
Bryophytes	-0.604^{***}	-0.337^{*}
Native peatland species	-0.491^{***}	0.121
Native non-peatland species	0.581^{***}	0.227^{*}
Exotic species	0.524^{***}	0.330^{*}

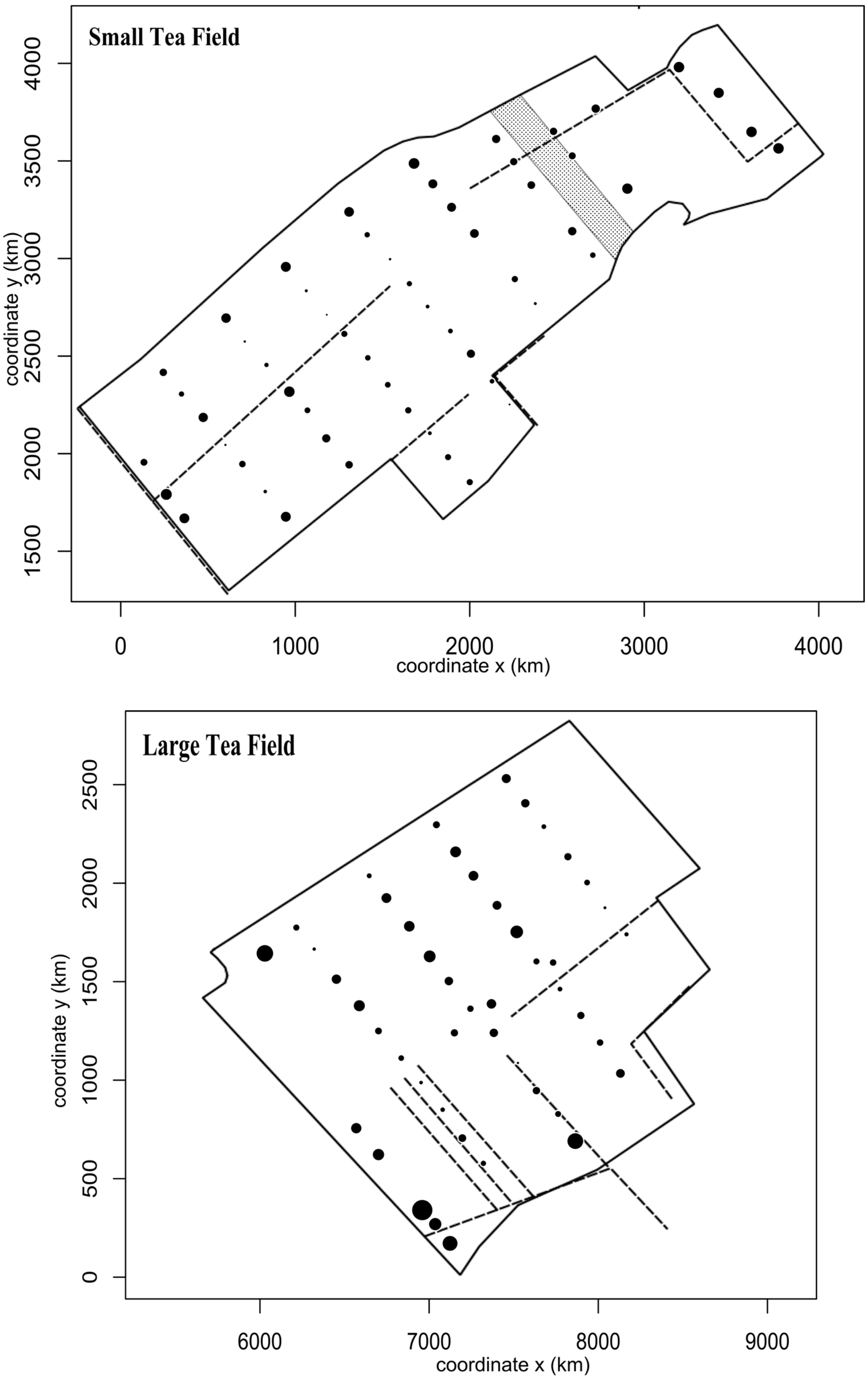


Figure 2. Map showing the local contribution of beta diversity for each sampling plot in the Tea Field peatlands. Dotted lines represent drainage ditch.

3.3.2 Plant species assemblage

Three plant species assemblages were recognized in the Small Tea Field, one typical of ombrotrophic peatland and two of minerotrophic conditions (Figure 3a). Overall, the RDA (Figure 4a) shows that minerotrophic and forest species (e.g., *Populus tremuloides*, *Alnus incana* subsp. *rugosa*, *Onoclea sensibilis*, *Impatiens capensis*) were mainly found at the margin of the peatland whereas ombrotrophic species (e.g., *Vaccinium corymbosum*, *Rhododendron canadense*, *Kalmia angustifolia*, *Polytrichum strictum*, *Sphagnum capillifolium* and *S. rubellum*) were mostly associated to peatland centre. Trees and shrubs (e.g., *Populus tremuloides*, *Alnus incana* subsp. *rugosa*, *Rubus idaeus*) were also mostly found at the margins where disturbances mostly occur (Figure 4a). The most widespread assemblage was the *Betula populifolia* and *Vaccinium* spp. bog that was located mainly at the center of the peatland (Figure 3a). This community was associated to thick peat deposit, low disturbance index and low water pH and corrected conductivity (Figure 4a). In this community, 85% of species were native peatland species (Table 7) with the following most abundant ones: *Aronia melanocarpa*, *Vaccinium* spp., *Rhododendron canadense*, *Kalmia angustifolia*, *Sphagnum capillifolium* and *S. rubellum*. The two fen communities, *Phragmites australis* and *Impatiens capensis* fen and, *Populus tremuloides* and *Rubus idaeus* fen, were well segregated in western and eastern portions of the peatland (Figure 3a). Both locations were characterized by a high disturbance index and high water pH and corrected conductivity, but the *Populus tremuloides* and *Rubus idaeus* community was characterized by more dense forests (higher tree basal area) and drier conditions (Figure 4a). They shared similar amount of native peatland species and native non-peatland species, but the *Phragmatis australis* and *Impatiens capensis* community had higher proportion of exotic species (Table 7).

Five plant species assemblages were recognized in the Large Tea Field, three ombrotrophic and two minerotrophic (Figure 3b). Patterns of vegetation in the Large Tea Field were similar to those in the Small Tea Field, minerotrophic species and forest species (e.g., *Betula populifolia*, *Acer rubrum*, *Aronia melanocarpa*, *Maianthemum canadense*, *Pteridium aquilinum*) being mostly associated to margins whereas ombrotrophic species (e.g., *Vaccinium angustifolium*, *Chamaedaphne calyculata*, *Eriophorum vaginatum* subsp. *spissum*, *Kalmia angustifolia*, *Polytrichum strictum*, *Sphagnum capillifolium* and *S. rubellum*) were mostly found at the centre (Figure 4b). Tree and shrub species (e.g., *Betula populifolia*, *Acer rubrum*, *Aronia melanocarpa*, *Alnus incana* subsp. *rugosa*, *Spiraea latifolia*) were also associated to high level of disturbances (Figure 4b). The three ombrotrophic communities shared similar amount of native peatland species (between 98 and 100%) (Table 7). The first assemblage, *Chamaedaphne calyculata* and *Vaccinium angustifolium* bog and the second assemblage, *Ilex mucronata* and *Kalmia angustifolia* bog were both found in the centre of the peatland (Figure 3b). These two communities were associated to thick peat deposit, but a higher disturbance index was found in the *Ilex mucronata* and *Kalmia angustifolia* bog (Figure 4b). Abundant species of these two communities included *Chamaedaphne calyculata*, *Eriophorum vaginatum* subsp. *spissum*, *Vaccinium angustifolium*, *Kalmia angustifolia*, *Ilex mucronata*, *Sphagnum rubellum* and *S. capillifolium*. The third ombrotrophic assemblage was a *Betula populifolia* and *Vaccinium corymbosum* bog and had lower water level than the two previous one (Figure 4b). The *Betula populifolia* and *Rubus hispidus* fen was located in the southwestern margins of the peatland (Figure 3b) and was associated to high water pH and corrected conductivity, high tree basal area, high disturbance index and thin peat deposit (Figure 4b). The *Betula populifolia* and *Aronia melanocarpa* fen, located at the northestern margins of the peatland (Figure 3b) was associated to a deep water level (Figure 4b). The two minerotrophic communities had different amount of native peatland species (61 and 78% for the *Betula populifolia* and *Rubus hispidus* fen and the *Betula populifolia* and *Aronia melanocarpa* fen respectively), native non-peatland species (32 and 20%) and exotic species (7 and 2%) (Table 7). Whereas the main species associated to the first minerotrophic assemblage were *Acer rubrum*, *Alnus incana* subsp. *rugosa*, *Rubus hispidus* and *Onoclea sensibilis*, species associated to the second assemblage were *Aronia melanocarpa*, *Spiraea latifolia* and *Pteridium aquilinum*.

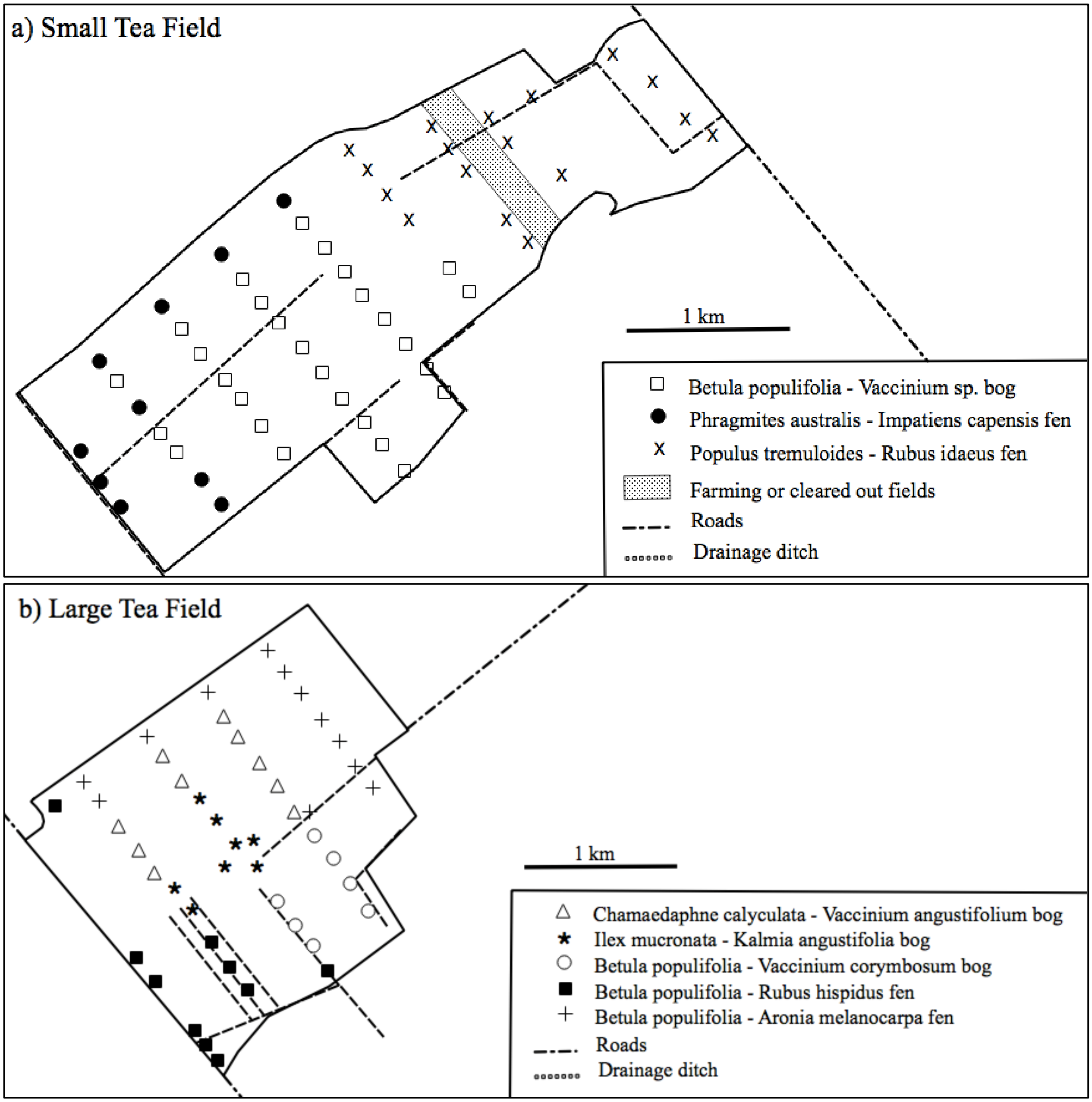
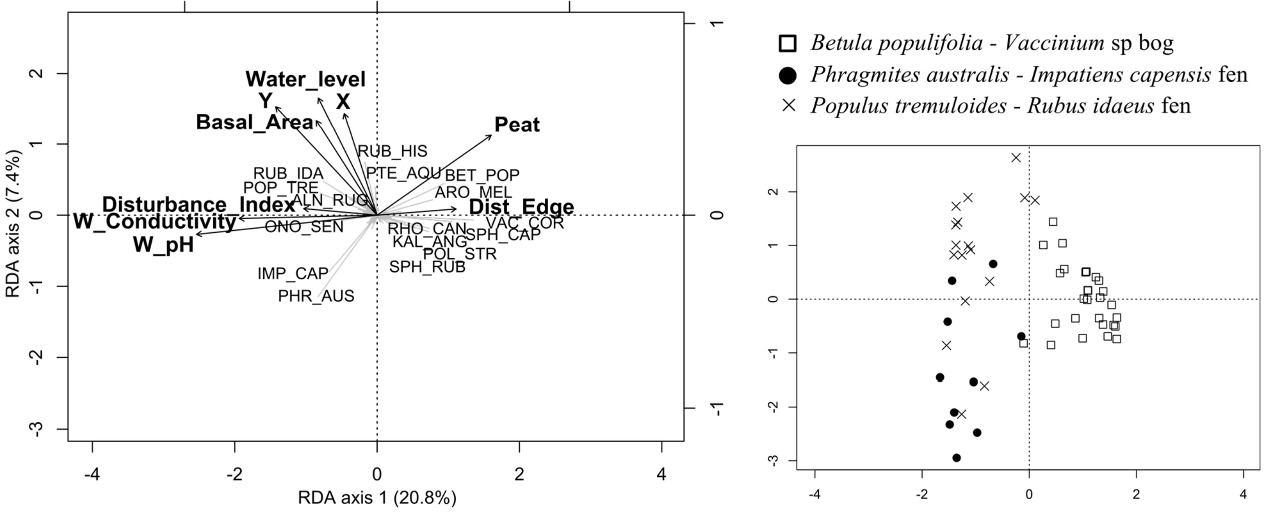


