**The Effects of Historical Land Use on Woodlot Vegetation in Eastern
Ontario, Canada**

By

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Abstract

Woodlots in Eastern Ontario, Canada often regenerate from abandoned farm land. The objective of this study was to investigate the effect of land use history on current vegetation. Study woodlots ($n=30$) were selected controlling for size, adjacent land use, and soil type. Current vegetation was surveyed and past land use determined via historical aerial photographs, field observations, land owner interviews, and tree cores. Detrended Correspondence Analysis resulted in woodlots positioned along a gradient based on species composition. Native forest herbs were placed near historically undisturbed woodlots while open habitat species were located close to sites with a more varied history. Sites were classified according to past cutting, historical grazing, presence of roads, planted trees, and wetness. General Linear Models indicated that introduced species richness was highest in sites historically completely cleared. Partially cut, non-grazed woodlots had the highest total, native, and spring ephemeral species richness, supporting the Intermediate Disturbance Hypothesis.

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Introduction

Transformation of the landscape

Preceding European settlement, Eastern Ontario was dominated by St. Lawrence Lowlands forest cover, consisting of a mix of hemlock (*Tsuga canadensis*), white pine (*Pinus strobus*), spruce (*Picea* spp.), and mixed hardwoods including beech (*Fagus grandifolia*), oak (*Quercus* spp.) and sugar maple (*Acer saccharum*) (Anderson 1989). Following European settlement, the forested regions of Eastern Ontario were altered by various anthropogenic disturbances. Logging and the clearing of land for agriculture resulted in the gradual fragmentation of the forest cover. Selective logging of *Pinus strobus* following European settlement dramatically changed the composition of Eastern Ontario forests (Anderson 1989). The vegetation of Eastern Ontario changed not only due to the removal of native vegetation for land clearing and harvesting, but also due to the introduction and establishment of European species (Keddy 1994).

Current landscape

The present mosaic of habitats in the St. Lawrence Lowlands is the result of a varied history of land use in the region. The origin of the forest stands that currently exist varies depending on this land-use history. While some stands may be remnants of natural forests, more often the stands are the result of the regeneration of a logged area, abandoned field, or pasture land. Natural forest patches and stands that have developed on abandoned farmland often occur on sites with poor quality soil originating from glacial deposit, while sites that have continued as cropland occur more often on soil originating from marine deposit (de Blois et al 2001).

High biodiversity is important in a fragmented landscape as it contributes to ecosystem resilience (Tilman and Downing 1994). High species diversity is thought to create stability in plant communities because the many individual species in an ecosystem will respond differently to variable conditions, such as competition for resources, predation, and disturbance (Tilman 1982, McCann 2000). Together, these species create stable community dynamics. In a study of farmland habitats in Eastern Ontario that included ditches, herbaceous and woody fencerows, old fields, pastures, crop and hay fields, woodlots, plantations, and roadsides, Freemark et al (2002; see also Jobin et al 1994) found that woodlots had the highest herbaceous and woody species richness of the sites studied and had the highest number of native species. Woodlots, therefore, play an increasingly important role in the conservation of biodiversity in the agricultural landscape, especially in regards to the conservation of native species (Boutin and Jobin 1998, de Blois et al 2002). They act as refuges for plant and animal species normally found in natural forested habitats, providing a habitat of low disturbance (Boutin et al 1994).

Factors affecting forest patch vegetation

Edge effects, isolation, and size

The vegetation of forest patches in a landscape of varying land use can be affected by a number of different factors. One of the more extensively researched influences on forest patches is the effect of edge and adjacent land use (Matlack 1993, Matlack 1994, Hersperger and Foreman 2003). A forest edge can be defined as a region of the forest

that is buffered from the climate by the above tree canopy but is exposed on one side due to the absence of adjacent trees (Matlack 1993). A difference often exists, to varying degrees, between the species composition and environmental and physical characteristics of the edge and the interior of a forest stand. The microclimatic conditions of the edge of a stand, such as light intensity, temperature and moisture, may exclude some interior species from colonising the area (Matlack 1993, Gehlhausen et al 2000, Honnay et al 2002). In a study of the extent of edge effects in woodlots, Matlack (1993) found that the influence of a forest edge on vegetation does not extend beyond 50 metres.

Along with edge effects, the isolation of a forest patch can affect the species composition of the woodlots. A forest patch isolated by cropland, pasture, or urban areas has a reduced probability of colonisation by species from another wooded area, or of the re-colonisation of a species that has become locally extinct (Fahrig and Merriam 1995, Grashof-Bokdam 1997, Petit et al 2004). The ability of a species to colonise isolated forest patches is dependent on the species' dispersal mechanism and the distance between patches (Matlack 1994, Contreras 2002). A species that is dispersed by animals or insects with small home ranges may be limited in its dispersal by the land use in between forest patches (Grashof-Bokdam 1997, Contreras 2002). In comparison, a wind-dispersed species may experience an increase in dispersal distance with the removal of wind-reducing barriers by the decrease of forest cover (Contreras 2002). In an agricultural landscape, a species' dispersal may also be limited by human activity in the farm fields in between forest stands. The colonisation of a species from one stand to

another may be restricted by the regular tilling of soil in the intermediate field, killing the seeds and vegetative parts of forest species (Matlack 1994).

The effect of patch size on species richness has been examined in scientific studies for several decades. The application of MacArthur and Wilson's theory of island biogeography (MacArthur and Wilson 1967) to agricultural landscapes has been attempted in several studies. The relationship between species richness and area is attributed to the tendency of smaller areas to have fewer habitat types and higher extinction rates (Weaver and Kellman 1981). The species-area relationship has been well supported, as many studies have shown that the number of species present in a forest patch increases with patch size (Usher et al 1992, Mikk and Mander 1995, Grashof-Bokdam 1997, Petit et al 2004). Although most studies have supported the species-area relationship, two studies testing the island theory of biogeography in southern Ontario woodlots found no evidence for a relationship between woodlot size and woody species richness (Weaver and Kellman 1981, Bricker and Reader 1998). It should be noted, however, that only woody species were considered.

Past Land Use

Edge, isolation, and size are known to influence woodlot vegetation and have been extensively studied. What is not as well understood is the influence of historical land use on current woodlot vegetation. Most research in this area has incorporated past land use as a variable in a larger study examining the effects of other factors, such as isolation, dispersal, and environmental variables, on vegetation (Matlack 1994, de Blois et al 2001,

Deckers et al 2004, Graae et al 2004). Research on past land use has been conducted to some degree in both North America (Foster 1992, Motzkin et al 1999, de Blois et al 2001) and Europe (Cousins and Eriksson 2002, Dupouey et al 2002, Grashof-Bokdam and Geertsema 1998, Peterken and Game 1984). In all of the studies, through various methods used to reconstruct land use histories, past land use has been identified as a factor contributing to current vegetation cover. While some studies focused on land surveys and aerial photography to research historical land use (Koerner et al 1997, Cousins and Eriksson 2002), others emphasised dendrochronology as method to investigate a stand's disturbance history (Orwig and Abrams 1994, de Blois et al 2001).

One of the challenges of conducting past land use research can be the lack of information available for reconstructing the land use history of study sites. Often, reconstructing the land use history of a site requires extensive research using many different sources (Egan and Howell 2001), such as historical maps and photographs, dendrochronology, oral histories, and soil analysis. Because of this, many studies in this field have used a coarse measure of historical land use, such as comparing original forest cover to secondary forests without identifying specific links between land use and vegetation (Grashof-Bokdam and Geertsema 1998, Bellemare et al 2002, Verheyen et al 2003, Vellend 2004, Verheyen and Hermy 2004, Windeballe et al 2004, Wulf 2004).

