Discussion Paper:

Alternative Approaches to Afforestation

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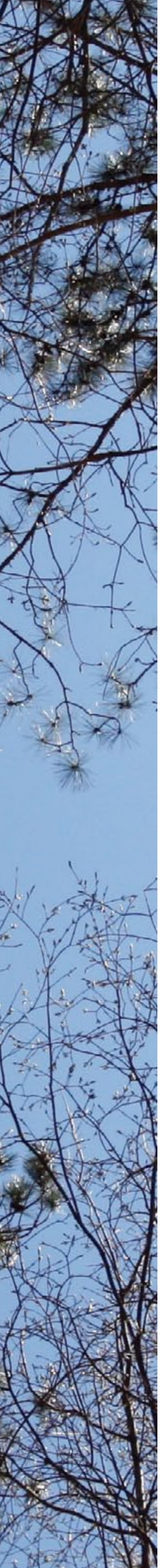
AUGUST, 2012

Through the support of:

Ontario Trillium Foundation
Fondation Trillium de l'Ontario

TREES ONTARIO



Executive Summary

by Al Corlett[1], Margaret Penner[2], Tom Clark[3] and Paul Gagnon[4]

This discussion paper is intended to assemble information related to both conventional afforestation and more recently applied afforestation approaches having an ecological restoration focus, and to organize it in a format that will facilitate considerations related to the methodologies, expected short and long-term results from both local and landscape perspectives, and relevant costs of achieving the intended objectives.

The area under consideration includes all of that portion of southern Ontario that is south of the Canadian Shield, although it is recognized that much of the work done to date, and within which significant habitat and diversity loss has already occurred is in south-western Ontario. Management options will vary greatly across southern Ontario because of obvious differences in site productivity, soil conditions, and current land use.

A basic description of the principal restoration focused field procedures is provided as a comparison with conventional afforestation methodologies. Some of the features of recent restoration work that many practitioners feel make their efforts distinct from conventional afforestation are:

- a greater diversity of species planted, including the establishment of a high proportion of hardwood species and the use of complex mixes of local native grass and herbaceous species,
- generally a greater focus on rapid restoration to a mature, diverse forest condition (species, structure) and less on wood products,
- local native seeds collected and sown,
- reduced planting density and variable spacing,
- hand planting favoured, with selective use of mechanical seeding,
- greater focus on control of persistent invasive species,
- site rehabilitation to address hydrological restoration,
- greater emphasis on re-establishing more natural habitat conditions,
- greater emphasis on connecting existing forests.

A consistent monitoring program that would provide direct measures of treatment success or support predictions of successional trajectory is not in place (note some exceptions, e.g. NCC's Lake Erie Farms project), therefore a summary of the available research and field observations for a range of treatment approaches is provided. The discussion highlights the importance of tailoring species selection to site characteristics (moisture & nutrients) as well as the need for ongoing competition and rodent control when managing hardwood species, the significant potential of mixed species plantations, the considerations to be made in selecting species to combine and the later challenges for an ongoing management program, the effect of variable spacing and pod (clumped pattern) planting on the structure of developing trees and choice of subsequent tending and protection measures, and options for incorporating a restoration focus when managing older plantations that have been established using conventional methodologies.

Case studies that identify long-term management intention as well as anticipated stand development trajectory and related habitat availability have been provided for a conifer plantation established using conventional approaches, and for two areas established using quite different methodologies but with primary goals of maximizing diversity and moving the treatment areas quickly along trajectories towards restored ecosystem conditions. The stand and habitat development trajectories for these three areas will differ, with each presumably filling important niches as they develop. The importance of retaining a diversity of diversities in the landscape, and thus leaving options for the future is noted.

A series of recommendations are provided, including references to landscape level considerations when establishing afforestation objectives, the need for consistent protocols for the assessment of the effectiveness of various afforestation approaches, as well as the use of species mixtures, native ground cover as a competition control tool, and direct seeding and bareroot or plug planting when establishing hardwood species.

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Acknowledgments

Many organizations and individuals made valuable contributions during the preparation of this paper, providing information, images, knowledge, and shared experience to the writing team.