Figure 3. Spatial distribution of the plant species assemblage with time-constrained clustering according to Ward method in Tea Field peatlands.

a) Small Tea Field



b) Large Tea Field

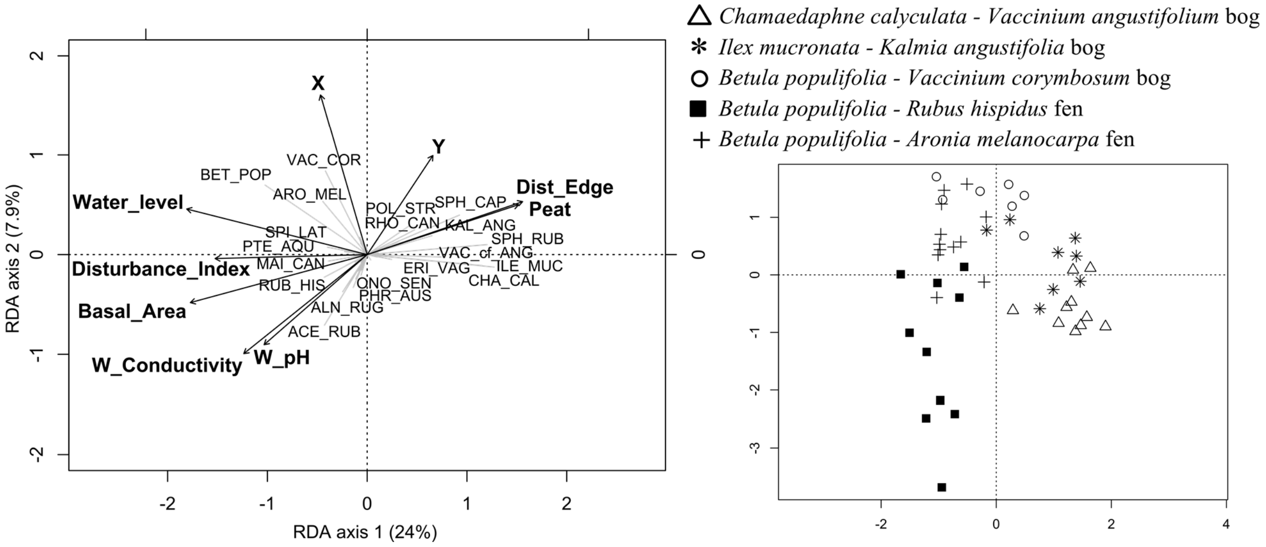


Figure 4. Canonical redundancy analysis biplot examining the strength of association among environmental variables, the plant species assemblages and the species in Tea Field peatlands. Species acronyms are based on the first three letters of genus and species name (full names of species are provided in Appendix 2).

Table 7. Mean percent of native peatland, native non-peatland and exotic species for each plant species assemblage.

	Native peatland species	Native non-peatland species	Exotic species
Small Tea Field			
Betula populifolia and *Vaccinium* spp. bog (28 plots)	85	11	4
Phragmites australis and *Impatiens capensis* fen (10 plots)	39	45	16
Populus tremuloides and *Rubus idaeus* fen (17 plots)	42	48	10
Large Tea Field			
Chamaedaphne calyculata and *Vaccinium angustifolium* bog (10 plots)	100	0	0
Ilex mucronata and *Kalmia angustifolia* bog (8 plots)	99	1	0
Betula populifolia and *Vaccinium corymbosum* bog (7 plots)	98	2	0
Betula populifolia and *Rubus hispidus* fen (10 plots)	61	32	7
Betula populifolia and *Aronia melanocarpa* fen (12 plots)	78	20	2

3.3.3 Species composition and relative influence of abiotic, anthropogenic and spatial factors

Abiotic, anthropogenic and spatial factors together explained 29.1% and 30.4% of the variation in the vegetation composition in Small and Large peatlands respectively (Figure 5). In the Small Tea Field (Figure 5a), abiotic factors explained on its own 13.6% of the variation, against 1.9% for anthropic disturbances and 3.6% for space. Abiotic and spatial factors shared 8.4% of the variation. In the Large Tea Field (Figure 5b), abiotic factors explained on its own 5.2% of the variation, against 2.2% for anthropogenic disturbances and 5.1% for space. While abiotic and spatial factors shared 1.5% of the variation, abiotic and anthropogenic disturbance shared 15.4% of the variation in the vegetation composition.

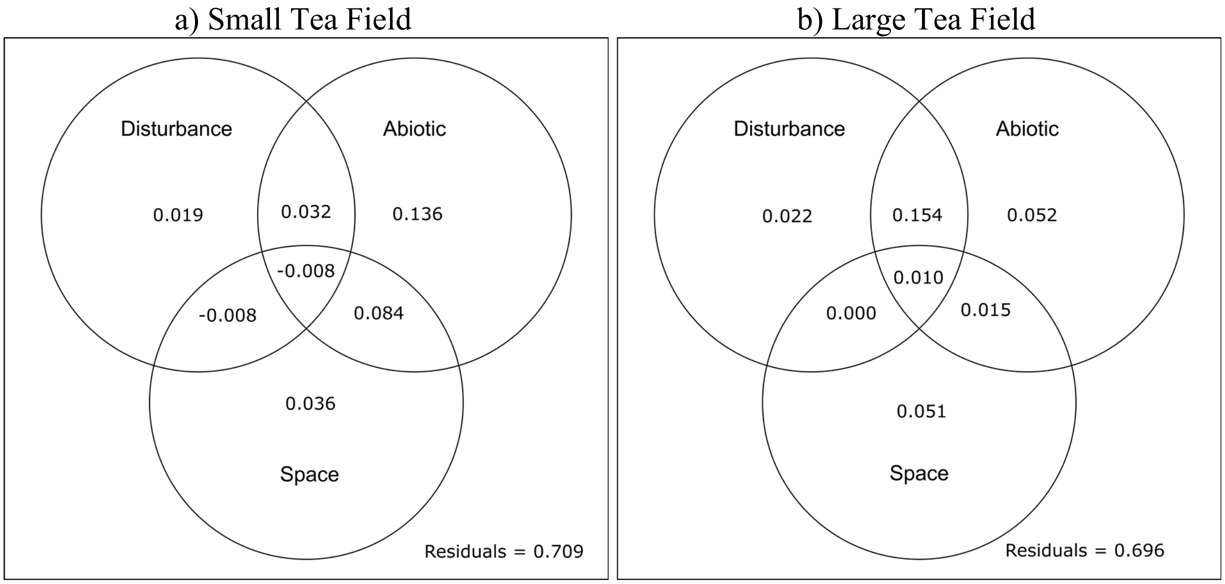


Figure 5. Venn diagrams showing the partition of the total variation explained by abiotic, anthropogenic disturbance and spatial variables in the vegetation composition of Tea Field peatlands.

3.4 Discussion

The main pattern of floristic composition found in the studied peatlands was associated with abiotic variables, and mostly water pH and corrected conductivity as well as water table depth, in conformity with the literature on both pristine and disturbed peatlands (e.g., Bragazza & Gerdol 2002; Sjörs & Gunnarsson 2002; Sottocornola et al. 2009; Tousignant et al. 2010; Sekulová et al. 2013). This acidity-alkalinity gradient was however spatially structured as indicated by the high proportion of variation share between abiotic and space variables. This spatial structure corresponds to the margin-expanse gradient with minerotrophic conditions found at the margins of the sites and ombrotrophic conditions associated to the centre (Sjors 1950; Damman & Dowhan 1981; Malmer 1986; Asada et al. 2003; Pellerin et al. 2009). Previous study also found that vegetation of both bogs was spatially structured in 1984 (Jean & Bouchard 1987). Moreover, the main pattern of floristic composition of Tea Field peatlands was at this time associated to trophic regime (peat pH, phosphorus and nitrogen levels) and moisture regime (organic content, peat deposit thickness, peat decomposition rate) (Jean & Bouchard 1987). Nevertheless, our study shows that human disturbances were also an important driver of the floristic patterns observed. For instance, results of RDA indicate that shrub and tree species as well as native non-peatland and exotic species were mostly found in disturbed sites. In the Large Tea Field, human disturbances even reach 18.6% of the variation in the floristic patterns, although most of the variation was spatially structured along the margin-expanse gradient, disturbances being higher in the margins than in the centre. On one hand, this could mean that margins have attributes favorable to human activities, such as thin organic deposits facilitating displacements or trees tall enough for wood-cutting practices. On the other hand, it could indicate that anthropogenic disturbances modified the abiotic conditions. For example, it has been shown that drainage alters the water chemistry of peatlands (Åström et al. 2001; Westman & Laiho 2003), accelerates decomposition and oxidation of the organic deposit (Van Seters & Price 2002) and changes the rate of nutrient mineralization (Holden et al. 2004). A deeper water-table level was indeed found along edges of both peatlands and the large range of values (between 0 and 1m) from the center to margins could easily be attributable to anthropogenic activities. Similarly, Jean and Bouchard (1987) showed that disturbances (including 1983's fire and artificial drainage) could also explain the floristic patterns. However, residuals of our multivariate analyses are high, indicating that most of the floristic pattern were related to non-measured variables such as biotic factors (competition, facilitation) or processes linked to species propagation.

Plant diversity in the studied peatlands followed the same patterns than floristic composition. Abiotic conditions, especially water pH, explained most of the variation in species richness in the Tea Field peatlands. In fact, diversity and unicity of species composition was higher at the margins, caracterized by minerotrophic conditions and high water pH. Locky & Bayley (2006) found that bryophyte and vascular plant richness was positively correlated with water pH. More precisely, plants diversity seemed favored by pH values between 5 and 7 (Vitt et al. 1995; Anderson & Davis 1997). Also, diversity of both groups increased with presence of a wooded overstory (Anderson & Davis 1997). The observed plant diversity pattern was likely influenced by disturbances as well since beta diversity was positively related to the richness of native non-peatland and exotic species, which are known to respond to anthropogenic disturbances. Indeed, these species are known to establish in peatlands after drainage (Lachance & Lavoie 2004; Tousignant et al. 2010), which in the Tea Field peatlands was found to be intense at the margins where water table level was as deep as about one meter. Prévost et al (1997) found that the greatest effect of drainage on water table level was to increase the frequency of lowering below the 30 cm depth by 40% compared to the pre-drainage period. The lowering of the water table level promotes the establishment of forest cover (Frankl & Schmeidl 2000; Freléchoux et *al*. 2000), which causes the gradual substitution of peatland species by non-peatland species in the invading forest (Vasander et al. 1997). Otherwise, bryophyte and especially *Sphagnum* mosses are extremely dependent on water regime (Clymo & Hayward 1982). The negative association found between floristic diversity and the richness of bryophyte species further indicates the impact of human activities on the Tea Field peatlands.