One research project that has overcome the obstacle of a lack of historical records is the work conducted at the Harvard Forest (Foster 1992, Motzkin et al 1999), where an extensive historical record exists of land use and past vegetation in the study area. The

research at Harvard Forest indicated that at the local scale of a woodlot, a trend was identified between the current vegetation and past land use (Foster 1992). Primary woodlands were largely associated with *Tsuga canadensis* and *Picea rubens* forests that had few herbaceous species due to low light infiltration to the forest floor. Secondary forests were associated with early successional species and species indicative of rich, dry habitats. While the current vegetation was found to be driven by past land use, the history of land use was linked with the original site conditions of the forest (Foster 1992). An additional finding of the research at the Harvard Forest was that historical land use predicted 1992 vegetation better than 1937 vegetation (Motzkin et al 1999).

Other recent historical ecology studies identified differences in vegetation between primary and secondary forests, citing dispersal limitations as one of the drivers of current vegetation in secondary forests (de Blois et al 2001, Bellamere et al 2002). Additional studies have identified species dispersal mechanisms and habitat requirements as drivers of vegetation composition in woodlots with differing land use histories, where secondary woodlots are composed of early and late successional species and have lower species diversity than primary woodlots (Peterken and Game 1984, Matlack 1994, Vellend 2004, Windeballe et al 2004).

Although there has been a recent increase in historical land use research, there are still many gaps in knowledge regarding the influence of past land use on vegetation. Much of the research that has occurred examined the effects of past land use on woody vegetation (e.g. Foster et al 1992, Ramey-Gassert and Runkle 1992, Orwig and Abrams 1994).

Excluding the herbaceous understory from a historical land use study may result in associations between past land use and current vegetation not being detected. Another key area of research needed is the identification of relationships between specific management histories and associated patterns in vegetation. This is a difficult task to achieve as many sites have had varying land uses over the years, and due to the confounding effects of the other factors that affect vegetation such as size, edge, and isolation.

Objectives

The main objective of this study was to examine the effects of historical land use on the present vegetation biodiversity of forested areas in Eastern Ontario. More specifically, the objectives were to:

1. Identify a relationship between past land use and current vascular plant composition in Eastern Ontario.
2. Relate specific management histories to variations in introduced vascular plant species richness and overall vascular plant species richness.

An additional objective was to apply these findings to make recommendations for the conservation of biodiversity and native species in the region.

Methods

Study site

The study area was located approximately 58 kilometres south of Ottawa near Kemptville, Ontario (45°01'N, 75°38'W) (Figure 1). In order to detect the effects of past land use on the current vegetation, 30 woodlots were selected for study controlling for a number of environmental and spatial parameters, such as size, edge, and adjacent land use, that are already known to affect woodlot vegetation. Using the vegetation and roads layers of digital topographic maps of the region (maps 31B/13 Edition 6, 31B/14 & 31B/11 Edition 9, 31G/3 Edition 6, and 31G/4 Edition 8 Natural Resources Canada), woodlots between 3.5 and 13.5 ha with a minimum amount of edge were selected. Sites chosen had similar topography, soil classification (Melanic Brunisolic), soil origin (glacial till), and drainage, which was determined using the Soil Landscapes of Canada (version 2.2 prepared by Agriculture and Agri-Food Canada). Adjacent land use was controlled for by selecting woodlots with a minimum of 50% edge bordering intensive farming. The remaining adjacent land was primarily comprised of old-fields, roads, or residential property. Woodlot isolation was measured as the distance to the nearest wooded area. Thirty-five study sites were originally selected for study and numbered from 1-35, but five of those sites were not suitable for study and eliminated.

Vegetation survey

Prior to conducting the vegetation surveys, a buffer was marked 50-metres interior to the edge of the woodlot with flagging tape. In order to avoid any edge effects (Matlack 1993) vegetation was surveyed interior to the buffer. Surveys were conducted in spring, summer, and late summer along 2-metre wide east-west transects placed 30-metres apart. This design ensured an equal sampling effort versus area for the study sites. Over the

field season, all vascular plant species were recorded and assigned an abundance rating using a modified Braun-Blanquet abundance estimation (Barbour et al 1999). The abundance of individual species was assigned at the end of each transect. Four categories of abundance were used: 1) 1-5% cover; 2) ~20% cover; 3) ~50% cover; 4) ~100% cover. Only native forest spring ephemerals, which are species that complete their life cycle before canopy closure in spring, were sampled during the spring survey. Herbs and shrubs were recorded during the summer survey and herbs and trees in the late summer survey. Any samples that could not be identified in the field were collected and identified in the laboratory. Nomenclature for all species followed Gleeson and Cronquist (1991). Study sites were sampled in approximately the same order during each seasonal survey. The data from the spring ephemeral survey was used to test whether all of the short-lived spring ephemeral species were captured over duration of the seasonal survey (Appendix 1, Figure A1-1).

Land use history

The land use history of each study site was determined using a combination of field observations, interviews with land owners, historical aerial photographs, and tree cores. During the late summer vegetation survey, all signs of past land use such as rock piles, open grown trees, and fences (Marks and Gardescu 2001) were recorded. Land owners were asked a set of questions about their past and current use of the study site (Appendix 2). In some cases, adjacent land owners were also interviewed to provide additional information.

Aerial photographs (1:9000 – 1:50000) were examined at the National Aerial Photo Library in Ottawa, Ontario. Photographs were available from 1936 to present, but information regarding the land use of the study sites was only obtained from photographs taken prior to 1980. Information on land use history obtained through field observation and interviews was validated for a sub sample of sites (20%) by comparing the data to historical aerial photographs from the same time period (Appendix 1, Table A1-1).

During the late summer vegetation survey, trees were randomly selected for measurement of the diameter at breast height (dbh). In each transect, the dbh of the first five individuals of each species present was measured. The average dbh was calculated for the most common tree species in each study woodlot, which was used to select individuals for coring. Trees selected for coring were not the same individuals as those measured for dbh. In each woodlot, one tree core was sampled from each of five individuals of the 2-3 most common species in each study site, most often *Acer rubrum* and *Fraxinus americana*. Tree cores were dried, mounted, sanded, and the rings counted to determine the minimum age of each individual. The mean tree age of each study site was compared to the mean dbh to determine whether dbh was an appropriate variable to represent woodlot age.

Statistical analysis

The total species richness, number of native species, number of introduced species, and number of spring ephemerals was calculated for each site. Introduced species are non-native plants established in a region outside of their natural range (Gleeson and Cronquist

1991). These species are most often introduced to an area by humans and may or may not be considered invasive. As a surrogate measure of moisture, the coefficient of wetness (WET) was assigned to each study site using the Floristic Quality Assessment System for Southern Ontario (Oldham et al 1995), and calculating the mode coefficient for each site.

The number of native species was plotted against the number of introduced species present in each site. The relationship between species richness and area was analyzed using linear regression. Presence/absence data from the vegetation survey was analyzed using Detrended Correspondence Analysis (DCA) using PC-ORD version 4 (McCune and Mefford 1999), with rare species down weighted. Correlations of individual species to the first two ordination axes were used to identify species representative of the hypothetical gradients, using species present in >2 study sites. As eigen values do not represent the variation explained by each axis in DCA (McCune and Mefford 1999), the variation was calculated for Axes 1, 2, and 3 using the Euclidean distance measure. Polynomial regression was used to test the species-area relationship.

The information from the reconstructed land use histories was used to create a set of land use variables that represented the mean age (MAGE) of each study site, land clearance (LAND), grazing (GRZ), tree planting (PLT), and the presence of roads (RDS). One-way ANOVAs were used to test the relationship between LAND and MAGE, PLT and species richness, RDS and species richness, WET and species richness, and LAND and spring ephemeral species richness. Linear regression was used to examine the

relationship between MAGE and mean dbh (MDBH) of both *Fraxinus americana* and *Acer rubrum*, and the relationship between woodlot isolation and total, introduced, native, and spring ephemeral species richness.

General Linear Models were used to examine the influence of the land use history variables on total species richness and introduced species richness. The influence of the land use variables on species richness was tested with area and mean age (MAGE) controlled for to ensure that the effects detected were due to the land use variables alone.