Ian Jean	Ausable Bayfield Conservation Authority
Jarmo Jalava, Michelle Kanter	Carolinian Canada Coalition
Kathryn Arthur, Paul Giroux, Mike Nelson	Essex Region Conservation Authority
Colin O'Neill, Jim Robb	Friends of the Rouge
Peter Arbour	Natural Resources Canada
Mathis Natvik	Natvik Ecological
Ian Payne, Viki Reynolds	Not so Hollow Farm
Ken Elliott, Dawn Burke, Scott McPherson, Al Stinson, Scott Reid, Bill Crins, Glenn McLeod, Barb Boysen, Terry Schwan, Harold Lee, Gary Nielsen	Ontario Ministry of Natural Resources
Steve Hounsell	Ontario Power Generation
Brian Craig	Parks Canada
Mary Gartshore, Peter Carson	Pterophylla Native Plants and Seeds
Ian Buchanan, Cat Cybulski, James Lane	Regional Municipality of York
Bob Clay	Rouge Park
Allan Arthur	St. Williams Nursery & Ecology Centre
Ron Wu-Winter, Ralph Toninger	Toronto Region Conservation Authority
Ron Thayer, Greg Greer, Brian Swaile, Tim Gray, Vrinda Vaidyanathan, Azadeh Chobak, Shelley McKay	Trees Ontario
Paul Robertson	Trees Unlimited
Madhur Anand	University of Guelph
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Figure 1: Spacing trial, 1953, red pine establishment on abandoned field

(photo: Petawawa Research Forest, Natural Resources Canada)

The long-term vision for most managers regardless of their methodology is to enhance the health and integrity of the environment through tree planting and sustainable management of Ontario's forests.

Introduction

Afforestation is the establishment of forests on lands that have been open and not covered by forest for quite some time (50 years by some definitions) (FAO, n.d.), and it has been undertaken on marginal or under-utilized farmlands in southern Ontario at various levels since the late 1800's. More than a billion trees have been planted on private lands across the province (OMNR, 2001) through the efforts of provincial and municipal governments, Conservation Authorities, corporations and private landowners.

The objectives have varied from soil stabilization and site rehabilitation to the provision of wood products, wildlife habitat, recreational opportunities, flood control, protection of riparian areas and more recently, sequestering carbon to meet obligations under the Kyoto Protocol. Although often not explicitly identified as an objective during the initial plantation establishment efforts, much of that rehabilitation work can have the effect over time of initiating ecosystem restoration and recovery with respect to ecosystem health, integrity and sustainability. As illustrated in Figure 1, plantation establishment techniques have been developed over the years as a result of experimentation and operational experience (White et al. 2005). Information on trends in species composition, stocking and structure has been gained from repeated measurements in stands representative of those establishment approaches.

Ecological restoration has become a focus for managers in southern Ontario who are attempting to return sites with a long history of human-caused disturbance to their historical trajectory as quickly as possible, with goals that include the re-establishment of the pre-settlement species composition and community structure. The actual implementation of afforestation with this focus varies depending on the interests and resources of the landowner (of critical importance since a very high percentage of the landscape south of the Canadian Shield is privately owned) and the nature of the site. Depending on the reference site, ecological restoration in southern Ontario often aims for increased tree diversity (through multi-species planting, use of bare-root or plug stock and/or tree seed, a high component of native hardwood), reduced occurrence of invasive exotic weed species (through use of herbicides and/or seeding of a diverse mix of early successional native plants) and may include restoration of microtopography (pit and mound) and macro topography (recreation of ox bows, berms, etc.). A key component is the use of complex plant mixes to provide for biodiversity conservation very early (year 1-2) in the planting program such that the ecological requirement for a rich variety of native species using open habitats is served. Old fields with Eurasian cool-season pasture grasses do not serve this function.

Most ecological restoration projects in southern Ontario are recent. The lack of older studies limits our understanding of forest establishment success rates and the degree and rate of achievement of longer term diversity and habitat targets. Some of the early results are promising.

The long-term vision for most managers regardless of their methodology is to enhance the health and integrity of the environment through tree planting and sustainable management of Ontario's forests. The considerations revolve around how best to achieve that vision and to identify approaches best suited to specific management goals.

The purpose of this discussion paper therefore is to gather information related to both conventional and more recently applied afforestation approaches, and provide it in a format that will assist managers in developing restoration strategies for specific sites and objectives.

The information assembled here is intended primarily for practitioners, the technical staff who are implementing field programs. It should also assist those who work at a policy level, making considerations of program delivery and focusing at a broader scale.