Overall, a join action of abiotic conditions and disturbances explained the main pattern of floristic composition and diversity in the Tea Field peatlands. The changes in vegetation observed in the Tea Field peatlands may have future pronounced impact on the functioning of the ecosystem. Indeed, the increase in tree and shrub cover at the margins of the peatlands will accelerate *Sphagnum* impoverishment already observed, due to litter accumulation and increased in shade intensity. This will have positive feedback on peat accumulation and carbon sequestration rates, which will accelerate at the margins. These changes may extend further towards the center as drainage from surroundings accentuate. Although most of the peatlands' area has been acquired for conservation, human activities and especially agriculture around the two peatlands will continue to strongly influence vegetation patterns. In humanly modified landscapes, it thus appears that peatland conservation can not be disentangled from restoration action, such as blocking of drainage ditches or tree cutting.

Chapitre 4 : Conclusion générale

Mon étude avait pour objectifs de comprendre la dynamique temporelle et les patrons floristiques actuelles de deux tourbières isolées dans un paysage agricole et d'identifier les facteurs anthropiques, environnementaux et spatiaux sous-jacents à cette dynamique ou organisation. Pour cette étude, j'ai utilisé les tourbières Small et Large Tea Field présentes dans la trame agricole des basses-terres du Saint-Laurent, dans le sud-ouest du Québec. Depuis la colonisation du territoire par les européens (début du $19^{\text{ième}}$ siècle) une grande portion de ses tourbières a été transformée en terre agricole de sorte qu'actuellement elles ne couvrent plus que 30% de leur superficie d'origine. Elles ont aussi été fréquemment brulées, le dernier feu remontant à 1983, ce qui aurait réduit l'épaisseur de leurs dépôts organiques. Enfin, elles sont actuellement localement perturbées par diverses activités humaines, notamment le drainage et la coupe forestière.

La première partie de mon mémoire de maîtrise portait sur la dynamique floristique temporelle de ces deux tourbières. Mon étude a montré que les tourbières isolées en paysage agricole sont des écosystèmes dynamiques dont la composition floristique peut se modifier de façon importante en trois décennies. Cette dynamique floristique est particulièrement rapide, puisque les tourbières sont généralement des écosystèmes stables dont les changements floristiques se produisent sur une échelle de temps beaucoup plus longue. En effet, selon des processus naturels, de faibles changements de végétation se produisent en plusieurs décennies (Backéus 1972), ou encore pendant plusieurs siècles, voire des millénaires (Svensson 1988; Rydin & Barber 2001). Le principal changement identifié était une augmentation considérable du couvert forestier, notamment en bordure des tourbières, associé à la prolifération d'espèces indigènes non-tourbicoles et exotiques. Ce boisement a fort probablement été favorisé par un assèchement des dépôts lié au drainage des terres agricoles environnantes et par le réchauffement climatique récent observé dans la région. Le haut niveau de dépôt atmosphérique d'azote (environ 0.7 g N m^{-2} an^{-1}) présent dans la région pourrait aussi avoir accentué le phénomène. En effet, plusieurs études ont montré que l'apport atmosphérique d'azote était lié à l'augmentation du couvert arborescent dans les tourbières puisque la disponibilité en azote est l'un des principaux facteurs limitant la croissance des arbres (Gunnarsson et al. 2002; Heijmans et al. 2002; Wiedermann et al. 2007). Enfin, certains changements observés telles que l'augmentation du couvert et de la fréquence des sphaignes ou la quasi-disparition de l'épilobe seraient plutôt attribuables à la succession suite à l'incendie de 1983.

Le second volet de mon mémoire a porté sur les patrons actuels de la végétation. Cette étude m'a permis de montrer que la variation floristique actuelle était essentiellement due à deux gradients écologiques: le gradient bordure-centre (lié à l'humidité) et le gradient d'ombrotrophie-minérotrophie (lié aux variables chimiques). En effet, les principales variables responsables de la distribution de la végétation étaient le pH, la conductivité corrigée de l'eau et l'épaisseur des dépôts. Mes analyses ont aussi montré que les conditions minérotrophes étaient surtout présentes en bordure des tourbières et qu'à l'inverse, les conditions ombrotrophes étaient surtout rencontrées au centre des sites. Cette distinction de statut trophique entre les bordures et le centre est à la base du gradient bordure-centre. De plus, ce gradient a été accentué par les perturbations humaines qui ont asséché les bordures des sites et ainsi favorisé les espèces non-tourbicoles et exotiques au détriment des espèces tourbicoles. De même, la diversité béta des tourbières a suivi un patron semblable à la composition floristique. En effet, la diversité béta, expliquée par le pH de l'eau, était corrélée positivement avec la richesse spécifique, notamment celle des espèces non-tourbicoles et exotiques, laissant supposer que les perturbations humaines ont également joué un rôle dans la distribution de cette diversité.

Quelles que soient les causes sous-jacentes de la distribution de la végétation actuelle ou bien des changements floristiques survenus dans les tourbières étudiées, elles sont susceptibles d'induire de profondes modifications dans le fonctionnement de ce type d'écosystème. Par exemple, les tourbières jouent un rôle significatif dans le cycle biogéochimique du carbone à l'échelle planétaire (Moore 2001). Or, le boisement des tourbières et le changement d'espèces associé sont souvent une entrave à l'accumulation de la tourbe. Le taux de séquestration du carbone pourrait alors être réduit ou le taux d'émission de CO_2 augmenté, provoquant ainsi un impact direct sur l'environnement (Moore 2001).

Bien que Conservation de la Nature ait acquis la majeure partie des tourbières Tea Field en 2009, mon étude a montré que cela n'était peut être pas suffisant pour protéger les fonctions écologiques de ces écosystèmes. Acquérir des tourbières dégradées ne fait que freiner la perte de superficie mais a souvent peu d'influence sur l'évolution de leurs communautés végétales. En effet, bien que les tourbières à l'étude aient été conservées, mes résultats montrent que les perturbations anthropiques présentent notamment aux abords des sites continuent d'influencer leurs communautés floristiques. Ainsi, dans l'optique de protéger à long terme les communautés végétales de ces tourbières ainsi que leurs fonctions écologiques, des actions de restauration devraient être envisagées. Par exemple, le blocage des canaux de drainage pourrait être effectué, permettant la remontée et la stabilisation de la nappe phréatique (Holden et al. 2004; Shantz & Price 2006; Worrall et al. 2007; Patterson & Cooper 2007). Cela favoriserait alors la végétation tourbicole au détriment d'espèces non-tourbicoles (Patterson & Cooper 2007), permettant le retour progressif des fonctions écohydrologiques propres aux tourbières (Price & Ketcheson 2009) et leur fonction de puits de carbone (Tuittila et al. 1999). D'autre part, des actions de répression des arbres pourraient être envisagées dans le but de ralentir le boisement des sites. En effet, les arbres contribuent à l'assèchement de la tourbière en interceptant les précipitations. Ils augmentent également la disponibilité des nutriments du sol et réduisent la lumière disponible aux strates inférieures (Ohlson et al 2001). Ces processus peuvent ainsi créer des conditions entravant la production de mousses mais stimulant davantage l'établissement et la croissance des arbres (Rietkerk et al. 2004; Eppinga et al. 2009). Bien que dans les faits, le boisement des tourbières n'est pas une menace en soit puisqu'il s'agit d'un phénomène récurrent dans plusieurs tourbières (Chambers 1997), le boisement observé dans les tourbières Tea Field est fort probablement le fait d'activités humaines qui perdureront dans les prochaines années, ce qui entraverait un retour éventuel à des conditions moins forestières et instaurerait des conditions forestières permanentes. Comme l'objectif de conservation de ces sites est de préserver une flore tourbicole représentative de la région où elles se sont mises en place, des actions d'aménagement ou de restauration devraient être prises pour arrêter le boisement et assurer un maintien des conditions d'origines ou tout au moins ralentir leur changement.

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Annexes

Appendix 1. Plant species found in the Small Tea Field and Large Tea field bogs in 1984 and 2012, southwestern Quebec (Canada). Vascular species are sorted between peatland, native non-peatland and exotic species. For taxa grouped at the genus level, they are sorted according to the species that were found. For instance, because the two species identified in the *Amelanchier* spp. were non-peatland, we classified *Amelanchier* as non-peatland despite that some species of *Amelanchier* are typical peatland species. Additional species used in tree encroachment analyses are indicated in right hand column.

PEATLAND SPECIES (1984-85 = 55 species; 2012 = 56 species)						**Added species: tree encroachment**
Species	**1984**	**2012**	**Species**	**1984**	**2012**	**2012**
Acer rubrum	x	x	*Lycopodium clavatum*	x	x	*Carex brunnrscens*
Ageratina altissima	x	x	*Lycopus uniflorus*	x	x	*Carex canescens* subsp. *disjuncta*
Alnus incana subsp. *rugosa*	x	x	*Lysimachia terrestris*	x		*Carex trisperma*
Aralia nudicaulis	x	x	*Maianthemum canadense*	x	x	*Picea glauca*
Arisaema triphyllum		x	*Maianthemum trifolium*	x	x	*Salix fragilis*
Aronia melanocarpa	x	x	*Monotropa uniflora*		x	*Salix bebbiana*
Athyrium filix-femina	x	x	*Oclemena nemoralis*	x	x	*Salix discolour*
Betula populifolia	x	x	*Onoclea sensibilis*	x	x	*Salix petiolaris*
Calamagrostis canadensis	x	x	*Orthilia secunda*	x		*Salix pyrifolia*
Calopogon tuberosus	x	x	*Osmunda regalis*	x	x	*Vaccinium* cf *angustifolium*
Carex spp.	x	x	*Osmundastrum cinnamomeum*	x	x	*Vaccinium corumbosum*
Chamaedaphne calyculata	x	x	*Picea glauca*		x	*Viola blanda*
Chelone glabra		x	*Pogonia ophioglossoides*	x	x	*Viola macloskeyi*
Cicuta bulbifera	x		*Prunus pensylvanica*	x	x	
Cinna arundinacea		x	*Pyrola elliptica*	x	x	
Cornus stolonifera	x	x	*Ranunculus sceleratus*	x		
Cypripedium acaule	x	x	*Rhododendron canadense*	x	x	
Drosera rotundifolia	x	x	*Rhododendron groenlandicum*	x	x	
Dryopteris carthusiana	x	x	*Ribes triste*	x		
Dryopteris cristata	x	x	*Rubus pubescens*	x	x	
Epilobium ciliatum subsp. *glandulosum*	x		*Salix* spp.	x	x	
Epilobium leptophyllum	x		*Scirpus cyperinus*	x	x	
Eriophorum vaginatum subsp. *spissum*	x	x	*Scutellaria galericulata*		x	
Eriophorum virginicum	x	x	*Solidago uliginosa*	x	x	
Galium palustre	x	x	*Spiraea* cf *latifolia*	x	x	
Gaultheria procumbens		x	*Spiraea tomentosa*	x	x	
Gaylussacia baccata		x	*Thalictrum pubescens*	x	x	
Ilex mucronata	x	x	*Thuja occidentalis*	x		
Ilex verticillata		x	*Trientalis borealis*	x	x	
Impatiens cf *capensis*	x	x	*Vaccinium* spp.	x	x	
Kalmia angustifolia	x	x	*Viburnum nudum* var. *cassinoides*	x	x	
Kalmia polifolia	x	x	*Viola* spp.	x	x	

Appendix 1. Continued

NATIVE NON-PEATLAND SPECIES (1984-85 = 89 species; 2012 = 77 species)						**Added species: tree encroachment**
Species	**2012**	**2012**	**Species**	**1984**	**2012**	**2012**
Achillea millefolium		x	*Eupatorium perfoliatum*	x	x	*Amelanchier humilis*
Agrimonia gryposepala	x		*Euthamia graminifolia*	x	x	*Carex bebbii*
Agrostis gigantea		x	*Eutrochium maculatum*	x	x	*Carex cristatella*
Agrostis scabra	x	x	*Fragaria virginiana*	x	x	*Carex cumulata*
Agrostis stolonifera	x		*Fraxinus* spp.	x	x	*Carex gracillima*
Amelanchier spp.	x	x	*Galium triflorum*	x	x	*Carex granularis*
Anaphalis margaritacea	x		*Geum aleppicum*	x	x	*Carex lacustris*
Anemone virginiana	x	x	*Geum canadense*		x	*Carex lupulina*
Apocynum androsaemifolium	x		*Glyceria striata*		x	*Carex lurida*
Aralia hispida	x		*Hieracium scabrum*	x	x	*Carex pedunculata*
Arctium minus		x	*Hieracium umbellatum*	x		*Carex scoparia*
Artemisia biennis	x		*Hypericum ellipticum*	x		*Carex tribuloides*
Asclepias syriaca	x		*Hypericum fraseri*		x	*Fraxinus americana*
Betula papyrifera	x	x	*Hypericum majus*	x	x	*Fraxinus pennsylvanica*
Bidens tripartita	x		*Hypericum mutilum* subsp. *boreale*		x	*Rubus allegheniensis*
Boehmeria cylindrica	x		*Hypericum virginicum*	x		*Rubus hispidus*
Capnoides sempervirens	x		*Iris versicolor*		x	*Rubus idaeus*
Carya cordiformis	x	x	*Juncus canadensis*	x		*Sisyrinchium montanum*
Celastrus scandens		x	*Lactuca biennis*	x	x	
Chamerion angustifolium	x	x	*Lactuca canadensis*	x	x	
Circaea canadensis	x	x	*Lactuca serriola*		x	
Clematis virginiana	x	x	*Lonicera canadensis*		x	
Cornus alternifolia	x	x	*Lonicera dioica*	x		
Cornus racemosa		x	*Ludwigia palustris*	x		
Cornus rugosa	x		*Lycopodium obscurum*	x	x	
Crataegus spp.	x	x	*Lycopus americanus*	x	x	
Danthonia compressa	x		*Maianthemum racemosum*		x	
Dichanthelium acuminatum	x	x	*Mentha arvensis* subsp. *borealis*		x	
Doellingeria umbellata	x	x	*Moehringia lateriflora*		x	
Dryopteris intermedia		x	*Muhlenbergia frondosa*		x	
Echinocystis lobata		x	*Muhlenbergia mexicana*	x		
Epilobium coloratum	x		*Nuttallanthus canadensis*	x	x	
Epilobium hirsutum	x		*Oenothera biennis*	x		
Equisetum arvense	x	x	*Parthenocissus* spp.	x	x	
Erechtites hieraciifolius	x		*Pilosella* spp.		x	
Erigeron annuus	x		*Poa palustris*	x	x	
Erigeron canadensis	x		*Polygala sanguinea*	x		