Results

A total of 359 vascular plant species, consisting of 187 herbs, 58 shrubs, 45 sedges, 34 trees, 20 ferns, 12 grasses, and 3 rushes, were inventoried in the 30 study sites (Appendix 3). The species richness of study woodlots ranged from 39 to 129 species. A positive, quadratic relationship between species richness and area was detected using polynomial regression ($R^2=0.306$, $p=0.029$; Figure 2). The species present most frequently in the study sites included *Ulmus americana* (present in 30 of the 30 study sites), *Poa compressa* (29 sites), *Prunus virginiana* (29 sites), *Fraxinus americana* (28 sites), *Parthenocissus vitacea* (28 sites), *Rubus ideaus* (27 sites), *Carex arctata* (25 sites), and *Onoclea sensibilis* (25 sites). Species found in high abundance within one or more study sites included *Caulophyllum thalictroides*, *Laportea canadensis*, *Viola pubescens*, *Impatiens capensis*, *Onoclea sensibilis*, *Acer rubrum*, *Fraxinus americanum*, and *Acer saccharum*.

One species found in the study woodlots, *Juglans cinera*, is considered endangered in Ontario (Ontario Ministry of Natural Resources 2004). It is present in low abundance in four of the study woodlots: Sites 7, 12, 26, and 29. The study sites contain 63 species (17.5% of total species richness) with high conservation value (Coefficient of Conservation of 7 or higher), determined from the Floristic Quality Assessment System for Southern Ontario, including *Asplenium resiliens*, *Streptopus amplexifolius*, *Habenaria obtusata*, *Carex festucacea*, *Trillium cernuum*, *Lycopodium complanatum*, *Allium tricoccum*, *Aralia racemosa*, and *Coptis trifolia* (Oldham et al 1995).

Of the total species richness (359 species), 13.9% (50 species) were introduced species. The number of introduced species per site ranged from 2 to 23. The relationship between the number of native species and the number of introduced species in each site was examined using linear regression. While overall, the relationship between native and introduced species had an $R^2=0.100$ ($p=0.088$), twenty-four of the 30 study sites had a positive, linear relationship ($R^2=0.73$, $p<0.001$; Figure 3). This discrepancy was due to six of the study sites, sites 1, 5, 15, 16, 20, and 34, which did not follow the same trend as the main group. While most of the sites had 3-13% of their species richness composed of introduced species, these sites had 17-33% introduced species. Seven of the fifty introduced species present in the study sites are considered species at serious risk of becoming invasive, according to the Floristic Quality Assessment System for Southern Ontario (Oldham et al 1995): *Hypericum perforatum*, *Lonicera tatarica*, *Lythrum salicaria*, *Melilotus alba*, *Pastinaca sativa*, *Rhamnus cathartica*, and *Rhamnus frangula*.

Vegetation composition among sites

Two DCA ordinations were run, one using abundance values and one using presence/absence data. Since the results for both analyses were very similar, the presence/absence data was used as it is a non-subjective way to measure species richness. The DCA using presence/absence data resulted in the distribution of study sites shown in Figure 4. The 30 study sites are distributed relatively evenly across Axis 1, except for a clump of sites (1, 5, 16) occurring on the extreme right hand end of the axis. The study sites are mostly located from the bottom to the centre of Axis 2, with site 12 occurring at the top end of the axis. The distribution of sites along Axes 1 and 2 is not associated with the geographic location of the sites in the study area or woodlot size.

Axis 1 of the DCA explained 24% of the variation in the data, whereas Axes 2 and 3 explained no variation. Species present in more than two study sites that were associated with the gradient represented by Axis 1 are shown in Table 1. Species positively correlated with Axis 1, such as *Chrysanthemum leucanthemum*, *Achillea millefolium*, *Trifolium hybridum*, *Oenothera perennis*, *Asclepias syriaca*, and others, tend to be associated with field and disturbed habitats. Those species negatively correlated with Axis 1 tend to be associated with rich woods, such as *Laportea canadensis*, *Mitella diphylla*, *Trillium erectum*, *Uvularia grandiflora*, *Dicentra cucullaria*, etc. The life history characteristics of these species suggest that Axis 1 may represent a gradient of land use history or disturbance.

The reconstructed histories of the 30 sites also indicate that Axis 1 represents a gradient of historical land use. Sites distributed along Axis 1 change from relatively undisturbed woodlots that have not been cleared in the recent past to sites that have been completely cleared and highly used in the recent past (i.e. in the last century). Sites 1, 2, 5, 15, 16, 20 and 34 are all sites that were completely cleared for agricultural purposes, and are located on the right hand end of Axis 1. In contrast, sites 6, 26, 27, 28, 29, and 31, located on the opposite end of Axis 1, appear to be remnants of the original forest cover. Sites 7, 14, 17, 18, and 35 are those with intermediate levels of past land use. All of these sites had been partially cleared at some point in their history for crop fields, grazing, or selective logging.

Historical patterns

Four land use history variables were created from the histories of each study site that were reconstructed using land owner interviews, field observations, and historical aerial photographs: the presence/absence of past grazing (GRZ), the presence/absence of roads within the woodlot (RDS), and the presence/absence of planted trees (PLT), and past land use (LAND) (Appendix 4, Tables A4-1 and A4-2). Sites designated as GRZ=1 were those that had been used by grazing livestock, such as cattle or sheep, within the past 100 years. RDS=1 sites had vegetation cleared for roads within the woodlot. Some sites with RDS=1 had roads that had not been used for several years, while others had signs of active use. While none of the study sites were considered plantations, some sites had trees planted within the naturally regenerated vegetation and were classified as PLT=1. Three categories grouping sites with similar land use history were created under the

variable LAND. Sites categorised as having LAND=1 were those that had been completely cleared and used as agricultural land in the recent past (i.e. within the last 100 years). They were all sites that had been heavily disturbed and have regenerated as woodlots from a field. Sites with a LAND=2 had been partially cleared by selective logging or had small sections of their area cleared for fields in the recent past. Sites with LAND=3 had not been cleared in the recent past. They were relatively undisturbed woodlots that appear to be remnants of original forest cover.

The mean age of *Fraxinus americana* in each site, calculated from the tree cores, was compared to the mean dbh of *Fraxinus americana* in each site (Figure 5). The positive, linear relationship ($R^2=0.756$, $p<0.0001$) indicates that mean dbh (MDBH) is an appropriate representation of mean age (MAGE). A positive, linear relationship ($R^2=0.374$, $p<0.046$) was also detected between the MAGE and MDBH of *Acer rubrum* (Figure 6). Tree cores were not sampled in site 35, as permission for the sampling was not granted by the landowner. The MAGE of site 35 was estimated by using the MDBH of *Fraxinus americana* and *Acer rubrum* and Figures 5 and 6 determine the approximate age of the two species, and then averaging the two ages. A relationship between LAND and MAGE was detected ($p=0.01$), where LAND=1 sites were significantly younger than both LAND=2 and LAND=3 sites.

The General Linear Model describing the relationship between species richness and land use history did not include RDS, PLT, or WET. It was determined that PLT was a redundant measure of LAND=2, as trees were planted in the woodlot following partial

cutting. Observations in the field indicated that the effect of roads was localized, which was corroborated by the one-way ANOVA showing no effect of RDS on overall species richness ($p=0.735$). WET was not included as 20 of the 30 study sites were classified as 8 or 10 on the coefficient of wetness index, meaning that they have very similar wetness, and the one-way ANOVA indicated no relationship on species richness ($p=0.480$).

AREA was included as a predictor variable as a species-area relationship was detected ($p=0.024$). Isolation from other wooded areas ranged from 300-2500 metres. Isolation was not included in the GLMs as there was no relationship between woodlot isolation and total species richness ($R^2=0.005$, $p=0.707$), introduced species richness ($R^2=0.002$, $p=0.812$) native species richness ($R^2=0.009$, $p=0.637$), or spring ephemeral species richness ($R^2=0.014$, $p=0.529$). Species richness was square-root transformed to better meet the GLM assumption of homogeneity of variance.

