Plant succession following restoration of riparian communities by tree plantation in agricultural landscapes

La succession végétale suivant la restauration des bandes riveraines par plantation d'arbres en milieu agricole

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RÉSUMÉ

L'héritage des pratiques agricoles peut représenter un défi majeur pour la restauration des écosystèmes forestiers. Les zones riveraines sont des milieux dynamiques soumis à l'influence du régime hydrologique des rivières et leur résilience aux pratiques agricoles reste encore mal connue. Nous avons étudié la succession végétale riveraine après plantation d'arbres dans deux bassins versants du sud-est du Canada. Nous avons fait des relevés botaniques dans 53 zones riveraines avec des plantations âgées de 3 à 17 ans, ainsi que dans 14 forêts riveraines naturelles (sites de référence). Nous avons aussi mesuré 16 variables environnementales et trois paramètres du paysage (rayon de 500 m). Des cartes de vecteurs propres asymétriques ont été utilisées pour la modélisation spatiale. Les courbes de réponses principales indiquent que les communautés de sous-étage dans les zones riveraines deviennent similaires à celles des sites de référence après 12 ans de succession. Trois variables locales ont été sélectionnées, soit l'élévation à partir de la rivière, le couvert d'arbres et le type de cultures adjacentes, alors que la proportion de forêts était la seule variable du paysage qui a été retenue comme importante. Ces facteurs contribuaient à expliquer respectivement seulement 5% et 1% de la variabilité dans la composition végétale alors que les facteurs spatiaux expliquaient plus de 25% de variabilité. Avec l'augmentation du couvert forestier, les espèces d'ombre et les fougères ont remplacé les espèces de lumière et les mauvaises herbes. L'importance des facteurs spatiaux suggère que la dispersion par hydrochorie est un processus clé dans la restructuration des communautés riveraines en paysages agricoles.

ABSTRACT

The ecological legacy of agricultural practices may represent an important challenge for restoring forested ecosystems. Riparian zones are dynamic systems influenced by hydrological regime of the rivers but their recovery after abandonment of agricultural practices is not yet well understood. We studied plant succession after tree plantation in agricultural riparian zones in two watershed of southeastern Canada. We performed botanical surveys in 53 riparian zones where plantations were done 3 to 17 years ago, and in 14 riparian natural forests, together with the measurement of 16 environmental variables including local, restoration, agricultural, hydrological and soil parameters. Three landscape components were also measured in 500 m wide buffer around sampling sites using ArcGIS. Moran's Eigenvector Maps and Asymmetric Eigenvectors Maps were used to modelize spatial components along watercourses.Principal Responses Curves indicate that understory communities of tree-planted riparian zones became more similar to natural riparian forest communities 12 years after tree planting. Three local factors were selected by forward selection, namely the elevation above river, the tree cover and the crop type, while the proportion of forests was the only key landscape factor. However, these factors only contribute to 5% and <1% to plant composition respectively, while spatial components accounted for 25% (of which 10% were correlated with local factors). As tree cover increased, sciaphilic and ferns species replaced heliophilic and weed species leading to the restoration of forest plant communities in tree-planted riparian zones. The importance of spatial components suggests that dispersal by hydrochory is a key process for spontaneous colonization of riparian communities in agricultural landscapes.

KEYWORDS

Canopy cover, Post-agricultural landscapes, Restoration ecology, Threshold dynamics, Understory communities

1. INTRODUCTION

Restoration ecology has largely developed these last decades as a discipline able to provide efficient methods to repair ecosystems formerly disturbed by widespread human activities (SERi, 2004). Among them, riparian zones have suffered considerable losses, principally due to agricultural intensification. The provision of numerous ecological services insured by riparian zones (water filtration, soil stabilization, etc.) as well as their role of regional biodiversity hotspots related to their multidimensional and dynamic abiotic gradients claim for their restoration (Naiman et al., 2005).