Appendix 1. Continued

NATIVE NON-PEATLAND SPECIES						**Added species: tree encroachment**
Species	**2012**	**2012**	**Species**	**1984**	**2012**	**2012**
Populus balsamifera	x	x	*Solidago gigantea*	x	x	
Populus deltoides		x	*Solidago nemoralis*	x		
Populus grandidentata	x		*Solidago rugosa*	x	x	
Populus tremuloides	x	x	*Sphenopholis intermedia*	x	x	
Potentilla norvegica	x		*Stellaria longifolia*	x		
Prunella vulgaris	x	x	*Symphyotrichum cordifolium*		x	
Prunus serotina	x	x	*Symphyotrichum lanceolatum*	x	x	
Prunus virginiana	x	x	*Symphyotrichum lateriflorum*		x	
Pteridium aquilinum	x	x	*Symphyotrichum novae-angliae*	x		
Quercus macrocarpa	x		*Symphyotrichum ontarionis*		x	
Quercus rubra		x	*Symphyotrichum puniceum*	x	x	
Ribes americanum	x	x	*Thelypteris palustris*	x	x	
Ribes oxyacanthoides	x	x	*Tilia americana*	x		
Rorippa palustris	x		*Typha angustifolia*	x		
Rubus spp.	x	x	*Typha latifolia*	x		
Rumex spp.	x	x	*Ulmus americana*	x	x	
Sambucus canadensis	x		*Urtica dioica*	x	x	
Sambucus racemosa subsp. *pubens*	x		*Viburnum lentago*	x	x	
Scirpus atrovirens		x	*Vitis riparia*	x	x	
Solidago altissima	x	x	*Zanthoxylum americanum*		x	
Solidago canadensis	x	x				
EXOTIC SPECIES (1984-85 = 15 species; 2012 = 17 species)						
Acer negundo	x	x	*Pastinaca sativa*		x	
Chenopodium album	x		*Persicaria maculosa*	x	x	
Cirsium arvense	x		*Phalaris arundinacea*		x	
Epipactis helleborine	x	x	*Phragmites australis*	x	x	
Frangula alnus		x	*Pilosella caespitosa*	x		
Galeopsis tetrahit		x	*Pilosella piloselloides*		x	
Gnaphalium uliginosum	x		*Poa compressa*	x	x	
Lapsana communis		x	*Rhamnus cathartica*	x	x	
Leontodon autumnalis	x		*Solanum dulcamara*	x	x	
Lonicera tatarica		x	*Taraxacum officinale*	x		
Lythrum salicaria	x	x	*Verbascum thapsus*	x		
Medicago lupulina		x	*Vicia cracca*		x	

Appendix 1. Concluded

NONVASCULAR SPECIES (1984-85 = 31 species; 2012 = 27 species)						**Added species: tree encroachment**
Species	**1984**	**2012**	**Species**	**1984**	**2012**	**2012**
Amblystegium serpens		x	*Marchantia polymorpha*	x		*Brachythecium campestre*
Amblystegium varium	x	x	*Mylia anomala*		x	*Brachythecium erythrorrhizon*
Aulacomnium palustre	x	x	*Physcomitrium pyriforme*	x		*Brachythecium laetum*
Brachythecium spp.	x	x	*Plagiomnium cuspidatum*	x	x	*Brachythecium oedipodium*
Bryum spp.	x		*Plagiomnium medium*	x		*Brachythecium rutabulum*
Callicladium haldanianum	x	x	*Plagiothecium denticulatum*	x		*Brachythecium salebrosum*
Calliergon cordifolium	x		*Plagiothecium laetum*		x	*Brachythecium velutinum*
Campylium stellatum	x	x	*Pleurozium schreberi*	x	x	*Dicranum flagellare*
Ceratodon purpureus	x		*Pohlia nutans*	x	x	*Dicranum polysetum*
Cladina mitis		x	*Polytrichum commune*	x	x	*Dicranum scoparium*
Cladina rangiferina	x	x	*Polytrichum juniperinum*	x		*Dicranum undulatum*
Cladonia cristatella	x	x	*Polytrichum strictum*	x	x	*Fissidens adianthoides*
Cladonia multiformis	x		*Ptilium crista-castrensis*		x	*Fissidens dubius*
Climacium dendroides		x	*Sphagnum* spp.	x	x	*Rosylabryum capillare*
Dicranum spp.	x	x	*Thuidium delicatulum*		x	*Sphagnum angustifolium*
Drepanocladus aduncus	x		*Thuidium recognitum*	x		*Sphagnum capillifolium*
Drepanocladus exannulatus	x		*Tomenthypnum nitens*	x		*Sphagnum centrale*
Eurhynchium pulchellum		x				*Sphagnum compactum*
Helodium blandowii	x					*Sphagnum fallax*
Hypnum cupressiforme		x				*Sphagnum fimbriatum*
Hypnum lindbergii		x				*Sphagnum girgensohnii*
Hypnum pallescens		x				*Sphagnum megellanicum*
Hypnum pratense		x				*Sphagnum palustre*
Leptobryum pyriforme	x					*Sphagnum papillosum*
Leptodictyum humile	x					*Sphagnum quinquefarium*
Lichen spp.		x				*Sphagnum rubellum*
Lophocolea heterophylla	x					*Sphagnum russowii*

Appendix 2. Code, name, number of sampling plots and classification of species sampled in Tea Field peatlands in 2012, southwestern Québec (Canada). All exotic species are non-peatland species.

Code	**Name**	**Number of sampling plots**		**Classification**
		Large Tea Field	**Small Tea Field**	
	TREES			
ACE NEG	*Acer negundo*	2	3	exotic
ACE RUB	*Acer rubrum*	10	22	native peatland
BET PAP	*Betula papyrifera*	1		native non-peatland
BET POP	*Betula populifolia*	44	40	native peatland
CAR COR	*Carya cordiformis*	1	2	native non-peatland
FRA AME	*Fraxinus americana*		2	native non-peatland
FRA PEN	*Fraxinus pennsylvanica*	3	8	native non-peatland
PIC GLA	*Picea glauca*		1	native peatland
POP BAL	*Populus balsamifera*		3	native non-peatland
POP DEL	*Populus deltoides*	1	1	native non-peatland
POP TRE	*Populus tremuloides*	9	27	native non-peatland
QUE RUB	*Quercus rubra*		1	native non-peatland
SAL SP	*Salix*	1		native peatland
SAL FRA	*Salix fragilis*		1	native peatland
SAL BEB	*Salix bebbiana*	1		native peatland
SAL DIS	*Salix discolor*	2		native peatland
SAL PET	*Salix petiolaris*	1	3	native peatland
SAL PYR	*Salix pyrifolia*		1	native peatland
ULM AME	*Ulmus americana*		4	native non-peatland
	SHRUBS			
ALN RUG	*Alnus incana* subsp. *rugosa*	3	18	native peatland
AME HUM	*Amelanchier humilis*	2		native non-peatland
ARO MEL	*Aronia melanocarpa*	44	34	native peatland
CHA CAL	*Chamaedaphne calyculata*	19	5	native peatland
COR ALT	*Cornus alternifolia*		2	native non-peatland
COR RAC	*Cornus racemosa*		3	native non-peatland
COR STO	*Cornus stolonifera*	2	12	native peatland
CRA SP	*Crataegus*		2	native non-peatland
FRA ALN	*Frangula alnus*		1	exotic
GAY BAC	*Gaylussacia baccata*	11	1	native peatland
ILE MUC	*Ilex mucronata*	19	7	native peatland
ILE VER	*Ilex verticillata*	3	2	native peatland
KAL ANG	*Kalmia angustifolia*	28	19	native peatland
KAL POP	*Kalmia polifolia*	3		native peatland
PRU PEN	*Prunus pensylvanica*	1	1	native peatland
PRU SER	*Prunus serotina*	2	5	native non-peatland
PRU VIR	*Prunus virginiana*	3	2	native non-peatland
RHA CAT	*Rhamnus cathartica*	3	12	exotic
RHO CAN	*Rhododendron canadense*	33	21	native peatland
RHO GRO	*Rhododendron groenlandicum*	5		native peatland
RIB AME	*Ribes americanum*		2	native non-peatland
RIB OXY	*Ribes oxyacanthoides*	1	1	native non-peatland
RUB ALL	*Rubus allegheniensis*	3	5	native non-peatland
RUB HIS	*Rubus hispidus*	12	15	native non-peatland
RUB IDA	*Rubus idaeus*	6	22	native non-peatland
SPI LAT	*Spiraea latifolia*	19	26	native peatland
SPI TOM	*Spiraea tomentosa*	3	6	native peatland

Appendix 2. Continued

Code	**Name**	**Number of sampling plots**		**Classification**
		Large Tea Field	**Small Tea Field**	
	SHRUBS			
VAC ANG	*Vaccinium angustifolium*	32	25	native peatland
VAC COR	*Vaccinium corymbosum*	24	27	native peatland
VIB LEN	*Viburnum lentago*		6	native non-peatland
VIB NUD	*Viburnum nudum* var. *cassinoides*	6	3	native peatland
ZAN AME	*Zanthoxylum americanum*	1	1	native non-peatland
	FORBS			
AGE ALT	*Ageratina altissima*	1		native peatland
AGR GIG	*Agrostis gigantea*		1	native non-peatland
AGR SCA	*Agrostis scabra*	1	2	native non-peatland
ARA NUD	*Aralia nudicaulis*	1	2	native peatland
ARI TRI	*Arisaema triphyllum*		2	native peatland
ATH FIL	*Athyrium filix-femina*	1	2	native peatland
CAL CAN	*Calamagrostis canadensis*	1	6	native peatland
CAL TUB	*Calopogon tuberosus*	3	3	native peatland
CAR BEB	*Carex bebbii*	1		native non-peatland
CAR BRU	*Carex brunnescens*		1	native peatland
CAR CAN	*Carex canescens* subsp. *Disjuncta*		1	native peatland
CAR CRI	*Carex cristatella*		1	native non-peatland
CAR CUM	*Carex cumulata*	1	1	native non-peatland
CAR GRAC	*Carex gracillima*	1	1	native non-peatland
CAR GRAN	*Carex granularis*	1		native non-peatland
CAR LAC	*Carex lacustris*		2	native non-peatland
CAR LUP	*Carex lupulina*		1	native non-peatland
CAR LUR	*Carex lurida*	1		native non-peatland
CAR PED	*Carex pedunculata*	1		native non-peatland
CAR SCO	*Carex scoparia*		1	native non-peatland
CAR TRI	*Carex trisperma*	7		native peatland
CAR TRIB	*Carex tribuloides*		1	native non-peatland
CAR SP	*Carex*		2	
CEL SCA	*Celastrus scandens*	1	2	native non-peatland
CHA ANG	*Chamerion angustifolium*	1		native non-peatland
CHE GLA	*Chelone glabra*		1	native peatland
CIN ARU	*Cinna arundinacea*		1	native peatland
CIR CAN	*Circaea canadensis*		5	native non-peatland
CLE VIR	*Clematis virginiana*	4	18	native non-peatland
CYP ACA	*Cypripedium acaule*	4		native peatland
DIC ACU	*Dichanthelium acuminatum*	2	1	native non-peatland
DOE UMB	*Doellingeria umbellata*	6	5	native non-peatland
DRO ROT	*Drosera rotundifolia*		2	native peatland
DRY CAR	*Dryopteris carthusiana*		18	native peatland
DRY CRI	*Dryopteris cristata*	2		native peatland
DRY INT	*Dryopteris intermedia*	2	6	native non-peatland
ECH LOB	*Echinocystis lobata*		2	native non-peatland
EPI HEL	*Epipactis helleborine*		2	exotic
EQU ARV	*Equisetum arvense*	2	2	native non-peatland
ERI VAG	*Eriophorum vaginatum* subsp. *Spissum*	21	5	native peatland
ERI VIR	*Eriophorum virginicum*	1	4	native peatland
EUP PER	*Eupatorium perfoliatum*	1	1	native non-peatland
EUT GRA	*Euthamia graminifolia*	3	3	native non-peatland