MAGE did not have a significant effect on the square root of species richness (SQSR) (Table 2), but as there was a relationship between MAGE and LAND ($p=0.01$), it was included in the model to measure the influence of historical land use while controlling for age. Table 3 shows that LAND has the largest effect on SQSR. The interaction term was not included in the final model as there were no significant interactions between LAND and GRZ detected (Table 2). The final GLM illustrating the relationship between species richness and land use history is:

$$\sqrt{SR} = 4.954 + (0.145)AREA + (0.017)MAGE + \begin{pmatrix} 0.888 \\ 2.954 \\ 0 \end{pmatrix} LAND + \begin{pmatrix} 1.192 \\ 0 \end{pmatrix} GRZ$$

All four of the explanatory variables had a positive effect on the square root of species richness. Thus, species richness is highest in partially cut (LAND=2) and non-grazed sites.

The GLM constructed to represent the relationship between introduced species richness (INTRO) and land use history had included the same variables used in the GLM describing overall species richness (Table 3). As in the overall species richness model, RDS, PLT, and WET were excluded. Neither AREA nor MAGE had a significant influence on the response variable (INTRO, in this case). The interaction terms were not included in the model as they were not significant. The final GLM representing the relationship between introduced species richness and land use history is:

$$INTRO = 0.674 + (0.065)AREA + (0.038)MAGE + \begin{pmatrix} 8.504 \\ 6.862 \\ 0 \end{pmatrix} LAND + \begin{pmatrix} 2.486 \\ 0 \end{pmatrix} GRZ$$

A large proportion of the variability in the data was explained by LAND, with very little variability explained by the other variables (Table 3). The GLM indicates that introduced species richness is highest in sites that have been completely cut.

A relationship was identified between land use history and native forest spring ephemeral species richness ($p=0.003$). Spring ephemeral species richness was greatest in LAND=2 woodlots, while LAND=1 woodlots had the lowest mean number of spring ephemerals (Figure 7). The spring ephemeral species richness in LAND=1 woodlots was significantly different than that of LAND=2 woodlots ($p=0.002$). The richness of LAND=3 woodlots was not significantly different than LAND=1 or LAND=2 woodlots.

Discussion

Vegetation patterns and past land use

There was a relationship between total species richness and land use history in the study woodlots, as total species richness was highest in sites that had been partially cut in the recent past (LAND=2). These woodlots may have a more heterogeneous habitat than those that were completely cleared (LAND=1) or not cleared (LAND=3) in the recent past. Openings in the woodlots were created by selective logging or by clearing sections of the woodlot for field. Allowing these areas to regenerate created unevenly aged woodlots with various stages of succession. Woodlots with a variety of habitats available for vegetation have been shown to support a more diverse plant community (Honnay et al 1999, Scheller and Mladenoff 2002). By having many microhabitats, the woodlots support species with a variety of life history characteristics and habitat requirements.

Selective cutting has been shown to have little impact on herbaceous vegetation (Collins and Pickett 1988, Hughes and Fahey 1991), as many of the original forest herbs are maintained in undisturbed sections of forest after cutting. Therefore, it appears that the small gaps created by historical partial clearing in LAND=2 sites may not have greatly affected the species composition of the undisturbed areas of the site. Frequent selective cutting has been shown to change the composition of the forest understory in unevenly aged stands while maintaining high species diversity, as the frequent disturbance prevents the re-colonization of disturbed areas (Scheller and Mladenoff 2002). Since the

LAND=2 woodlots have both a high species diversity and forest herb composition, it appears that they were not frequently disturbed by selective clearing.

The high species richness in historically partially cleared woodlots and lower species richness in less and more disturbed sites seems to support the Intermediate Disturbance Hypothesis (IDH). IDH proposes that the greatest species richness will occur at intermediate levels of disturbance (Connell 1978) where the destruction of biomass through disturbance (Grime et al 1987) balances competitive exclusion by opening habitat for new individuals to colonize (Li et al 2004, Roxburgh et al 2004). Although IDH has been validated by a number of studies (e.g. see Connell 1978, Tilman 1982, Collins et al 1995, Pollock et al 1998, Wilson and Tilman 2002), the shape of the diversity-disturbance curve has recently come under scrutiny (Mackey and Currie 2001, Li et al 2004). Alternatives to the unimodal IDH have been proposed and tested (Mackey and Currie 2001 and references therein), and potential problems concerning the measures of species diversity and disturbance gradient identified (Li et al 2004). Despite the continued research into this hypothesis, no consensus has been made regarding the dynamics of the diversity-disturbance relationship. Under the circumstances of this study, which measured species richness and disturbance intensity within 100 years since disturbance, IDH is a valid model.

In addition to supporting the highest total species diversity, LAND=2 woodlots also had the highest number of spring ephemerals. Spring ephemerals were examined as many of them are provincially important native species of high conservation value, such as

Trillium cernuum, *Allium tricoccum*, *Cardamine diphylla*, *Coptis trifolia*, and *Medeola virginiana*. They tend to be indicative of rich, woodland habitat, although they have different requirements for growth than other woodland species. Spring ephemerals take advantage of the full sun exposure that is available before canopy closure and the emergence of other species in the spring. By the time the rest of the woodlot vegetation has matured, spring ephemeral species have completed their life cycle. Partially cut woodlots provide both a seed source for spring ephemerals to become established and a variety of microhabitats for colonization. As the spring ephemerals considered in this study are all forest herbs, LAND=1 woodlots are at a disadvantage in terms of colonization by these species, which are often dispersed by gravity or insect vectors (McLachlan and Bazely 2001). In addition, spring ephemeral species in LAND=1 woodlots would have to compete for light with fast growing ‘disturbed habitat’ species. McLachlan and Bazely (2001) found an absence of spring ephemerals in restored forest habitat in Southern Ontario and categorised these species as highly vulnerable to disturbance.

When examining species richness alone, it appears that woodlots that have been completely cleared in the past support the same spring ephemeral species richness as woodlots that have not been cleared, but the composition of the two groups indicates that they support very different communities. Spring ephemerals found in LAND=3 woodlots tended to be species characteristic of rich woods, such as *Smilacina racemosa*, *Allium tricoccum*, *Uvularia grandifolia*, *Hepatica acutiloba* and *Dicentra cucullaria*. In contrast, the spring ephemerals found in LAND=1 woodlots were characteristic of open

habitats that would be found in woodlots that had been previously cleared, such as *Antennaria neglecta*, *Iris versicolor*, *Viola pensylvanica*, *Equisetum sylvaticum*, and *Ranunculus abortivus*.

A relationship was also identified between introduced species richness and land use history, where the highest number of introduced species occurred in woodlots that had been completely cleared in the recent past (LAND=1). Many of the introduced species in Eastern North America colonize disturbed habitats (Stapanian et al 1998), such as the LAND=1 woodlots, where woodland species are at a disadvantage due to their regeneration strategies. While LAND=2 and LAND=3 woodlots have a constant source of woodland herbs, LAND=1 sites lost most forest herbs during the historical clearing event. Introduced species may flourish in woodlots that have been completely cleared in the past (LAND=1) because they can easily disperse into open sites via their wind and animal dispersed seeds (Graae and Sunde 2000, McLachlan and Bazely 2001) and may have a greater ability to utilize limited resources than native species (Stapanian et al 1998). Native woodland species are often slow to mature to a reproductive state, lack a persistent seed bank, and have limited seed dispersal (Ehrlén and Eriksson 2000, Graae and Sunde 2000, Vellend 2003, Verheyen et al 2003, Verheyen and Hermy 2004). In a site that has been completely cleared of vegetation, native woodland species would be slow to establish as they have no means of vegetative reproduction and the animal and insect vectors that disperse their seeds may not enter the cleared site. The woodlots used in this study were surrounded by at least 50% intensively farmed land, potentially isolating them from forest herb seed sources.