The objective of this study is to assess plant succession in riparian zones of agricultural watersheds after restoration by tree plantation. We studied succession of understory plant communities after tree plantation and determined the role of ecological and agricultural drivers that influence the composition and structure of riparian communities both at the local and at the landscape scales. More precisely, we aimed to 1) quantify the understory species richness and the vegetation structure dynamics of riparian communities after tree plantation using a time-for-space substitution design, 2) determine the spatial processes that influence the understory composition of tree-planted riparian zones using recent advances in the statistical modelling of spatial autocorrelation, namely Moran Eigenvector Maps and Asymmetric Eigenvector Maps methods, and 3) identify the relative contribution of local environmental variables, landscape factors and spatial processes to the understory composition of riparian zones after restoration.

2. METHODS

The study was conducted in two agricultural watersheds of southeastern Québec, Canada, where governmental policy has excluded farming crops from at least a 3m-wide buffer along agricultural streams since 2005. The two watersheds are characterized by having an agricultural landscapes (with mainly annual crops) with 24 to 66% of the lands still occupied by forests. To improve water quality and reduce soil erosion, local stakeholders undertook extensive tree planting programs, from 1995 to 2009, in post-agricultural riparian zones. Fifty-three tree-planted riparian zones representing a chronosequence of 3 to 17 years after planting were sampled along two relatively uniform rivers within each of the studied watersheds during summer 2012. Besides these restored riparian zones, 14 natural low-disturbed mature riparian forests were also sampled to be used as reference ecosystem.

Vegetation structure was assessed at the site scale by recording the cover of trees, shrubs, dicots, monocots and Pteridophytes strata using the Braun-Blanquet index. Two surveys of vegetation structure were conducted for each site, the first one in the actual zone where trees were planted: on the flat edge of the agricultural field, the second one in the spontaneous plant communities of the sloped riverbanks. Understory community composition was sampled by estimating visually the species cover (%) in 1-m² plots along transects perpendicular to the river from the field edge to the riverbank. Canopy cover (%) in the plots was estimated based on stereoscopic measurements taken at 1 m height. A total of 16 environmental variables were measured, including local, restoration, agricultural, hydrological and soil parameters. Three landscape components were also measured in 500 m wide buffer around sampling sites using ArcGIS. As a preliminary Principal Component Analysis showed a clear separation of field edge and riverbank plots based on their species composition, all subsequent analyses were conducted separately for field edges and riverbanks. Therefore, a community weighted mean of species cover was calculated separately for the field edge and the riverbank of each site, as the mean cover of plant species among the corresponding plots. Understory plant species were then classified into six groups of ecological relevance, i.e. natives or exotics, wetland obligates or wetland facultatives, and shade-tolerant or light demanding species based respectively on the database of Vascular Plants of Canada (VASCAN; Brouillet et al., 2010+).

We fitted a linear model testing the effect of the age of tree planting on the cover of each of the five vegetation strata and each of the six ecological groups, separately. Composition dynamics of understory riparian communities after tree planting compared to natural riparian forests was evaluated using Principal Response Curves (PRC). Spatial components were modelized using Asymmetric Eigenvectors Maps. The relative role of different explanatory variables was assessed using variance partitioning.

3. RESULTS AND DISCUSSION

Vegetation structure of tree-planted riparian communities was largely influenced by the age of plantation: for both field edge and riverbank, tree and shrub covers increased over time whereas monocots cover decreased. Only dicots and Pteridophytes cover remained stable over time. Plantations became similar to riparian forest communities 12 years after tree planting. Elevation above river, tree cover and crop type were key local factors explaining community changes, while the proportion of forests was the only important landscape factor. However, they contributed to only 5% and <1% to plant composition, respectively, while spatial components accounted for 25% (of which 10% interacted with local factors). As tree cover increased, forest plant communities were characterized by the replacement of heliophilic and weed species by sciaphilic and ferns species. The importance of spatial components suggests that dispersal by hydrochory is a key process for spontaneous colonization of riparian communities in agricultural landscapes.

Planting trees appears to be an efficient method to restore understory riparian communities. By increasing canopy cover, trees initiate a plant succession of understory communities which become more similar to riparian forest communities with increasing cover of shade-tolerant species. The major role of unidirectional spatial components demonstrates the huge influence of seed dispersal through water flows on the understory composition of riparian communities. Planting trees from upstream to downstream is recommendable to accelerate the re-establishment of forest riparian communities, as well as preserving forest remnants in the surrounding landscape and encouraging the farming of hay meadows.

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