Plantations of single species and ages and with uniform spacing may exhibit growth patterns, stand structures and wood properties that are quite different from the preceding natural stands.

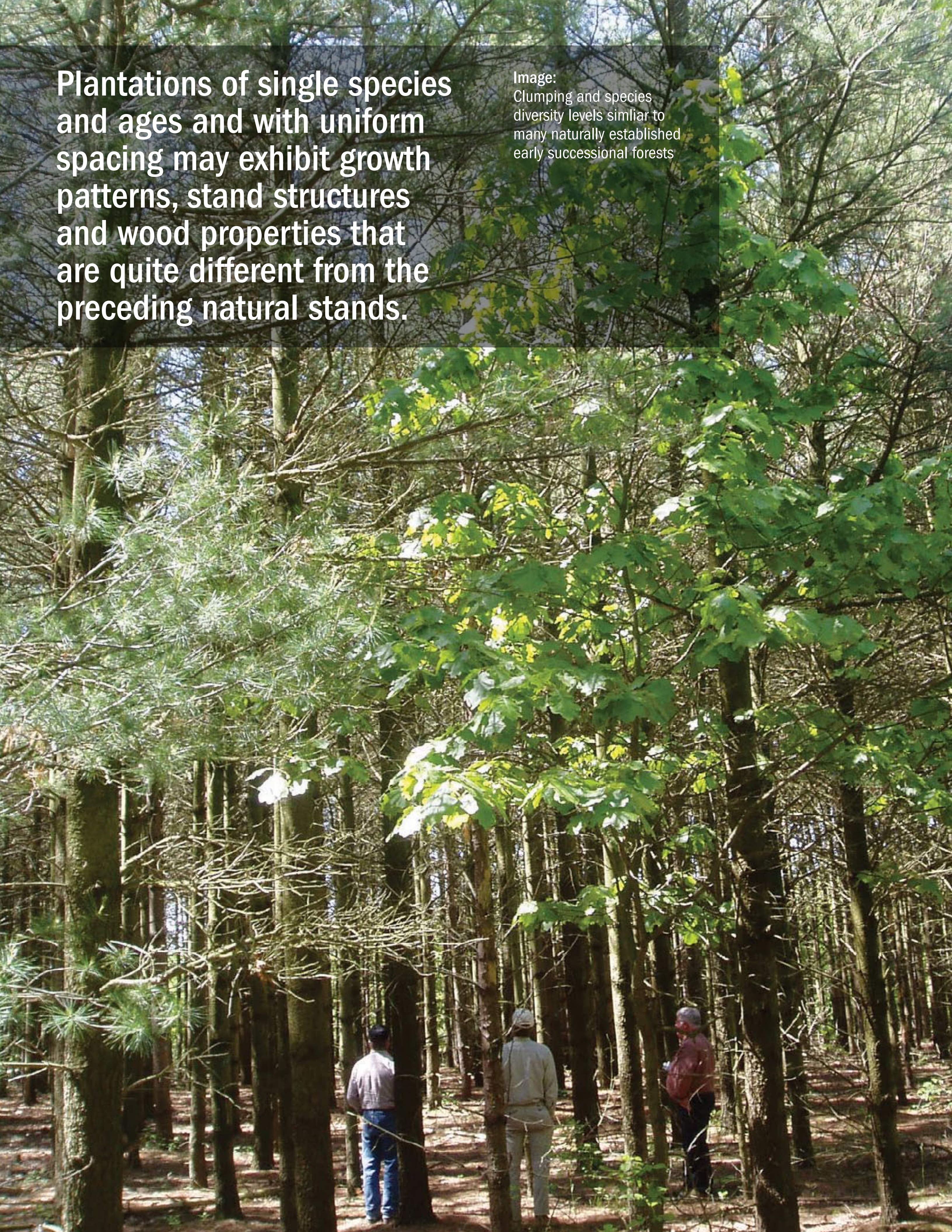


Image:
Clumping and species diversity levels simliar to many naturally established early successional forests

01

Projecting Forest Development

The afforestation approach will be guided by the objectives of the owner, the potential of the property and the funding available to implement the program. The landowner's objectives should of course have a temporal component, i.e. an expression of the desired short-term condition and more importantly, the long-term species composition, stocking and structure goals.