This pattern of introduced and native forest species distribution is well represented by the disturbance gradient represented by Axis 1 in the DCA. LAND=3 woodlots are associated with native forest herbs, while LAND=1 woodlots are associated with species of disturbed habitats. LAND=2 woodlots represent an intermediate assemblage of species, with a complement of both native forest herbs and species of disturbed habitats. This provides further evidence for the Intermediate Disturbance Hypothesis, as LAND=2 woodlots are able to support a diverse array of species with a variety of life history characteristics.

There are several exceptions to the main trend of land use history groupings along Axis 1. Site 3, for example, was historically completely cleared but is located in between the group of cleared and partially cleared sites on Axis 1 of the DCA (Figure 4). This is because site 3, although classified as completely cleared, had one small clump of forest remaining in the corner of the study site. Once the cleared portion was left to regenerate, this small clump might have provided a source of native forest herbs to colonize the site along with species characteristic of disturbed habitats. Since presence/absence data was used in the DCA, the presence of relatively few forest herbs in site 3 may account for its position on Axis 1, regardless of how abundant those species were.

The proximity of site 19 to a forest seed source indicates that woodlot isolation may be contributing to some of the vegetation patterns observed in the study sites. None of the study sites are directly connected to other woodlots by hedgerows or other natural

corridors, but the proximity of the study sites to adjacent woodlots ranges from approximately 300 to 2500 metres. It is clear from the one-way ANOVAs that isolation does not affect species richness in the study sites. From the General Linear Models and Detrended Correspondence Analysis, land use history seems to be the dominant factor influencing vegetation in the study sites. These results are similar to those of de Blois et al (2001), who found that land use history had an overwhelming influence on the vegetation of disturbed sites, and that isolation only had a significant effect on older, undisturbed sites. Graae et al (2004) found that distance to nearest forest patch did have a significant effect on species richness, but it was not a negative relationship. They proposed that many species present in managed woodlots were the result of persistence, not colonization, and therefore isolation of the woodlot played a less important role.

Grazing also had an influence on vegetation, as species richness was greater in woodlots that had not been grazed in the past. Little research has been conducted comparing historically grazed and undisturbed woodlots, but the results of this study do agree with similar research conducted in grassland habitat (Willems 1983, Persson 1984, Luoto et al 2003). Reduced species richness in formerly grazed sites can be the result of soil compaction, increased runoff causing lowered infiltration, and increased erosion (Belsky and Blumethal 1997), as well as the selective removal of native herbs. *Thuja occidentalis* was present in 18 of the study woodlots, and has been associated with formerly grazed sites (de Blois and Bouchard 1995, de Blois et al 2001). In this study area, however, only 4 of the 7 sites known to have been historically grazed contained *T. occidentalis*, suggesting that the presence of this species may not be a suitable indicator of past

grazing. It should be taken into consideration that not all formerly grazed sites may have been captured in the past land use reconstruction process.

In addition to livestock grazing, deer grazing can have a significant impact on woodlot vegetation by reducing plant abundance and diversity, thus simplifying forest vegetation (Stockton et al 2005). In Eastern North America, where deer live in the absence of natural predators, deer grazing has been associated with the local extinction of woody species (Hough 1965, Whitney 1984, Allison 1990, Rooney and Waller 2003) and the reduced abundance of native herbaceous species (Augustine and Frelich 1998, Stockton et al 2005). Although measuring deer grazing can be a challenge, it has been documented that certain native herbs, such as *Trillium* species, are selectively grazed by deer (Augustine and Frelich 1998, Rooney and Waller 2001). Measuring the abundance and distribution of such species in woodlots may provide measure of deer grazing intensity. Other plant indicators of deer grazing have been proposed, such as using the average stem height of *Trillium grandiflorum* (Anderson 1994) or the flower scape height of *Clintonia borealis* (Balgooyen and Waller 1995). Some of the vegetation patterns observed among the woodlots in this study may be attributed to deer if there was unequal grazing pressure across the study sites. Deer grazing may have had an impact on the detection of species indicative of past land use if those species were selectively browsed. Although *Trillium* species abundances were measured in each study site, the average stem height and the local deer population in each site are unknown, therefore making a comparison between species composition and grazing intensity not possible for this data set.

Challenges

Constructing complete and accurate land use histories for sites can be difficult due to incomplete and inaccurate records (Swetnam et al 1999). One of the challenges of conducting a past land use study is identifying variables by which to group the study sites. Many of the woodlots in this study had varied land use histories that changed through the chronology of the study site. In addition, some of the study woodlots had more than one land use occurring simultaneously in different sections of the site. For example, in 1946 site 34 had hay, crop, and wooded areas occurring simultaneously within the study site.

The variability in land use histories created an inability to link specific past land uses, such as corn fields, to current plant assemblages. The method of study site selection may have also contributed to this problem. Due to time and resource constraints, the study sites were selected in the same general geographic region, east of Kemptville, Ontario. By selecting the sites in the same general region, environmental variables such as soil type, moisture, soil origin, and topography were controlled for and travelling time between sites was minimized. However, choosing sites with similar environmental conditions may have reduced the range of independent variables in the study, as sites with similar environmental conditions would likely have similar past land uses.

The study area is also an important factor to consider in terms of the application of this research. This study was conducted in a relatively wet, agricultural landscape, where

historically undisturbed woodlots may be present on the landscape because they could not be drained for farmland. The historically undisturbed woodlots were grouped in the same general geographic location in the study area, indicating that there may have been an environmental variable such as moisture preventing those sites from being cleared. In contrast, the historically cleared and historically partially cleared sites were randomly scattered across the study area. This research should be repeated in a drier, more productive region to test whether the same associations between past land use and current vegetation exist.

Despite the difficulties encountered grouping study sites by past land use, this study was able to incorporate a finer measure of land use history than many previous studies (Grashof-Bokdam and Geertsema 1998, Bellemare et al 2002, Verheyen et al 2003, Vellend 2004, Verheyen and Hermy 2004, Windeballe et al 2004, Wulf 2004).

Incorporating past grazing as a historical land use variable added an additional aspect of past land use not included in other studies. Grazing can have an important impact on the vegetation of a woodlot and thus should be included in historical land use studies. In addition, this study is unique in that only the interior of the woodlots were surveyed.

Many introduced species present in woodlots are only found in the peripheral areas of the site, as a result of edge effects. By surveying only the interior of the woodlot, it can be inferred that the species present have become established there as a result of environmental conditions and land use rather than edge effects.

Conservation implications

This study has shown that a suite of species with various life history characteristics can coexist in woodlots that have been partially cut in the past. These sites, which maintain a variety of microhabitats, support the highest species richness in the Eastern Ontario study woodlots. Partially cut woodlots have undergone disturbance that may be comparable to selective logging, and maintain a plant community containing species found in both relatively undisturbed woodlots and woodlots that have been completely cleared in the past. Relatively undisturbed woodlots have species assemblages composed primarily of native woodland species, whereas sites that have been completely cleared in the past have a plant community comprised of many species of disturbed habitats. It should be noted that these sites, which have been clear-cut in the recent past, have not recovered a species composition similar to relatively undisturbed woodlots, even several decades after clearing. The abundance of spring ephemeral species in partially cut sites indicates that these species can withstand a certain level of disturbance, as long as there remain undisturbed patches within their habitat to act as seed sources. These areas that are rich in forest species will maintain a source to colonize areas cleared within the same patch, and potentially other forest patches.

Although partially disturbed woodlots do maintain a suite of native forest species, they may not support all forest species indigenous to the region. A small number of species, such as *Smilacina stellata* and *Streptopus amplexifolius* were only found in relatively undisturbed woodlots, indicating that some rare species may be lost with the disturbance of this habitat. *Streptopus amplexifolius* is of particular conservation importance, as it has the highest rating on the coefficient of conservation scale (Oldham et al 1995).