Appendix 2. Continued

Code	**Name**	**Number of sampling plots**		**Classification**
		Large Tea Field	**Small Tea Field**	
	FORBS			
EUT MAC	*Eutrochium maculatum*	2	1	native non-peatland
FRA VIR	*Fragaria virginiana*	1	5	native non-peatland
GAL PAL	*Galium palustre*		4	native peatland
GAL TET	*Galeopsis tetrahit*		1	exotic
GAL TRI	*Galium triflorum*	1	8	native non-peatland
GAU PRO	*Gaultheria procumbens*	1		native peatland
GEU ALE	*Geum aleppicum*		1	native non-peatland
GEU CAN	*Geum canadense*		5	native non-peatland
GLY STR	*Glyceria striata*	1	3	native non-peatland
HIE SCA	*Hieracium scabrum*	3		native non-peatland
HYP FRA	*Hypericum fraseri*		2	native non-peatland
HYP MAJ	*Hypericum majus*		1	native non-peatland
HYP MUT	*Hypericum mutilum* subsp. *Boreale*		1	native non-peatland
IMP CAP	*Impatiens capensis*	1	15	native peatland
IRI VER	*Iris versicolor*	1		native non-peatland
LAC BIE	*Lactuca biennis*		1	native non-peatland
LAC CAN	*Lactuca canadensis*	1		native non-peatland
LAC SER	*Lactuca serriola*	1		native non-peatland
LAP COM	*Lapsana communis*	1	2	exotic
LON CAN	*Lonicera canadensis*		1	native non-peatland
LON TAT	*Lonicera tatarica*	1	3	exotic
LYC AME	*Lycopus americanus*	2	1	native non-peatland
LYC UNI	*Lycopus uniflorus*	2	5	native peatland
LYC OBS	*Lycopodium obscurum*	1		native non-peatland
LYC CLA	*Lycopodium clavatum*	1		native peatland
LYT SAL	*Lythrum salicaria*	3	7	exotic
MAI CAN	*Maianthemum canadense*	5	15	native peatland
MAI RAC	*Maianthemum canadense*		1	native peatland
MAI TRI	*Maianthemum trifolium*	2	1	native peatland
MED LUP	*Medicago lupulina*	1		exotic
MEN ARV	*Mentha arvensis* subsp. *borealis*		1	native non-peatland
MOE LAT	*Moehringia lateriflora*	2	1	native non-peatland
MON UNI	*Monotropa uniflora*		1	native peatland
NUT CAN	*Nuttallanthus canadensis*		1	native non-peatland
MUH FRO	*Muhlenbergia frondosa*	1		native non-peatland
OCL NEM	*Oclemena nemoralis*		10	native peatland
ONO SEN	*Onoclea sensibilis*	3	19	native peatland
OSM REG	*Osmunda regalis*	1	2	native peatland
OSM CIN	*Osmundastrum cinnamomeum*	4	3	native peatland
PAR INS	*Parthenocissus inserta*	3	16	native non-peatland
PAS SAT	*Pastinaca sativa*	1		exotic
PER MAC	*Persicaria maculosa*		1	exotic
PHA ARU	*Phalaris arundinacea*	1	3	exotic
PHR AUS	*Phragmites australis*	3	23	exotic
PIL SP	*Pilosella*	2		native non-peatland
PIL PIL	*Pilosella piloselloides*		2	exotic
POA COM	*Poa compressa*	1		exotic
POA PAL	*Poa palustris*		1	native non-peatland
POG OPH	*Pogonia ophioglossoides*		1	native peatland

Appendix 2. Continued

Code	Name	Number of sampling plots		Classification
		Large Tea Field	Small Tea Field	
	FORBS			
PRU VUL	*Prunella vulgaris*		1	native non-peatland
PTE AQU	*Pteridium aquilinum*	9	10	native non-peatland
PYR ELL	*Pyrola elliptica*	2	6	native peatland
RUB PUB	*Rubus pubescens*	6	9	native peatland
RUM ACE	*Rumex acetosella*	2	2	native non-peatland
RUM SP	*Rumex*		1	native non-peatland
SCI ATR	*Scirpus atrovirens*		1	native non-peatland
SCI CYP	*Scirpus cyperinus*	1	2	native peatland
SCU GAL	*Scutellaria galericulata*	1	1	native peatland
SIS MON	*Sisyrinchium montanum*	1		native non-peatland
SOL ALT	*Solidago altissima*		1	native non-peatland
SOL CAN	*Solidago canadensis*	3	3	native non-peatland
SOL DUL	*Solanum dulcamara*		6	exotic
SOL GIG	*Solidago gigantea*	2	16	native non-peatland
SOL RUG	*Solidago rugosa*	6	10	native non-peatland
SOL ULI	*Solidago uliginosa*		1	native peatland
SPH INT	*Sphenopholis intermedia*		1	native non-peatland
SYM COR	*Symphyotrichum cordifolium*	1		native non-peatland
SYM LAN	*Symphyotrichum lanceolatum*	3	3	native non-peatland
SYM LAT	*Symphyotrichum lateriflorum*		1	native non-peatland
SYM ONT	*Symphyotrichum ontarionis*		3	native non-peatland
SYM PUN	*Symphyotrichum puniceum*	1	1	native non-peatland
THE PAL	*Thelypteris palustris*	2	4	native non-peatland
THA PUB	*Thalictrum pubescens*	3	1	native peatland
TRI BOR	*Trientalis borealis*	1	3	native peatland
URT DIO	*Urtica dioica*		7	native non-peatland
VIC CRA	*Vicia cracca*	1		exotic
VIO BLA	*Viola blanda*	2		native peatland
VIO MAC	*Viola macloskeyi*		1	native peatland
VIT RIP	*Vitis riparia*	3	12	native non-peatland
	BRYOPHYTES			
AUL PAL	*Aulacomnium palustre*	22	15	native peatland
AMB SER	*Amblystegium serpens*		1	native peatland
AMB VAR	*Amblystegium varium*		1	native non-peatland
BRA CAM	*Brachythecium campestre*		3	native peatland
BRA ERY	*Brachythecium erythrorrhizon*	1	3	native non-peatland
BRA LAE	*Brachythecium laetum*		1	native non-peatland
BRA OED	*Brachythecium oedipodium*		2	native peatland
BRA RUT	*Brachythecium rutabulum*	3	7	native non-peatland
BRA SAL	*Brachythecium salebrosum*	2	12	native non-peatland
BRA VEL	*Brachythecium velutinum*		3	native non-peatland
CAL HAL	*Callicladium haldanianum*	3	8	native peatland
CAM STE	*Campylium stellatum*	2	1	native peatland
CLA MIT	*Cladina mitis*		2	native peatland
CLA RAN	*Cladina rangiferina*	8	10	native peatland
CLA CRI	*Cladonia cristatella*	6	5	native peatland
CLI DEN	*Climacium dendroides*		1	native peatland
DIC FLA	*Dicranum flagellare*	1	1	native peatland
DIC POL	*Dicranum polysetum*	5	9	native peatland

Appendix 2. Concluded

Code	**Name**	**Number of sampling plots**		**Classification**
		Large Tea Field	**Small Tea Field**	
	BRYOPHYTES			
DIC SCO	*Dicranum scoparium*	2	2	native peatland
DIC UND	*Dicranum undulatum*	2	2	native peatland
EUR PUL	*Eurhynchium pulchellum*		1	native non-peatland
FIS ADI	*Fissidens adianthoides*	1		native peatland
FIS DUB	*Fissidens dubius*	1		native peatland
HYP CUP	*Hypnum cupressiforme*		5	native non-peatland
HYP LIN	*Hypnum lindbergii*	1		native peatland
HYP PAL	*Hypnum pallescens*	1	2	native non-peatland
HYP PRA	*Hypnum pratense*		1	native peatland
MYL ANO	*Mylia anomala*	1		native peatland
PLA CUS	*Plagiomnium cuspidatum*	2	4	native non-peatland
PLA LAE	*Plagiothecium laetum*		1	native non-peatland
PLE SCH	*Pleurozium schreberi*	16	15	native peatland
POH NUT	*Pohlia nutans*	4	1	native peatland
POL COM	*Polytrichum commune*	17	15	native peatland
POL STR	*Polytrichum strictum*	32	22	native peatland
PTI CRI	*Ptilium crista-castrensis*	1		native peatland
ROS CAP	*Rosulabryum capillare*	1		native non-peatland
SPH ANG	*Sphagnum angustifolium*	2		native peatland
SPH CAP	*Sphagnum capillifolium*	28	19	native peatland
SPH CEN	*Sphagnum centrale*	5	4	native peatland
SPH COM	*Sphagnum compactum*		4	native peatland
SPH FAL	*Sphagnum fallax*	4	1	native peatland
SPH FIM	*Sphagnum fimbriatum*	2	1	native peatland
SPH GIR	*Sphagnum girgensohnii*		4	native peatland
SPH MAG	*Sphagnum magellanicum*	10	4	native peatland
SH PAL	*Sphagnum palustre*		1	native peatland
SPH PAP	*Sphagnum papillosum*	11	7	native peatland
SPH QUI	*Sphagnum quinquefarium*	1		native peatland
SPH RUB	*Sphagnum rubellum*	21	8	native peatland
SPH RUS	*Sphagnum russowii*		5	native peatland
THU DEL	*Thuidium delicatulum*		2	native non-peatland
LICHEN SP	*Lichen*	18	12	

Annexe 3. Coordonnées géographiques des 102 parcelles échantillonnées dans les tourbières Small et Large Tea Field. Indice S: Small Tea Field; L: Large Tea Field.

Parcelles	Longitude	Latitude	Parcelles	Longitude	Latitude	Parcelles	Longitude	Latitude	Parcelles	Longitude	Latitude
S1	-74.30743	45.13187	S28	-74.28148	45.13075	S55	-74.26165	45.15270	L43	-74.21186	45.12933
S2	-74.30565	45.13006	S29	-74.29109	45.14599	S56	-74.25904	45.15050	L44	-74.21168	45.12778
S3	-74.30421	45.12871	S30	-74.28965	45.14470	S57	-74.25689	45.14957	L45	-74.20986	45.12617
S5	-74.30589	45.13694	S31	-74.28783	45.14332	L18	-74.22208	45.12268	L46	-74.20846	45.12469
S6	-74.30444	45.13572	S32	-74.28629	45.14194	L19	-74.22040	45.12127	L47	-74.20682	45.12344
S7	-74.30271	45.13440	S33	-74.28484	45.14065	L20	-74.21709	45.11830	L48	-74.20552	45.12199
S8	-74.30094	45.13285	S34	-74.28302	45.13927	L21	-74.21611	45.11755	L49	-74.21602	45.13891
S9	-74.29959	45.13177	S35	-74.28139	45.13799	L22	-74.21499	45.11652	L50	-74.21457	45.13746
S10	-74.29777	45.13022	S36	-74.27971	45.13644	L23	-74.22899	45.13203	L51	-74.21322	45.13618
S11	-74.29613	45.12880	S37	-74.27831	45.13513	L24	-74.22661	45.13341	L52	-74.21144	45.13460
S12	-74.30089	45.14000	S38	-74.28592	45.14872	L25	-74.22526	45.13226	L53	-74.20995	45.13318
S13	-74.29940	45.13868	S39	-74.28442	45.14757	L26	-74.22358	45.13065	L54	-74.20846	45.13160
S14	-74.29767	45.13736	S40	-74.28293	45.14625	L27	-74.22185	45.12923	L55	-74.20720	45.13154
S15	-74.29585	45.13585	S41	-74.28111	45.14477	L28	-74.22040	45.12788	L56	-74.20668	45.13012
S16	-74.29441	45.13480	S42	-74.27789	45.14220	L29	-74.21868	45.12643	L57	-74.20510	45.12871
S17	-74.29291	45.13322	S43	-74.27626	45.14082	L30	-74.21718	45.12512	L58	-74.20365	45.12726
S18	-74.29109	45.13173	S45	-74.27938	45.15010	L31	-74.21555	45.12367	L59	-74.20211	45.12561
S19	-74.29613	45.14289	S46	-74.27798	45.14882	L32	-74.21406	45.12215	L60	-74.21074	45.14138
S20	-74.29450	45.14154	S47	-74.27658	45.14750	L33	-74.21247	45.12080	L61	-74.20930	45.14006
S21	-74.29287	45.14019	S48	-74.27332	45.14490	L36	-74.21466	45.12778	L62	-74.20790	45.13881
S22	-74.29147	45.13911	S49	-74.27168	45.14355	L37	-74.22110	45.13618	L63	-74.20608	45.13720
S23	-74.28960	45.13776	S50	-74.27481	45.15053	L38	-74.21980	45.13499	L64	-74.20463	45.13582
S24	-74.28801	45.13624	S51	-74.27332	45.14915	L39	-74.21807	45.13348	L65	-74.20328	45.13447
S25	-74.28638	45.13480	S52	-74.26893	45.14730	L40	-74.21653	45.13187	L66	-74.20165	45.13305
S26	-74.28466	45.13351	S53	-74.27145	45.15181	L41	-74.21508	45.13055			
S27	-74.28321	45.13216	S54	-74.26482	45.15415	L42	-74.21345	45.12907			

Annexe 4. Caractéristiques physico-chimiques des 102 parcelles échantillonnées dans les tourbières Small et Large Tea Field. Indice S: Small Tea Field; L: Large Tea Field. Dist_bord: distance à la bordure (m); Ind_pert: Indice global de perturbation; Surf_ter: surface terrière (m^2/ha); Epais_tourbe: épaisseur de tourbe (cm); Nappe_phré: Profondeur de la nappe phréatique (cm); pH_eau: pH de l'eau; Cond_eau: conductivité corrigée de l'eau (us/cm).