Forests go through significant change as they mature. Oliver and Larson (1996) describe the growth patterns of forests following a disturbance. Their description of the four stages of stand development – stand initiation, stem exclusion, understory re-initiation and old growth – is summarized below since it is applicable to the development of both artificially and naturally established forests. The patterns and processes that are discussed may help managers to develop and fine-tune successional trajectories such as those to be presented in the Case Studies, should allow managers to better predict habitat condition and thus diversity level through time, and ultimately may help them to design afforestation prescriptions for new forests that will more effectively contribute to specific long-term landscape level goals.

1.1 Stand Initiation

The period after disturbance and as new forests begin their development is one of high diversity, with new individuals and species continuing to appear for several years. The variety of plants and seeds resulting from this high species richness produces an abundance and diversity of food and habitat. Many species and individuals are generally found during the stand initiation stage since unoccupied growing space allows many individuals to either invade or reappear from soil seed banks. Fewer individuals survive and some species may disappear as the trees and shrubs increase in size, fill the growing space and compete during the later stem exclusion stage. Many herbaceous species eventually die out as the stand initiation prices. Taller woody plants, trees and shrubs suppress smaller woody plants and shrubs. Eventually the trees grow taller, suppressing the remaining understory layer.

Individuals will continue to invade an area as long as growing space is available. Factors leading to shortened invasion periods include:

- site factors favourable to fast growth,
- the rapid appearance of new plants (seeds, root collars, or advance regeneration surviving the disturbance, or seeds coming in rapidly from adjacent areas),
- species that grow fast and in directions that occupy the most growing space when young,
- a high frequency of plants (each plant filling the available space), and
- the absence of animal browsing or predation.

Generally, more productive sites have shortened invasion periods. As well, very productive sites may show fewer individual stems because the early invading trees and other plants expand rapidly and exclude younger stems.

Species composition is determined by the type of disturbance, which germinating seeds are favoured by the disturbance type, and which species are producing seeds immediately after the disturbance. Their establishment pattern and density will vary as well, since trees don't invade at the same time, and don't begin growing at uniform spacing unless planted that way. Many new forests begin in aggregated or clumped patterns with some areas containing no individuals. The initial, usually clumped pattern is caused by the spatial distribution of advance regeneration and stumps and roots for sprouting, suitable seedbeds, competition from other plants, and behaviour of the stand initiating disturbance.

Clumps affect growth and stem quality of individual trees for decades. A clumpy distribution of trees during stand initiation can lead to wolf trees on the outside of clumps, and interior trees with small diameter, small branches and slow growth. Trees growing without trees of the same age next to them are more tapered and have larger branches.

There are obvious similarities between this clumpy pattern that often develops naturally, and some of the efforts that utilize pod or scatter plants. The clumps that develop naturally will likely vary greatly in size, with some very large and others that are quite small.

It is worth noting that plantations of single species and ages and with uniform spacing may exhibit growth patterns, stand structures and wood properties that are quite different from the preceding natural stands. In addition, the extended period preceding crown closure in many natural stands has created longer periods of herb and shrub growth than experienced in plantations. These herbs and shrubs may have had beneficial effects on soil development, tree pathogen eradication, and survival of browsing animals. As well, a diverse herbaceous layer can promote increased insect diversity (including both pollinators and predators), and an increased diversity of breeding birds (most of which are insect predators), with both effects contributing to ecosystem stability and resilience (M. Gartshore, 2009. pers. comm.). Many herbaceous species prevalent during stand initiation fix nitrogen which is recycled in the stand during later stages. Shortening the stand initiation stage through weed control and planting of vigorous seedlings at close spacing may reduce the nitrogen level and growth of the stand. The long-term consequences for individual locations may or may not be significant, but these factors, as well as any site related constraints that must be dealt with, may be considered when prioritizing areas to receive a particular afforestation treatment.

Managers can easily affect species composition during the stand initiation period. It is also an important point at which eventual stand structure may be predicted, assuming that initial species and numbers of individuals are known and the basic silvics and competitive ability of the species involved are understood.

1.2 Stem Exclusion

A stand may take several decades before all parts make the transition from stand initiation to stem exclusion, but eventually crowns close, new individuals do not appear and some of the existing ones die. Survivors grow larger and express differences in height and diameter; first one species and then another may appear to dominate the stand.