The maintenance of selective cutting as a conservation strategy would have a minimum impact on land owners' current practices while conserving a suite of native forest species in the region. However, the presence of potentially invasive species in many of these woodlots could pose a risk to native species richness if they became well established following disturbance. Either *Rhamnus frangula* or *Rhamnus cathartica*, for example, are present in all thirty study woodlots. These two species have been identified as invasive introduced species in forests across Eastern North America (White et al 1993, Oldham et al 1995). There is the potential for species such as these to become invasive; more so if a woodlot is under disturbance. Endangered species such as *Juglans cinera*, which is present in four of the study sites, two of those being historically partially cut, may become threatened by these invasive species. Selective cutting, therefore, should be conducted with caution. The most appealing conservation strategy, ecologically, would be to protect undisturbed woodlots from all anthropogenic disturbances.

Conclusion

Historical land use affects both species richness and composition in woodlots of Eastern Ontario. Woodlots that have historically been partially cut have the highest total species richness, while woodlots that have historically been fully cut have the highest introduced species richness. Vegetation is dispersed along a gradient of historical land use, from native forest species in relatively undisturbed woodlots to species characteristic of disturbed habitats in woodlots that have been completely cleared in the past.

While they have vegetation primarily composed of native forest herbs of conservation importance, woodlots that have been left relatively undisturbed are not common in Eastern Ontario. The most frequent method of woodlot management in this region is to partially clear trees for timber, firewood, and land. The results of this study are somewhat reassuring in that the most common intensity of woodlot disturbance in the region supports high species richness and communities that include a diversity of native forest species. However, the risk of invasive species and loss of native herbs in historically partially cleared sites indicates that the sites of highest conservation importance are undisturbed woodlots.

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Tables

Table 1: Species correlations with Axis 1 of the Detrended Correspondence Analysis conducted using presence/absence data. Only species present in >2 sites were examined to avoid emphasizing rare species. Species in bold are indicative of the historical land use gradient represented by Axis 1.

Species	Native (n) or Introduced (i)	Habitat Characteristics (Gleeson and Cronquist 1991)	Pearson Correlation (r) with Axis 1
<i>Chrysanthemum leucanthemum</i>	i	Fields, roadsides, waste places	0.715
<i>Achillea millefolium</i>	n	Various habitats, especially disturbed sites	0.680
<i>Trifolium hybridum</i>	i	Fields, roadsides	0.663
<i>Oenothera perennis</i>	n	Fields, meadows, open woods	0.644
<i>Asclepias syriaca</i>	n	Fields, meadows, roadsides	0.638
<i>Rudbeckia hirta</i>	i	Disturbed habitats	0.621
<i>Vicia cracca</i>	i	Fields, roadsides, meadows	0.591
<i>Pyrus sp</i>	i	Escaped from cultivation	0.554
<i>Penstemon digitalis</i>	n	Moist open woods, prairies	0.521
<i>Hypericum perforatum</i>	i	Abundant weed in fields, meadows, roadsides	0.507
<i>Lobelia inflata</i>	n	Open woods	0.464
<i>Verbena hastata</i>	n	Moist fields, meadows, prairies, swamps	0.428
<i>Phleum pratense</i>	i	Escaped from cultivation	0.420
<i>Cornus alternifolia</i>	n	Rich woods and thickets	0.410
<i>Hieracium caespitosum</i>	i	Weed in fields, pastures, roadsides, occasionally dry woods	0.388
<i>Cornus amomum</i>	n	Moist or wet woods, along streams	0.310
<i>Sisyrinchium</i>	n	Meadows, grassy	0.297

<i>angustifolium</i>		places, damp woods	
<i>Agrimonia gryposepala</i>	n	Moist or dry open woods	0.295
<i>Carex praticola</i>	n	Meadows	-0.178
<i>Viola canadensis</i>	n	Moist woods	-0.195
<i>Aralia racemosa</i>	n	Rich woods	-0.222
<i>Cardamine diphylla</i>	n	Rich woods	-0.249
<i>Adiantum pedatum</i>	n	Moist woods and streamsides	-0.274
<i>Sambucus racemosa</i>	n	Rich woods	-0.288
<i>Acer nigrum</i>	n	Rich, moist woods	-0.296
<i>Juglans cinerea</i>	n	Rich, moist soil	-0.300
<i>Hepatica acutiloba</i>	n	Upland woods	-0.303
<i>Carex radiata</i>	n	Moist woods and pond edges	-0.314
<i>Caulophyllum thalictroides</i>	n	Rich, moist woods	-0.329
<i>Uvularia grandiflora</i>	n	Rich woods	-0.376
<i>Dicentra cucullaria</i>	n	Rich woods	-0.376
<i>Acer spicatum</i>	n	Moist woods	-0.386
<i>Trifolium pratense</i>	i	Fields and roadsides	-0.400
<i>Trillium erectum</i>	n	Moist woods	-0.410
<i>Mitella diphylla</i>	n	Rich woods	-0.434
<i>Laportea canadensis</i>	n	Rich, moist woods	-0.512

Table 2: General Linear Model showing the effects of area, mean age (MAGE), past land use (LAND), and historical grazing (GRZ) on the square root of total species richness (SQSR).

Tests of Between-Subjects Effects

Dependent Variable: SQSR

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	34.738 ^a	7	4.963	4.810	.002	.605
Intercept	41.584	1	41.584	40.302	.000	.647
AREA	2.655	1	2.655	2.573	.123	.105
MAGE	1.125	1	1.125	1.091	.308	.047
LAND	11.076	2	5.538	5.367	.013	.328
GRZ	4.714	1	4.714	4.569	.044	.172
LAND * GRZ	5.565	2	2.782	2.697	.090	.197
Error	22.700	22	1.032			
Total	2457.000	30				
Corrected Total	57.437	29				

a. R Squared = .605 (Adjusted R Squared = .479)

Table 3: General Linear Model showing the effects of area, mean age (MAGE), past land use (LAND), and historical grazing (GRZ) on introduced species richness (INTRO).

Tests of Between-Subjects Effects

Dependent Variable: INTRO

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	581.582 ^a	7	83.083	5.218	.001	.624
Intercept	44.888	1	44.888	2.819	.107	.114
AREA	.536	1	.536	.034	.856	.002
MAGE	5.431	1	5.431	.341	.565	.015
LAND	250.967	2	125.484	7.881	.003	.417
GRZ	25.798	1	25.798	1.620	.216	.069
LAND * GRZ	68.817	2	34.409	2.161	.139	.164
Error	350.284	22	15.922			
Total	3774.000	30				
Corrected Total	931.867	29				

a. R Squared = .624 (Adjusted R Squared = .505)

Figures

Figure 1: Study area, approximately 58 kilometres south of Ottawa, Ontario, Canada. The 30 study woodlots are indicated in black and grey represents all other forest cover.

Figure 2: Scatterplot of species richness and area with the 30 study woodlots labelled, showing the quadratic line of fit ($R^2=0.306$, $p=0.029$).

Figure 3: Scatterplot showing the positive relationship between native and introduced species richness in the 30 study woodlots. Sites within the ellipse show a linear relationship with $R^2=0.73$, $p<0.001$. Overall relationship, with all points included, has $R^2=0.074$, $p=0.145$.

Figure 4: Scatterplot of species scores from Axis 1 and Axis 2 of the Detrended Correspondence Analysis calculated using presence/absence data. Axis 1 explains 24% of the variation in the data; Axis 2 explains no variation in the data.

Figure 5: Correlation between mean age and mean diameter at breast height of *Fraxinus americana* ($p < 0.0001$) in 22 of the 30 study sites.

Figure 6: Correlation between mean age and mean diameter at breast height of *Acer rubrum* ($p=0.046$) in 11 of the 30 study sites.