Parcelles	Dist_bord	Ind_pert	Surf_ter	Epais_tourbe	Nappe_phré	pH_eau	Cond_eau
S1	75	7	8	102	22	4.92	115
S2	60	9	2	108	74	4.77	387
S3	54	8	0	40	4	5.75	281
S5	150	4	0	75	15	5.48	260
S6	320	2	8	185	46	5.91	164
S7	530	1	14	147	23	5.26	121
S8	560	5	6	234	24	4.04	31
S9	550	0	16	246	9	3.94	22
S10	320	1	16	167	11	4.62	44
S11	120	2	7	119	29	4.58	92
S12	140	3	12	248	41	4.84	91
S13	340	1	13	225	14	4.1	57
S14	540	0	0	277	16	4.32	118
S15	720	4	0	197	0	4.52	24
S16	550	0	0	405	15	3.69	2
S17	340	1	0	238	4	3.8	2
S18	124	3	4	226	10	3.73	6
S19	150	3	12	122	29	5.37	128
S20	360	1	13	286	22	4.39	79
S21	550	0	2	227	21	3.84	108
S22	715	5	8	310	0	5.2	46
S23	640	0	0	221	6	3.59	0
S24	450	0	4	345	13	3.46	0
S25	320	1	0	308	7	3.55	0
S26	275	6	6	357	20	3.54	0
S27	275	2	3	189	21	3.53	0
S28	60	3	0	220	32	3.94	37
S29	160	3	4	81	0	5.84	111
S30	345	1	3	313	41	3.82	43
S31	560	0	5	218	51	4.06	29
S32	750	0	13	181	21	4.19	48
S33	580	0	8	304	33	3.55	0
S34	370	1	18	320	21	3.56	0
S35	170	1	0	519	9	3.35	0
S36	13	10	1	313	27	3.43	0
S37	18	9	4	190	19	3.67	0

Annexe 4. Suite

Parcelles	Dist_bord	Ind_pert	Surf_ter	Epais_tourbe	Nappe_phré	pH_eau	Cond_eau
S38	120	3	11	231	55	4.66	93
S39	280	1	13	220	25	4.62	115
S40	470	0	4	283	24	5.57	81
S41	670	0	9	139	0	5.77	121
S42	360	1	20	34	0	3.91	12
S43	160	3	14	303	34	3.68	0
S45	120	5	14	248	44	4.91	110
S46	280	10	15	298	19	5.28	82
S47	480	3	10	277	33	4.28	60
S48	370	5	17	267	45	3.97	44
S49	170	4	21	127	24	5.5	129
S50	280	9	7	91	29	5.78	474
S51	460	3	8	240	95	5.9	120
S52	200	3	10	212	36	5.92	182
S53	145	8	0	74	25	5.71	362
S54	80	3	28	14	12	5.63	492
S55	170	3	6	320	26	5.85	140
S56	190	3	8	237	36	5.9	176
S57	130	6	8	122	43	6.28	489
L18	54	7	25	352	36	3.75	70
L19	50	5	14	326	40	4.34	77
L20	45	6	11	217	31	5.31	258
L21	45	8	19	119	84	4.43	331
L22	40	5	14	94	29	5.36	265
L23	100	3	17	10	39	6.45	566
L24	80	3	8	275	57	4.43	89
L25	250	1	17	455	21	4.22	167
L26	460	0	0	452	18	3.89	43
L27	540	0	0	400	13	3.92	47
L28	520	0	0	408	8	3.73	51
L29	520	3	0	452	0	4.04	72
L30	520	7	5	493	47	4	50
L31	520	8	3	384	43	4	59
L32	500	8	0	439	44	4.28	189
L33	210	8	4	290	38	3.97	88
L36	875	7	5	402	16	3.84	41
L37	80	2	13	365	31	3.68	7
L38	240	1	0	417	0	3.82	84
L39	460	0	0	394	10	4.16	66
L40	680	0	0	411	12	3.86	56

Annexe 4. Fin

Parcelles	Dist_bord	Ind_pert	Surf_ter	Epais_tourbe	Nappe_phré	pH_eau	Cond_eau
L41	870	0	0	386	28	3.58	29
L42	1020	2	0	387	32	3.86	83
L43	1120	5	0	366	28	3.72	19
L44	950	4	0	414	24	3.68	52
L45	720	7	3	345	30	3.8	58
L46	520	7	17	360	64	4.09	49
L47	330	7	10	311	84	4.70	89
L48	130	11	15	220	98	5.53	145
L49	70	3	0	313	63	5.4	78
L50	260	1	0	358	23	4.22	52
L51	440	0	0	408	19	4.34	78
L52	670	0	0	386	13	4.27	62
L53	710	0	0	410	12	3.93	43
L54	550	4	0	294	27	4.25	61
L55	450	6	11	301	26	3.89	51
L56	430	0	1	353	19	4.15	72
L57	260	1	3	306	12	3.84	57
L58	125	6	14	258	39	3.85	39
L59	130	6	0	227	52	4.28	44
L60	80	3	4	323	64	4.8	88
L61	270	1	6	180	42	4.48	440
L62	410	1	6	227	53	4.63	89
L63	415	1	7	259	46	3.87	83
L64	260	1	9	272	30	4.49	222
L65	140	6	9	244	38	4.75	254
L66	110	3	14	224	39	4.25	64

Annexe 5. Classes d'abondances des espèces échantillonnées dans les 102 parcelles des tourbières Small et Large Tea Field. Les espèces rares ne sont pas présentées ici. + : >1%; 2 : 6-10%; 3 : 11-25%; 4 : 26-50%; 5 : 51-75%; 6 : 76-100%. Les noms complets des espèces sont présents dans l'annexe 2. Indice S : Small Tea Field; L : Large Tea Field.

Parcelles	ACE NEG	ACE RUB	BET POP	FRA PEN	POP BAL	POP DEL	POP TRE	SAL SP	ULM AME	ALN RUG	ARO MEL	CHA CAL	COR RAC	COR STO	GAY BAC	ILE MUC	ILE VER	KAL ANG	PRU PEN	PRU SER	PRU VIR	RHA CAT	RHO CAN	RHO GRO	RUB ALL	RUB HIS	RUB IDA	SPI LAT	SPI TOM	VAC cf ANG	VAC COR	VIB LEN	VIB NUD	ARA NUD	CAL CAN	CAL TUB	CAR TRIS
S1	+	0	3	+	0	3	4	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0
S2	2	0	+	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	5	0	0	0	0	0
S3	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S6	0	+	4	0	0	0	5	0	0	0	4	0	0	0	0	0	0	+	0	0	0	0	1	0	0	0	0	1	0	3	4	0	0	0	0	0	0
S7	0	1	4	0	0	0	4	0	0	4	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	2	1	0	0	0	0	1	0	0
S8	0	0	4	0	0	0	0	0	0	0	2	0	0	0	0	+	0	1	0	0	0	0	1	0	0	0	0	0	0	1	5	0	0	0	0	0	0
S9	0	3	4	0	0	0	0	0	0	0	3	+	0	0	0	0	0	+	0	0	0	0	2	0	0	0	0	0	0	0	4	0	0	0	0	0	0
S10	0	1	5	0	0	0	4	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	1	1	0	+	1	0	0	0	0	0	0
S11	0	0	0	0	0	0	6	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S12	0	+	0	0	0	0	2	0	0	5	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	2	0	0	0	0	3	0	0	0	0	0
S13	0	0	3	0	0	0	1	0	0	2	2	0	0	0	0	0	0	1	0	0	0	0	1	0	0	3	1	1	0	1	3	0	1	0	0	0	0
S14	0	0	2	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	2	3	0	0	0	0	0	0
S15	0	+	1	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1	0	0	0	0	0	1	0	0
S16	0	0	3	0	0	0	1	0	0	0	3	0	0	0	0	0	0	3	0	0	0	0	1	0	0	0	0	0	0	1	4	0	0	0	0	1	0
S17	0	+	+	0	0	0	0	0	0	0	3	0	0	0	0	0	0	4	0	0	0	0	2	0	0	0	0	1	0	0	5	0	0	0	0	1	0
S18	0	0	3	0	0	0	0	0	0	0	3	0	0	0	0	0	0	3	0	0	0	0	2	0	0	0	0	2	0	0	4	0	0	0	0	+	0
S19	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
S20	0	+	4	0	0	0	2	0	0	+	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	2	3	0	2	0	0	0	0
S21	0	0	3	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	0	2	4	0	0	0	0	0	0
S22	0	0	4	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	3	1	2	1	0	0	0	0	0	0
S23	0	0	2	0	0	0	0	0	0	0	3	0	0	0	0	0	0	2	0	0	0	0	3	0	0	0	0	0	0	1	4	0	0	0	0	0	0
S24	0	0	4	0	0	0	0	0	0	0	1	1	0	0	3	4	0	1	0	0	0	0	2	0	0	0	0	0	0	1	4	0	0	0	0	0	0
S25	0	0	2	0	0	0	0	0	0	0	1	1	0	0	0	1	0	3	0	0	0	0	3	0	0	0	0	0	0	1	4	0	0	0	0	0	0
S26	0	0	5	0	0	0	+	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0
S27	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	3	0	0	0	0	0	0	2	4	0	0	0	0	0	0

Annexe 5. Suite

Parcelles	CIR CAN	CLE VIR	CYP ACA	DOE UMB	DRY CAR	DRY INT	EQU ARV	ERI VAG	ERI VIR	EUT GRA	FRA VIR	GAL PAL	GAL TRI	GEU CAN	GLY STR	HYP FRA	IMP CAP	LON TAT	LYC UNI	LYT SAL	MAI CAN	OCL NEM	ONO SEN	OSM REG	OSM CIN	PAR cf INS	PHA ARU	PHR AUS	PTE AQU	PYR ELL	RUB PUB	RUM ACE	SOL CAN	SOL DUL	SOL GIG	SOL RUG
S1	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	1	0	0	0	0	3	0	0	0	0	0	1	0	0
S2	+	2	0	0	1	0	0	0	0	0	0	0	0	1	0	0	2	0	0	0	0	0	2	0	0	1	0	3	0	0	0	0	+	0	1	0
S3	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	1	+	0	0
S5	0	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	3	0	0	+	0	0	2	0	0	0	1	6	0	0	0	0	0	0	2	0
S6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
S7	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	2	0	6	0	0	0	0	+	0	0	0	0	0	0	1	0
S8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
S9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	3	4	0	0	1	0	0	0	0	0	0	0	0
S10	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	+	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0
S11	0	2	0	0	3	0	0	0	0	0	0	0	0	1	0	0	5	0	0	0	0	0	0	0	0	1	0	5	0	0	0	0	0	1	1	1
S12	1	1	0	0	4	3	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	4	0	0	+	0	0	0	0	0	0	0	0	0	0
S13	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S14	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0
S15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	2	+	0	0	0	0	1	0	0	0	0	0	0	1	0
S16	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S17	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	+	0	0	0	0	0	0	0	0	0	0	0
S18	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S19	1	1	0	0	3	1	0	0	0	0	0	0	2	+	0	0	4	0	0	0	0	0	2	0	0	1	0	3	0	0	0	0	0	2	1	1
S20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
S21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S22	0	0	0	0	0	0	0	0	0	+	0	2	0	0	0	2	0	0	1	0	0	1	0	0	0	0	0	4	0	0	0	0	0	0	0	0
S23	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S24	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S25	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S26	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
S27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Annexe 5. Suite