The foliage layer rises as trees grow taller, and leaves cannot survive in the diminished sunlight beneath. Plants which cannot grow tall enough to stay in the foliage layer often die. The shaded forest floor becomes devoid of living plants and consists of brown, dead leaves, twigs and stems.

Trees expand their crowns horizontally and intercept more light as they become bigger. Most of the competition between trees in southern Ontario is for light and to a lesser extent nutrients and moisture, so the larger/taller trees tend to dominate and suppress the growth of smaller trees and this may result in the death of the smaller tree (self-thinning).

Growth patterns vary by species. For instance, some species cannot compete with either woody or herbaceous weed competition unless they are dominant during the brushy stage (the period when all trees are within the same layer at the beginning of the stem exclusion stage). Red pine must be dominant at this stage to survive, while yellow birch may grow through the competition during the brushy stage. Some species (pioneers) grow rapidly when young and dominate the stand, but depending on their adaptations, may dominate the stand for a long period or succumb to competition or live in a subordinate position. If species are tolerant of shade enough to survive in subordinate positions, the forest can develop a vertical stratification of foliage levels. If the species which lags behind cannot survive beneath the overstory, it dies as suppressed trees in single-species stands do, and the number of species in the stand is reduced. Thus a stand which begins with many species can potentially be reduced to a single-species stand.

Growth rates vary by species, resulting in a predictable pattern in which one species overtops the other. Or they may have similar growth patterns causing them to interact as a single species, with one asserting dominance and killing the other based on subtle differences in age, site or spacing.

The height growth pattern of individual trees is also affected by stand density. In examining the development of young red oak, Miller et al. (2007) observed that when the canopy is closed, lateral crown expansion is limited and the tree maintains its competitive position through height growth. When neighbouring trees are removed, crown expansion shifts to lateral growth and height growth slows. This suggests that where early stocking is deliberately set at a low level, height growth may be reduced.

Where height growth patterns vary greatly, species with the most rapid early height growth generally form the upper strata. Where only slight differences in height growth exist, factors such as branch stiffness may allow one species to stratify above another. For instance hickories can first grow in the lower strata but eventually grow into the upper strata, battering associated red oak crowns with their stiff branches during windstorms (or the lateral branches of stiff-branched dominants may batter the terminals of other trees, breaking the terminal shoots and reducing their height). Trees with preformed growth tend to develop stiffer lateral branches than lateral branches and terminals of those with sustained growth, thus giving them an advantage.

Trees compete and die earlier at the narrower spacing within clumps, and surviving trees change from a clumped to a random distribution and then approach over time a more regular, evenly spaced distribution. Species in mixed stands appear clumped at first and more regularly distributed with time. Dominant trees approach a regular distribution even more rapidly although the spatial patterns continue to reflect the initial spacing and relative ages within the stand.

Trees that grow rapidly at first but later grow slowly will dominate other species when grown at close spacing (quickly overtopping competitors and relegating them to slow growth in lower strata). At wider spacing a species with slower, continued growth is not overtopped when small and eventually overtops species which later slow in height growth.

Other factors that influence development include:

- shade tolerance,
- level of high shade,
- spatial pattern,
- differences in age,
- regeneration mechanisms,
- site (red oak may surpass red maple on mesic sites, but the opposite will be true on wetter sites), and
- numbers of trees.

Obviously these development patterns become increasingly complex and more difficult to predict as the number of species increase.

Both natural stands and plantations go through the stem exclusion stage. However, the way that single species stands appear and because of the fact that in some areas relatively few plantations have progressed far into the understory re-initiation stage before harvest, may lead some to assume that the stem exclusion structure is unique to plantations.

Image: Stem Exclusion

1.3 Understory Reinitiation

Increasingly more light penetrates into lower strata as trees grow larger – overlapping limbs abrade and break against each other until crowns no longer overlap, greater swaying causes crowns to stay further apart, the death of a single large tree releases more growing space than that of a small tree, heights and crown sizes are less uniform as differentiation proceeds, as trees grow taller, the base of the live crown rises, and more light penetrates diagonally between the crowns. At this point, forest floor herbs and shrubs and advance regeneration again appear and survive in the understory but tend to grow very little.