Figure 7: Error bar chart comparing spring ephemeral species richness in the three categories of woodlot land use history showing the mean and standard error for each past land use, where Land use 1=sites fully cleared in the recent past, Land use 2=sites partially cleared in the recent past, and Land use 3=sites relatively undisturbed in the recent past.

Appendices

Appendix 1: Quality assurance/quality control information for spring ephemeral survey and historical land use data

Figure A1-1: Scatter plot showing relationship between survey date and number of spring ephemerals recorded during spring vegetation survey ($R^2=0.123$, $p=0.058$), with sites labelled. When the relationship between survey date and number of spring ephemerals is tested with site 12 removed, the relationship changes to $R^2=0.054$, $p=0.224$.

Table A1-1: Validation of land use histories obtained from land owner interviews using information from historical aerial photographs.

YEAR	Site 6		Site 8		Site 16		Site 26		Site 31		Site 34	
	Aerial Photo	Interview	Aerial Photo	Interview	Aerial Photo	Interview	Aerial Photo	Interview	Aerial Photo	Interview	Aerial Photo	Interview
pre-1930		1919: purchased property		Site owned by family, never planted trees or grazed				Woods original		Woods original		Area farm settled in 1800s; woodlot high graded, grazed
1930s		Used for firewood and grazing	1936: Old field on west side; Woods on east side	Cleared section of site left to regenerate into woods								
1940s		Firewood, grazing	Young woods, same shape as present	Owners could see over trees in woodlot			Woods same shape as now		Woods, scattered trees spreading to west field	Owners purchased site, woods mature	Crop field and hay field, wooded on west side	Planted with conifers
1950s		Firewood, grazing		Firewood	Unplowed field, wet; hedgerow all around; few scattered trees	Early 1950's planted corn but very wet			Some open patches, scattered trees gone	Firewood		
1960s	Mature woods, no sign of recent clearance	Firewood, grazing		Firewood	Old field; some trees in south end of site	Cattle grazing	Woods same shape as now	Owners purchased site, woods mature	Some trees cleared from south end	Firewood		
1970s	Mostly mature trees	Stopped grazing, Firewood	Woods same shape as present	Firewood		Planted white pine; stopped grazing		Firewood	Field cleared b/w site and nearby woodlot; woods same shape as present	Firewood	Woods same shape as present	Purchased by owners, Stopped grazing; upgraded tree stock by planting; active sugar bush
last 20 years		Firewood		Took 130 cords of wood from ice storm damage				Firewood		Firewood		Tree thinning and stocking; active sugar bush

Appendix 2: Set of questions used to interview land owners on past and current land use of each study site.

Name: _____ Date: _____
 Address: _____ Phone #: _____

Description of woodlot location (e.g. on Main Rd. 1.5 km north of the Main and First Rd. intersection):

Please answer as many of the following questions as you can to the best of your knowledge. If you do not know the answer please indicate so, and list if anyone else may have that information. If you have any questions regarding the questionnaire or the project please contact me (Carissa Brown) at 990-2357.

Approximately how long have you/your family owned the property on which the woodlot is located?

The following section applies to the former land use of the woodlot:

How was the land used for the majority of time before it became a woodlot?
 (e.g. was it mainly used as cropland or for grazing?)

Please circle all of the following that apply to the former land use of the woodlot:

pasture cropland orchard hay plantation fallow

If you circled cropland, what were the main crops grown?

How long was the area farmed before it was converted into a woodlot?

The following section applies to the current woodlot:

When was the area left to mature into a woodlot? (approximate year or decade)

Since the area has become a woodlot, has it ever been used for cattle grazing, and if so how long ago?

Is the woodlot currently used for grazing? If so, for how many cattle?

Do you cut trees for firewood/lumber? Approximately how much and how often?

Which of the following recreational activities occur in the woodlot?

ATV	hiking	hunting	horse back riding	snow- mobiling	other (specify)	none
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Do you regularly see wildlife in the woodlot (e.g. deer)?

Appendix 3: Species list showing presence/absence of all species in the 30 study woodlots.

[illegible]

[illegible]

[illegible]

65

Appendix 4: Designation of land use history variables from historical land use summaries.

Table A4-1: Land use variable designation.

YEAR	Site 1: 6.65 ha	Site 2: 8.03 ha	Site 3: 7.83 ha	Site 4: 7.38 ha	Site 5: 5.93 ha	Site 6: 5.38 ha
pre-1930						1919:Family bought property; use woodlot for firewood and grazing ; never cleared LU3
1930s			1936: crop field ; clump of woods in middle, old field in back; S hedge LU1	1936:Woods; larger on W side than present		
1940s		1949: Old Field ; Hedge on one side filling in with trees/shrubs LU1				
1950s	1959:seems to be field ; adjacent lot is scattered woods/open at S half; E, S, W hedge LU1				1950: Fields ; wet; can see stream LU1	
1960s	1969:very open front half; back with some open patches		1969:Same: fields at front and side and wood clump middle and back	<i>Current owners</i> ; 1969:Scrubby but probably just b/c spring	1969:still cultivate at front; small veg patches at back (uncult)	1967: Dense woods except NE corner and E side - younger
1970s	<i>Current owners</i> ; hay behind house; 1975:some mature trees scattered S; dark in mid - wet or young trees? N side open	1975:filling in but clumpy; can see it was once crop field	1975:front half and NE corner still being plowed; back half maturing; 1978:same as 1975	Size selective logging ; 1971:scattered mature trees, more open near centre; 1978: maturing LU2	1972: <i>Current owners</i> ;	<i>Woods used for grazing until 1974</i> ; 1978:mostly mature trees
last 20 years	2000: wood cleared in centre	2002: <i>Current owners</i> ; don't know anything about history; firewood	<i>Current owners</i> ; don't use or visit woodlot; think it used to be farm	firewood and cut cedar; hunting	don't use woodlot	
Field Observations	Old road going in. Next to pine plantation. Wetland at one side of veg plot. Clearing with stumps and slash in middle.	Road coming into side, some logging by road. Older trees near back.	Younger forest at front half. Can see old crop rows and troughs in front half. Open water at back in spring, dry in summer.	Older road going halfway in. Large pit near back. Old metal chair.	Clearing in centre, no stumps just field. Wetland near front dried up in summer.	Drainage ditch through woodlot, between buffer and veg plot.

Site 7: 9.86 ha	Site 8: 6.40 ha	Site 10: 5.47 ha	Site 12: 5.95 ha	Site 14: 8.57 ha	Site 15: 4.92 ha
<i>Owned by family</i>	<i>Owned by family, they don't think it was ever planted, never grazed</i>	<i>Very wet, probably always bush;</i>			<i>House built in 1875</i>
	1936: young woods/old field on S end ; NE corner and E side mature LU2				
	<i>Owned by family again, could see over trees in woodlot; 1946: Woods same shape as now</i>				
1950: OF to dense woods as you move S; wet in spring; Strong rectangle shape; 1958: More evenly aged; cut on S end LU2		1959: maybe original woods; Can see fence line; wet	1950: woods; S hedge; open areas where cut LU2	1950: Wood patch N; south end Old Field with scattered young trees; LU2	1950: wood clump NW side, rest is scattered trees and large open areas; SW side obviously former crop . N, E hedge LU1
1969: S half is most dense; still some open patches		1969: woods			1963: N side filling in w mature trees; lots open S and E; 1969: filling in
<i>Current owners; regular cattle grazing;</i>	1975: Still younger or season	1975: lot to right has been cut; N 1/4 of lot cut , S 1/4 most mature; centre filling in where wet LU2	1975: E hedge widened; young trees filling in gaps	1975: filling in N to S; S very open, just scattered mature trees	
<i>no longer grazed; firewood</i>	130 cords from ice storm, firewood, moving plants from garden in	<i>Current owners; 2004 cut side to straighten field; no grazing</i>	<i>Current owners; take firewood</i>	Sheep grazed until 5 years ago: all died due to white snake root.	2001: <i>Current owners; firewood</i>
Big pine near rear.	Garbage dumped at front of woodlot, metal etc. Roads well maintained throughout. Cleanup up after ice storm.	Road coming partway into woodlot, not maintained. Fence dividing woodlot at buffer. Very wet at front, drying some with summer.	Roads maintained throughout woodlot. Grasses, sedges and small herbs growing on them.	Old road going in. Horse trails in some areas. Former sheep pasture.	Some trash. Large openings in centre with stumps and slash.