Parcelles	SYM LAN	THE PAL	THA PUB	TRI BOR	URT DIO	VIT RIP	AUL PAL	BRA CAM	BRA ERY	BRA OED	BRA RUT	BRA SAL	CAL HAL	CLA RAN	CLA CRI	DIC POL	DIC SCO	DIC UND	EUR PUL	HYP CUP	PLA CUS	PLE SCH	POH NUT	POL COM	POL STR	SPH ANG	SPH CAP	SHP CEN	SPH COM	SPH FAL	SPH FIM	SPH GIR	SPH MAG	SPH PAP	SPH RUB	SPH RUS	LIC SP
S1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S2	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S5	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S6	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0
S7	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	4	0	0	0	0	0
S8	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S9	0	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	2	1	0	0	0	0	0	0	0	0	0
S10	0	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
S11	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S12	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S13	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	+	1	0	0	0	+	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
S14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	+	+	0	1	0	0	0	0	0	0	3	4	0	0
S15	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	+	0	0	0	4	0	0	4	0	1	0	0	0	1
S16	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	3	0	5	0	0	0	0	0	0	1	0	0	0
S17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	5	1	0	0	0	0	0	3	0	0	0
S18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	0	0	0	0	3	0	3	2	0	4	0	0
S19	0	0	0	0	2	2	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S20	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
S21	0	0	0	0	0	0	1	0	0	0	0	0	0	+	+	0	0	0	0	0	0	1	0	1	1	0	1	0	0	0	0	0	0	0	0	1	+
S22	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	2	+	0	0	0	1	0	0	2	0	0	0	1	0
S23	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	5	0	0	0	0	0	0	2	0	0	0
S24	0	0	0	0	0	0	1	0	0	0	0	0	0	+	0	1	0	0	0	0	0	0	0	0	0	0	3	0	1	0	0	0	1	1	0	0	+
S25	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3	0	2	0	0	0	0	0	0	0	5	0	+
S26	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	+	0	0	0	+	0	1	0	0	3	0	1	0	0	0	0	0	0	0	0	0	1
S27	0	0	0	0	0	0	0	0	0	0	0	0	0	1	+	0	0	0	0	0	0	0	0	0	3	0	3	0	0	0	0	0	+	0	2	2	1

Annexe 5. Suite

Parcelles	ACE NEG	ACE RUB	BET POP	FRA PEN	POP BAL	POP DEL	POP TRE	SAL SP	ULM AME	ALN RUG	ARO MEL	CHA CAL	COR RAC	COR STO	GAY BAC	ILE MUC	ILE VER	KAL ANG	PRU PEN	PRU SER	PRU VIR	RHA CAT	RHO CAN	RHO GRO	RUB ALL	RUB HIS	RUB IDA	SPI LAT	SPI TOM	VAC cf ANG	VAC COR	VIB LEN	VIB NUD	ARA NUD	CAL CAN	CAL TUB	CAR TRIS
S28	0	1	4	0	0	0	0	0	0	0	5	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	1	2	0	1	0	0	0	0	0	0
S29	0	+	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
S30	0	0	5	0	0	0	2	0	0	0	4	0	0	0	0	+	0	0	0	0	0	0	0	0	1	2	0	3	0	1	0	0	0	0	0	0	0
S31	0	0	4	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0	0	4	0	0	0	0	0	0
S32	0	0	4	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	2	0	0	5	0	0	0	0	0	0
S33	0	0	4	0	0	0	0	0	0	0	2	0	0	0	0	+	0	+	0	0	0	0	+	0	0	0	0	1	0	2	5	0	0	0	0	0	0
S34	0	0	5	0	0	0	0	0	0	0	2	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	1	5	0	0	0	0	0	0
S35	0	0	3	0	0	0	0	0	0	0	1	1	0	0	0	4	0	4	0	0	0	0	1	0	0	0	0	0	0	3	0	0	0	0	0	0	0
S36	0	0	4	0	0	0	0	0	0	0	2	1	0	0	0	0	0	3	0	0	0	0	1	0	0	0	0	0	0	1	5	0	0	0	0	0	0
S37	0	0	4	0	0	0	1	0	0	0	2	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0	0	1	4	0	0	0	0	0	0
S38	0	2	0	1	0	0	1	0	2	4	0	0	0	1	0	0	0	0	0	0	0	5	0	0	2	0	2	1	0	0	0	4	0	0	0	0	0
S39	0	0	4	0	0	0	0	0	0	6	1	0	3	2	0	0	0	0	0	2	0	2	0	0	0	4	2	0	0	0	0	0	0	0	+	0	0
S40	0	+	0	1	0	0	3	0	0	2	0	0	3	0	0	0	0	0	0	0	0	3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
S41	0	+	0	0	0	0	0	4	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S42	0	0	3	0	0	0	4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	+	1	0	0	0	0	0	0
S43	0	0	4	0	0	0	+	0	0	0	3	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	+	2	1	0	2	0	0	0	0	0	0
S45	0	1	5	0	0	0	3	0	0	0	2	0	0	1	0	0	0	0	0	4	0	0	0	0	3	4	2	1	0	0	0	0	0	2	0	0	0
S46	0	1	3	2	0	0	4	0	0	5	0	0	0	1	0	0	0	0	0	1	0	+	0	0	0	4	3	2	0	0	0	0	0	0	0	0	0
S47	0	4	3	0	0	0	0	0	0	3	4	0	0	1	0	0	0	0	0	0	3	0	0	0	0	2	2	1	0	0	1	0	0	2	0	0	0
S48	0	+	2	0	0	0	1	0	0	0	4	0	0	1	0	0	0	1	0	5	0	0	1	0	0	6	0	0	0	1	0	0	0	0	0	0	0
S49	0	0	2	0	0	0	4	1	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	+	3	0	0	0	0	0	0	0	1	0	0
S50	0	1	0	2	0	0	2	0	2	2	0	0	0	1	0	0	+	0	0	0	1	3	0	0	1	3	3	1	0	0	0	0	0	0	0	0	0
S51	0	1	2	0	0	0	5	0	0	5	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0	3	2	1	0	1	0	+	3	0	+	0	0
S52	0	5	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	+	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
S53	0	0	3	0	2	0	0	3	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	1	1	1	3	0	0	0	0	0	0	0	0	0
S54	0	4	0	6	1	0	4	0	2	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	3	0	0	0	0	+	0	0	0	0	0
S55	0	0	0	1	0	0	3	0	0	4	0	0	0	2	0	0	5	0	0	0	0	1	0	0	0	0	3	1	0	0	0	1	0	0	0	0	0

Annexe 5. Suite

Parcelles	CIR CAN	CLE VIR	CYP ACA	DOE UMB	DRY CAR	DRY INT	EQU ARV	ERI VAG	ERI VIR	EUT GRA	FRA VIR	GAL PAL	GAL TRI	GEU CAN	GLY STR	HYP FRA	IMP CAP	LON TAT	LYC UNI	LYT SAL	MAI CAN	OCL NEM	ONO SEN	OSM REG	OSM CIN	PAR cf INS	PHA ARU	PHR AUS	PTE AQU	PYR ELL	RUB PUB	RUM ACE	SOL CAN	SOL DUL	SOL GIG	SOL RUG
S28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	+	0	0	1	0	0	0	+
S29	0	0	0	0	3	0	0	0	0	0	0	0	0	0	1	0	3	0	0	0	0	0	1	0	0	+	0	6	0	0	1	0	0	1	0	0
S30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0
S31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S32	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
S38	0	2	0	0	2	0	0	0	0	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	+	0	0	3	0	2	0	0	0	1	1
S39	0	1	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	1	0	3	0	1	0	0	0	0	1	0
S40	0	0	0	0	2	0	0	0	0	0	0	1	0	0	4	0	4	0	1	0	0	0	3	0	0	1	0	2	0	0	2	0	0	0	0	0
S41	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	1	0	1	1	0	0	2	0	0	0	0	6	0	0	0	0	0	0	0	0
S42	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
S43	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1
S45	0	0	0	1	1	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	3	1	0	0	0	0	0	1
S46	0	+	0	0	2	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	3	0	0	1	0	0	0	0	0	0	0	0	1	1
S47	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	4	1	0	0	0	0	0	1
S48	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
S49	0	2	0	1	2	0	0	0	0	0	0	0	1	0	0	0	2	0	+	0	1	0	3	0	0	0	0	2	0	1	1	0	0	0	0	+
S50	0	2	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	2	1	0	0	2	0	0	2	0	0	0	0	0	0	0	0	2	0
S51	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	+	0	0	1	0	1	0	0	1	0	0	1	1	0	0	0	0	1	1
S52	0	1	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	3	0	1	1	0	2	0	0	0	1	0
S53	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	0	0	2	3	0	0	0	6	0	0	0	0	0	1	0	0
S54	1	1	0	0	0	1	0	0	0	0	0	0	+	1	0	0	0	0	0	0	0	0	2	0	0	1	0	1	0	0	1	0	0	0	1	0
S55	0	2	0	2	0	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0	2	0	2	0	1	0

Annexe 5. Suite

Parcelles	SYM LAN	THE PAL	THA PUB	TRI BOR	URT DIO	VIT RIP	AUL PAL	BRA CAM	BRA ERY	BRA OED	BRA RUT	BRA SAL	CAL HAL	CLA RAN	CLA CRI	DIC POL	DIC SCO	DIC UND	EUR PUL	HYP CUP	PLA CUS	PLE SCH	POH NUT	POL COM	POL STR	SPH ANG	SPH CAP	SHP CEN	SPH COM	SPH FAL	SPH FIM	SPH GIR	SPH MAG	SPH PAP	SPH RUB	SPH RUS	LIC SP
S28	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	+	5	0	0	0	0	0	0	0	0	0	1	0	2
S29	0	1	0	0	0	1	0	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S30	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	2	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0
S31	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	+	0	0	0	0	0	1	0	1	2	0	1	0	0	0	0	0	0	0	1	0	1
S32	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	+	2	0	4	0	1	0	0	2	0	0	2	0	1
S33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	+	0	4	0	0	0	0	0	0	0	0	0	+
S34	0	0	0	0	0	0	+	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
S35	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	4	0	0	0	0	0	0	2	4	0	0
S36	0	0	0	0	0	0	+	0	0	0	0	0	0	+	1	+	0	0	0	0	0	0	0	0	+	0	4	0	0	0	0	0	0	0	0	2	+
S37	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	+	0	+	0	0	0	+	0	0	2	0	2	0	0	0	0	0	0	0	0	0	1
S38	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S39	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S40	1	0	0	0	2	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S42	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	3	0	3	0	+	0	0	0	0	2	0	5	0
S43	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
S45	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0
S46	0	0	0	0	0	1	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S47	0	0	0	1	0	0	0	0	0	0	0	0	2	0	0	0	1	0	0	0	+	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S48	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S49	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S50	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S51	0	0	0	+	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S52	1	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S53	0	1	0	0	0	1	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S54	0	0	0	0	0	+	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S55	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Annexe 5. Suite