Understory reinitiation occurs sooner on droughty sites since trees retain less of their lower foliage. Shade tolerant species usually predominate in the forest floor stratum (but some mid-tolerant oaks can survive as advanced regeneration, dying back to the root collar and resprouting continually until released). The understory becomes more vigorous as more growing space is available, but without significant disturbance, understory trees remain quite small and distinct from the overstory for a long time.

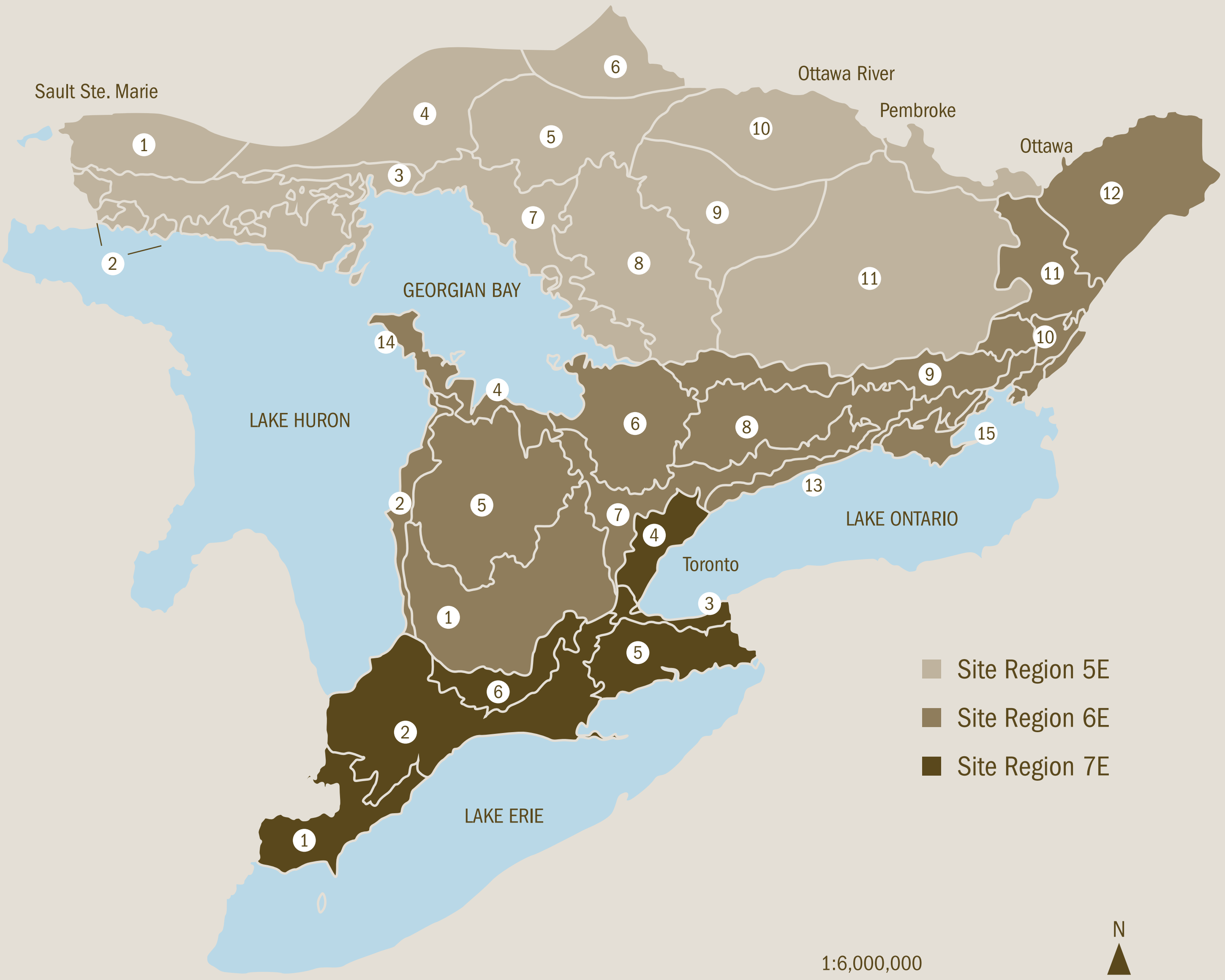
In terms of habitat and other management implications, there is less browse created than in the stand initiation stage, but the added cover of tall trees is very important for some species. If the understory includes an undesired species component, additional silvicultural effort is required, particularly when encountering invasives like buckthorn that may disrupt the successional trajectory and prevent normal stand evolution.