Site 16: 4.63 ha	Site 17: 9.46 ha	Site 18: 6.03 ha	Site 19: 3.57 ha	Site 20: 8.14 ha	Site 22: 6.69 ha
					Neighbour thinks woodlot around long time
				1936: Crop or hay fields on East half; wide hedge or woods in W half LU1	
	1946: Woods at back, younger scrub/wood at front		1949: <half Old Field /young woods; rest has crop rows; LU1	1949: Wet; N 1/3 has been plowed in last few years	
Current owners; planted some corn but very wet; 1950: Field not recently plowed; wet; Few scattered trees S; Hedge all around LU1	Woodlot present; 1958: filling in; NW corner is oldest; NE youngest (OF); S and mid lots of open patches	1958: Woods at rear, Filling in with trees from N; E hedge; open at front (S) LU2	1958: filling in more with trees; large wetland filling in too		1950: S 1/3 fairly dense wood; N completely open , wet, not plowed; division b/w two; 1958: N end maturing, some harvesting LU2
Cattle grazing ; 1963: OF; no trees; maybe young trees planted	Woodlot partially cut ; 1969: scrubby and wet; can see old plow lines in ground b/c of h2o LU2		1963: some mature trees NE corner, otherwise scrubby		1969: SE corner filled in w trees; rest scrubby
Planted pine late 70s; stopped cattle from grazing afterwards	1975: maybe planted at rear; filling in; centre clump of dense trees dispersing	1975: most dense rear 2/3; more open at front; road cut in // to E side	1975: filling in		
	Current owners; firewood	1997: current owners; use for firewood	Cattle graze ; very wet;	1991: current owners; previous owners cut it all;	1994: current owners;
Old pasture, old trails, planted pines, stone piles at edge near field.	Maintained roads going in and around, selective logging by road.	Logging near houses, muddy and wet in spring, adjacent to marshy old road.	Active pasture, some cow trails, rock piles at edge.	Old orchard in middle. Older clump of trees in back corner, shell casings.	Old wire fence across middle

Site 23: 13.51 ha	Site 24: 11.65 ha	Site 25: 9.21 ha	Site 26: 3.51 ha	Site 27: 4.18 ha	Site 28: 4.61 ha
Always been woods LU3	<i>Current owners; think always woods;</i>		<i>Current owners think always woods, wet;</i>		
1946:Wooded; adjacent old field	1946:woods; very open, large patches esp near centre and N; cows? N, E, and W hedge LU2	1946:Patchy woods with open areas ; Fence line through mid indicate part once cleared LU2	1946: Mature woods ; same shape as now LU3	1946:Loose woods LU3	1946: Woods more open than now LU3
<i>Current owners; not grazed; 1969:woods</i>	1969:mostly woods; SE corner very open	1969:woods	1960:current owners, woodlot present; 1969:woods	1969:pretty open; trees present but no lvs so hard to tell density	
	<i>Previously and currently used for grazing, now 30 cattle; firewood;</i>	<i>Current owners;</i>	<i>Firewood, some for lumber; Drives tractor in sometimes</i>	<i>Current owners; built cabin 1998;</i>	
Houses and yards cut into lot.	Road going in to cabin and outbuildings. Older road goes further into woodlot. Old wood fence around woodlot. Cow trails.	Property stakes in middle.	Some active selective logging, esp from ice storm damage. Road for tractor.	Some quad trails . Cabin and outbuildings in buffer. Hunting blind.	Fire pit in use at edge of woodlot. Recent garbage in woodlot. Open wetland area near back of woodlot, drier after spring.

Site 29: 6.40 ha	Site 31: 3.47 ha	Site 32: 6.24 ha	Site 33: 6.52	Site 34: 9.93 ha	Site 35: 6.17 ha
Owned by family since 1800s; never cleared LU3	Present woodlot never cut; too wet; technology not available to drain until recently; LU3			Area farm settled in 1800's; woodlot area high graded; grazed ;	
1946: Woods ; younger on small side of stream	1945:current owners; 1946:Woods; scatters out into field more than now	1946: Mature woods on old side of farm rd/ditch; LU3	1946:Woods; older on W side	1946: Crop fields in middle 1/3; hay or crop on either side; <i>planted with conifers</i> ; LU1	1946:Patchy woods mixed with Old Field . E hedge. No 416 LU2
	1958:some open patches; scattered trees in field gone		1959:mature woods; opening on E side		
1969:woods	1969:pretty open b/c spring; S half cleared some, more like current shape	1969:woods	1969:seems kind of open but maybe b/c spring		
	1975:land cleared b/w woodlot and E lot; now has present shape		1975: cut in centre and towards road; solid mature trees E and S; W hedge LU2	1970:Bought by KC; <i>grazing stopped</i> ; <i>upgraded stock</i> ; <i>active sugar bush until 2003</i> ;	
<i>Cut dead wood</i>	<i>Some firewood</i>	<i>Some firewood; leases small area for bee hives;</i>		<i>Owned by Kemptville College; Sugar bush; maintained trails; thinning and stocking;</i>	<i>Owned by MTO; no active cutting or use; trying to sell woodlot</i>
Bee hives near edge of woodlot. Stream dissects woodlot. Some garbage piles throughout with tires, metal. Hunting blind.	Damp in spring.	Bees. Old stone fence w barb by road at front , drain ditch in middle. Metal and bee garbage, shell casings, animal bones.	In spring open water in back of woodlot with very few trees. Some signs of very old trail.	Cutting in buffer, maintained public trails , small new cut in middled, planted pine, piled logs in sugar bush section.	Deer skeleton, mounds of earth.

Table A4-2: Land use history variable designations of each study site, including past land use (LAND), historical grazing (GRZ), presence of planted trees (PLT), presence of roads (RDS), coefficient of wetness (WET), mean age (MAGE), and area.

SITE	LAND	GRZ	PLT	RDS	WET	MAGE (years)	AREA (ha)
1	1	0	0	1	10	52.1	6.652
2	1	0	0	1	8	42.91	8.03
3	1	0	0	0	8	22.4	7.831
4	2	0	0	1	10	46.28	7.383
5	1	0	0	0	8	23.11	5.934
6	3	1	0	0	10	52.53	5.38
7	2	1	0	0	10	40.16	9.859
8	2	0	0	1	8	59.85	6.402
10	2	0	0	1	0	56.25	5.474
12	2	0	0	1	10	41.3	5.948
14	2	1	0	1	0	60.2	8.571
15	1	0	0	0	10	49.47	4.92
16	1	1	1	0	8	27.5	4.631
17	2	0	1	1	5	40.63	9.455
18	2	0	0	1	8	49.69	6.025
19	1	1	0	0	2	30.6	3.571
20	1	0	1	0	10	22.4	8.137
22	2	0	0	0	2	56.13	6.685
23	3	0	0	0	5	48.4	13.509
24	2	1	0	1	10	44.05	11.653
25	2	0	0	0	2	56.6	9.205
26	3	0	0	1	3	83.47	3.512
27	3	0	0	1	10	45.31	4.181
28	3	0	0	0	5	48.33	4.612
29	3	0	0	0	10	61.1	6.401
31	3	0	0	0	8	51.82	3.47
32	3	0	0	1	3	37.7	6.24
33	2	0	0	0	10	41.82	6.516
34	1	1	1	1	10	55.83	9.93
35	2	0	0	0	8	70	6.167