Parcelles	ACE NEG	ACE RUB	BET POP	FRA PEN	POP BAL	POP DEL	POP TRE	SAL SP	ULM AME	ALN RUG	ARO MEL	CHA CAL	COR RAC	COR STO	GAY BAC	ILE MUC	ILE VER	KAL ANG	PRU PEN	PRU SER	PRU VIR	RHA CAT	RHO CAN	RHO GRO	RUB ALL	RUB HIS	RUB IDA	SPI LAT	SPI TOM	VAC cf ANG	VAC COR	VIB LEN	VIB NUD	ARA NUD	CAL CAN	CAL TUB	CAR TRIS
S56	3	0	0	5	0	0	3	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	3	0	0	0	0	0	0	0	1	0	0
S57	0	+	0	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
L18	0	5	2	0	0	+	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	1	0	0	+	0	0	0	0
L19	0	2	3	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	1	0	0	0	0	3	2	1	0	2	0	0	1	0	0	0	0
L20	0	4	0	0	0	0	0	0	0	4	0	0	0	0	0	0	+	0	0	0	+	2	0	0	0	1	3	1	0	0	0	0	0	1	0	0	0
L21	0	+	5	+	0	0	0	0	0	3	2	0	0	0	0	0	+	0	+	1	2	0	0	0	0	2	1	2	0	0	0	0	0	0	0	0	0
L22	0	5	3	1	0	0	0	0	0	2	2	0	0	+	0	0	2	0	0	0	0	1	+	0	0	1	0	1	0	0	0	0	0	0	0	0	0
L23	+	+	1	1	0	0	3	3	0	0	0	0	0	+	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L24	0	0	3	0	0	0	2	+	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	2	+	1	0	0	0	0	0	0	0
L25	0	0	3	0	0	0	0	0	0	0	1	0	0	0	0	4	0	+	0	0	0	0	1	0	0	0	0	+	0	1	2	0	0	0	0	0	0
L26	0	0	1	0	0	0	0	0	0	0	1	5	0	0	0	3	0	2	0	0	0	0	2	1	0	0	0	0	0	1	0	0	+	0	0	0	0
L27	0	0	0	0	0	0	0	0	0	0	1	5	0	0	0	3	0	1	0	0	0	0	2	0	0	0	0	0	0	2	0	0	1	0	0	0	1
L28	0	0	1	0	0	0	0	0	0	0	1	4	0	0	0	3	0	1	0	0	0	0	3	1	0	0	0	0	0	2	1	0	0	0	0	0	1
L29	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	3	0	1	0	0	0	0	2	0	0	0	0	0	0	4	0	0	0	0	0	0	0
L30	0	+	5	0	0	0	+	0	0	0	1	1	0	0	1	3	0	1	0	0	0	0	2	0	0	0	0	0	0	2	3	0	1	0	0	0	0
L31	0	0	5	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	+	0	0	0	0	1	0	4	0	0	0	0	0	0	0
L32	0	+	1	0	0	0	0	0	0	0	4	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	3	0	0	0	0	0	0	0	0	0
L33	0	+	6	0	0	0	+	0	0	0	1	0	0	0	0	0	0	+	0	0	0	0	+	0	0	2	0	0	0	1	0	0	0	0	0	0	0
L36	0	0	4	0	0	0	0	0	0	0	2	+	0	0	0	5	0	+	0	0	0	0	4	0	0	0	0	0	0	2	3	0	0	0	0	0	1
L37	0	0	4	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	3	0	0	0	0	0	0
L38	0	0	1	0	0	0	0	0	0	0	+	2	0	0	+	3	0	2	0	0	0	0	1	0	0	0	0	0	0	5	0	0	0	0	0	0	0
L39	0	0	1	0	0	0	0	0	0	0	+	4	0	0	1	1	0	1	0	0	0	0	3	0	0	0	0	0	0	3	0	0	0	0	0	+	2
L40	0	0	1	0	0	0	0	0	0	0	+	4	0	0	2	2	0	2	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	+	1
L41	0	0	2	0	0	0	0	0	0	0	1	1	0	0	1	4	0	2	0	0	0	0	1	0	0	0	0	0	0	2	2	0	0	0	0	0	2
L42	0	0	2	0	0	0	0	0	0	0	2	1	0	0	1	3	0	3	0	0	0	0	3	+	0	0	0	0	0	2	1	0	0	0	0	0	0
L43	0	0	2	0	0	0	0	0	0	0	2	1	0	0	2	6	0	3	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0
L44	0	0	1	0	0	0	0	0	0	0	1	+	0	0	2	3	0	4	0	0	0	0	+	+	0	0	0	0	0	0	0	0	0	0	0	0	0
L45	0	0	3	0	0	0	0	0	0	0	2	3	0	0	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	1	2	0	0	0	0	0	0

Annexe 5. Suite

Parcelles	CIR CAN	CLE VIR	CYP ACA	DOE UMB	DRY CAR	DRY INT	EQU ARV	ERI VAG	ERI VIR	EUT GRA	FRA VIR	GAL PAL	GAL TRI	GEU CAN	GLY STR	HYP FRA	IMP CAP	LON TAT	LYC UNI	LYT SAL	MAI CAN	OCL NEM	ONO SEN	OSM REG	OSM CIN	PAR cf INS	PHA ARU	PHR AUS	PTE AQU	PYR ELL	RUB PUB	RUM ACE	SOL CAN	SOL DUL	SOL GIG	SOL RUG
S56	0	3	0	1	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0	2	2	0	1	0	2	0	0	0	1	0
S57	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	6	0	0	0	1	0	0	0	1	0
L18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	+	0	0	0	+	0	1	0	0	0	0	0
L19	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	1	0	0	0	3	0	0	0	0	0	0	0
L20	0	1	0	1	0	1	0	0	0	1	0	0	0	0	1	0	0	0	+	1	0	0	2	0	0	1	0	1	0	0	+	0	0	0	0	1
L21	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	1	1	0	0	0	0	2	0	0	0	0	0	0	0
L22	0	1	0	0	0	0	+	0	0	+	0	0	0	0	0	0	0	0	+	+	0	0	2	0	0	1	0	0	0	0	0	0	0	0	1	0
L23	0	0	0	0	0	0	+	0	0	0	0	0	+	0	0	0	0	2	0	1	0	0	0	0	0	+	0	4	0	0	+	0	1	0	0	0
L24	0	0	0	1	0	0	0	0	0	1	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	2	0	0	0	+	0	0	1
L25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L26	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L27	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L28	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L29	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L30	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L32	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
L33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	+	+	0	0	0	0
L36	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L37	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L38	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L39	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L40	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L41	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L42	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L43	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L44	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L45	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Annexe 5. Suite

Parcelles	SYM LAN	THE PAL	THA PUB	TRI BOR	URT DIO	VIT RIP	AUL PAL	BRA CAM	BRA ERY	BRA OED	BRA RUT	BRA SAL	CAL HAL	CLA RAN	CLA CRI	DIC POL	DIC SCO	DIC UND	EUR PUL	HYP CUP	PLA CUS	PLE SCH	POH NUT	POL COM	POL STR	SPH ANG	SPH CAP	SHP CEN	SPH COM	SPH FAL	SPH FIM	SPH GIR	SPH MAG	SPH PAP	SPH RUB	SPH RUS	LIC SP
S56	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S57	0	0	0	0	0	3	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L18	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+
L19	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	+	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L20	0	0	+	0	0	0	0	0	0	0	0	+	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L21	0	+	1	0	0	+	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L22	+	+	2	0	0	1	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L23	+	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L24	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
L25	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L26	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	5	0	0
L27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0	+	5	0	0
L28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	0	0	1	0	3	0	0
L29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	3	1	0	0	0	0	0	1	2	0	0
L30	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	+	0	1	0	0	0	0	0	0	0	0	0	1
L31	0	0	0	0	0	0	+	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	+	0	+	0	0	0	0	0	0	0	0	0	0
L32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	3	0	+	0	+	0	0	0	0	0	0	+	0	0	0
L33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	+	0	1	0	0	0	0	0	0	0	0	0	0	0	0
L36	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	+	0	0	1	0	0	0	0	0	0	0	1	0	+
L37	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	2	0	0	+	0	0	0	1	3	0	0
L38	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	1	0	5	0	0	0	0	0	0	1	0	0	0
L39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	5	0	0
L40	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	3	0	6	0	0	0	0	0	0	1	0	0	0
L41	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	2	0	0	0	0	0	2	0	5	0	0
L42	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	4	0	0	0	0	0	1	0	4	0	0
L43	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	+	0	3	1	0	0	0	0	0	0	3	0	+
L44	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	1	0	4	0	1
L45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	+	0	3	0	0	0	0	0	1	0	3	0	1

Annexe 5. Suite

Parcelles	ACE NEG	ACE RUB	BET POP	FRA PEN	POP BAL	POP DEL	POP TRE	SAL SP	ULM AME	ALN RUG	ARO MEL	CHA CAL	COR RAC	COR STO	GAY BAC	ILE MUC	ILE VER	KAL ANG	PRU PEN	PRU SER	PRU VIR	RHA CAT	RHO CAN	RHO GRO	RUB ALL	RUB HIS	RUB IDA	SPI LAT	SPI TOM	VAC cf ANG	VAC COR	VIB LEN	VIB NUD	ARA NUD	CAL CAN	CAL TUB	CAR TRIS
L46	0	0	5	0	0	0	0	0	0	0	3	0	0	0	0	0	0	1	0	0	0	0	3	0	0	0	0	0	0	0	5	0	0	0	0	0	0
L47	0	0	4	0	0	0	0	0	0	0	2	0	0	0	0	0	0	+	0	0	0	0	3	0	0	0	0	1	0	+	5	0	0	0	0	0	0
L48	+	1	6	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	3	1	0	0	1	0	0	0	+	0	0
L49	0	0	3	0	0	0	1	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	2	0	1	3	+	2	+	1	2	0	0	0	0	0	0
L50	0	0	4	0	0	0	0	0	0	0	1	3	0	0	1	3	0	1	0	0	0	0	3	0	0	0	0	0	0	4	0	0	0	0	0	0	0
L51	0	0	2	0	0	0	0	0	0	0	1	3	0	0	3	3	0	3	0	0	0	0	3	0	0	0	0	0	0	2	0	0	1	0	0	0	1
L52	0	0	0	0	0	0	0	0	0	0	1	5	0	0	0	1	0	1	0	0	0	0	1	+	0	0	0	0	0	2	0	0	0	0	0	1	0
L53	0	0	1	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	3	0	0	0	0	0	0	0
L54	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	3	0	0	0	0	0	0	0
L55	0	0	4	0	0	0	0	0	0	0	4	0	0	0	0	0	0	1	0	0	0	0	3	0	0	0	0	1	0	1	3	0	0	0	0	0	0
L56	0	0	3	0	0	0	0	0	0	0	2	2	0	0	0	2	0	2	0	0	0	0	2	0	0	0	0	0	0	2	4	0	0	0	0	0	0
L57	0	0	3	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2	0	0	0	0	3	0	0	0	0	0	0	0	4	0	0	0	0	0	0
L58	0	0	4	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	0	0	0	0	0	0
L59	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	3	0	0	0	0	4	0	0	1	0	0	0	2	3	0	0	0	0	0	0
L60	0	0	3	0	0	0	3	+	0	0	3	0	0	0	0	0	0	0	0	0	0	0	3	0	0	1	1	0	0	0	2	0	0	0	0	0	0
L61	0	0	5	0	0	0	1	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	3	0	0	0	0	0	0
L62	0	0	5	0	0	0	0	0	0	0	2	1	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
L63	0	0	5	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0
L64	0	0	4	0	0	0	+	0	0	0	3	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	2	+	0	3	0	0	0	0	0	0
L65	0	0	3	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	+	0	1	3	0	0	0	0	0	0
L66	0	0	3	0	0	0	1	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	2	0	0	0	0	0	0

Annexe 5. Suite

Parcelles	CIR CAN	CLE VIR	CYP ACA	DOE UMB	DRY CAR	DRY INT	EQU ARV	ERI VAG	ERI VIR	EUT GRA	FRA VIR	GAL PAL	GAL TRI	GEU CAN	GLY STR	HYP FRA	IMP CAP	LON TAT	LYC UNI	LYT SAL	MAI CAN	OCL NEM	ONO SEN	OSM REG	OSM CIN	PAR cf INS	PHA ARU	PHR AUS	PTE AQU	PYR ELL	RUB PUB	RUM ACE	SOL CAN	SOL DUL	SOL GIG	SOL RUG
L46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L48	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	3	0	0	0	0	0	0	1	+	0	1	1
L49	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
L50	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L51	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L52	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L53	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L54	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
L56	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L57	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L59	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
L60	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	1	0	0	0	0	1
L61	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	2	0	0	0	0	0	+
L62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L63	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L64	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L65	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+
L66	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Annexe 5. Fin

Parcelles	SYM LAN	THE PAL	THA PUB	TRI BOR	URT DIO	VIT RIP	AUL PAL	BRA CAM	BRA ERY	BRA OED	BRA RUT	BRA SAL	CAL HAL	CLA RAN	CLA CRI	DIC POL	DIC SCO	DIC UND	EUR PUL	HYP CUP	PLA CUS	PLE SCH	POH NUT	POL COM	POL STR	SPH ANG	SPH CAP	SHP CEN	SPH COM	SPH FAL	SPH FIM	SPH GIR	SPH MAG	SPH PAP	SPH RUB	SPH RUS	LIC SP
L46	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+
L47	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+
L48	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	+
L49	0	0	0	0	0	0	2	0	0	0	0	0	0	+	0	0	0	0	0	0	0	2	0	2	1	0	0	+	0	0	+	0	0	0	0	0	+
L50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	1	0	0	3	3	4	0	0
L51	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	+	0	0	4	0	0	0	0	0	1	0	4	0	0
L52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	2	0	4	0	0
L53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	5	0	0	0	0	0	0	+	0	0	0
L54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	4	0	2	0	0	0	1	0	0	1	0	0	0
L55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	+	+	+	0	0	0	0	0	0	0	0	0	0	0	0	+
L56	0	0	0	0	0	0	1	0	0	0	0	0	0	0	+	0	0	0	0	0	0	1	0	0	1	0	4	2	0	0	0	0	0	0	1	0	1
L57	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	+	1	0	4	2	0	0	0	0	0	0	3	0	2
L58	0	0	0	0	0	0	+	0	0	0	0	0	0	1	1	+	0	1	0	0	0	+	0	1	3	0	3	0	0	0	0	0	0	1	2	0	2
L59	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	2	0	3	2	2	2	0	0	0	0	0	0	0	3	0	1
L60	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
L61	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	1	0	2	0	0	0	0	0	0	0	2	0	+
L62	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	+	+	0	+	0	0	0	0	0	0	0	0	0	+
L63	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	1	0	0	0	0	0	0	0	0	0	+	0	0
L64	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	3	0	3	0	0	1	0	0	+	0	0	0	0
L65	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	+	0	1	2	0	0	0	0	0	+	0	0	0	0
L66	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	+	0	0	0	0	0	1	0	+	1	0	+	0	0	0	0	0	0	0	0	0	+