1.4 Old Growth

Much later, as the forest enters the “old growth” stage, individual large overstory trees senesce and die in an irregular fashion. Other overstory trees are unable to reoccupy the released space rapidly. Newly germinating and sprouting trees and advance regeneration grow upward into the main canopy. Younger trees usually include several age classes as older trees die at irregular intervals. The result is the development of a wide range of ages and heights, with foliage well distributed vertically. The time required for the onset of this stage is usually 100-500 years, but sooner on poor sites as less time is needed for older trees to senesce.

Image: Understory Reinitiation

Site Regions and Districts, Southern Ontario



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Description of the Area and its Variability

The area considered in this discussion paper includes that portion of southern Ontario that is generally south of the Canadian Shield and extending north into Renfrew County. Much of the restoration focused afforestation work to date has been in south-western Ontario within Ecoregion 7E. This area is unique in terms of its distinct vegetation, flora and fauna, the high concentration of Species at Risk (SAR), the extensive loss of forest cover as well as the impacts of agricultural, urban and industrial development. Nevertheless many of the approaches discussed are of interest and are being considered for application in other areas of southern Ontario and for that reason, this discussion will include the broader area.

Dry-fresh blowsands such as those found in the St. Williams, Vivian, Midhurst, Ganaraska, Limerick, Larose and Renfrew areas have a history of land restoration and timber production as evidenced by the abundance of red and white pine forests established on typically dry-fresh sites. Clay dominated, poorly drained sites such as those found in Essex, Simcoe or Stormont and Dundas counties present unique challenges related to root establishment and poor subsequent growth. On shallow dry-moist sites in the Owen Sound and Smith's Falls areas, high drought related mortality and species such as the native Prickly Ash can be a particular challenge during afforestation efforts.

This variation in soil condition will limit the options for afforestation in some areas and increase them in others, particularly with respect to the use of direct seeding as opposed to bareroot or plug stock, opportunities for the immediate establishment of hardwood species, approaches to and effectiveness of vegetation management efforts, or long-term expectations of eventual cover type. Thus the management challenges posed by local site conditions as well as the likely successional pathways and species composition on a given site have to be a consideration when establishing long-term management objectives and certainly in the development of treatment approaches that may effectively lead to the achievement of those objectives. In this regard it is critical to match species to site conditions—in a systems approach; all species selected should match the conditions.

More recent restoration efforts often seek to quickly move sites to a diverse hardwood forest condition...

03

Management Objectives and Related Treatment Approaches

Landowners and land managers in southern Ontario usually identify several objectives to be achieved through their afforestation programs. The production of "marketable volume" is rarely the sole or even principal objective, but it certainly can be a by-product of efforts aimed at ecological restoration, site rehabilitation, biodiversity enhancement, carbon sequestration, improved wildlife habitat, improved hydrological functions, better water quality, and/or aesthetics. Some jurisdictions with a long history of forest management are now realizing significant revenues as a result of early afforestation efforts which can now be reinvested in further restoration and forest management work, and feel that that aspect is an important consideration. Some owners or managers may determine that harvest operations are not compatible with the long-range objectives for certain sites and those considerations are important as well.

Conventional and more recently applied ecological restoration-focused afforestation efforts differ in terms of the time-frame within which specific restoration objectives are to be attained. Conventional approaches tend to emphasize conifers which are capable of putting on fast early growth and achieving quick crown closure intended to reduce and remove heavy sod layers which otherwise would challenge the early establishment of hardwoods. On degraded sites, soil amelioration may be an objective of those conventional approaches as well since over time, many of those sites become more amenable to the natural establishment of diverse hardwood species. This process can take decades, but as will be discussed later, can be accelerated by specific management actions. More recent restoration efforts often seek to quickly move sites to a diverse hardwood forest condition citing concerns related to habitat loss particularly in the southwest, related issues of species at risk (for example, the Eastern Hognose Snake) and the need to maintain and restore diversity. The approach is often to establish a collection of species from the same vegetation community in order to meet biodiversity objectives in a very short time frame (for instance at Lake Erie Farms, 144 native bee species were noted two years after initial treatment (Alana Taylor. 2009. pers. comm.)). The sense of urgency expressed by the landowner is certainly a factor.

Treatment cost is a consideration as well. It is recognized that many of the conventional approaches are based on early work that focused on capturing and converting sites from agricultural use to forest cover quickly and in the most cost effective means possible. Conventional afforestation work has usually incorporated considerations to lower costs to the landowner for site preparation and planting, and to permit ease of tending as required to ensure high survival. Those prescriptions may also include modifications to enhance value and opportunities for later cost recovery by incorporating considerations for eventual stem size, degree of taper, uniformity or knot characteristics. Some of these factors may have no relevance if the owner/manager is solely concerned with restoration, or may be quite relevant if immediate treatment costs or later potential revenues that may help to offset treatment costs are of interest.

A well-informed landowner who has clear goals and is aware of the opportunities and costs for either approach on a specific site is key to determining the approach to afforestation. This has to be coupled with an excellent understanding of the potential of the site, the landscape context, and the management challenges that are likely to be encountered—skills and knowledge to be provided by the land manager. Finally, funding organizations need to be aware of the relevant landscape level goals along with the balance of ecosystem representation to be targeted, and incorporate those goals into their funding criteria.

3.1 Afforestation with a Restoration Focus

Restoration efforts stress the principles outlined in *The SER International Primer on Ecological Restoration* (Society for Ecological Restoration International Science & Policy Working Group, 2004), all of which make good biological sense whether attempting restoration at a very basic or fairly intensive level. Some of the critical attributes of a restored ecosystem include a characteristic assemblage of indigenous species, representation of all functional groups necessary for the development and/or stability of the ecosystem, and a physical environment capable of sustaining reproducing populations of the species necessary for its continued stability or development.

From a field applications viewpoint, restoration focused afforestation often includes all or some of the following characteristics that practitioners feel differentiate it from conventional afforestation:

· a greater diversity of species planted, including the establishment of a high proportion of hardwood species (where the reference ecosystem indicated such a condition should be targeted),

· generally a greater focus on rapid restoration to a mature, diverse forest condition (species, structure) and less on wood products,

· native seeds collected and sown,

· reduced planting density and variable spacing,

· hand planting favoured, with selective use of mechanical seeding,

· focus on control of persistent invasive species,

· site rehabilitation to address hydrological restoration,

· greater emphasis on re-establishing more natural habitat conditions, and

· greater emphasis on connecting existing forests.

Of course the model or reference ecosystem being employed will drive the selection of species and the degree of diversity. Thus if a low diversity ecosystem such as a cedar swamp or pine barren is being restored, the plantings would be dominated by white cedar or pine species. However, many of the restoration projects in south-western Ontario do occur on naturally diverse sites.

The restoration plan in Appendix A illustrates the range of objectives, the planting materials required (in this case 13 species of graminoids, 27 tree species, 12 shrub species, and 41 species of wildflowers), the importance of hardwood tree species in the planting program and the reliance (in many cases) on planting tree seed rather than bareroot or plug stock, for one typical site. This plan is offered as an example only since each restoration plan should be customized to the conditions and appropriate vegetation for the site. The wide diversity of species to be established on this particular site is intended to emulate that occurring in naturally regenerating stands on similar site types and is hoped to mitigate the impacts of potential invasive insect or disease infestations. Species distribution is random within this planting site, but can be influenced at a coarse level by adjusting the amount of seed by species that is committed to various strata. While this particular plan utilizes a broadcast seeding approach, other projects may incorporate pod planting, scatter plants or the creation of oxbows and/or pit and mound with subsequent planting of seed and bareroot stock on the prepared site.

3.1.1 POD PLANTINGS

Pod plantings (Figure 2) are intended to create as much habitat and structural diversity on a site as possible. Tending is more challenging since trees are not planted in rows so effective site preparation, species selection and site design are essential for success. Generally "pods" or clusters of trees are planted throughout the site and range from five to 30 meters in diameter with six or more metres between adjacent pods. Pod size is highly variable depending on topography and overall restoration goals – for instance smaller pods are established when promoting oak savanna and open habitat.

Tree spacing within the pod is usually closer (1.2 – 1.8 m between trees) than typical row plantings (1.8 by 2.4 m), since the intention is to promote earlier crown closure, earlier shading of the competing ground vegetation, and more rapid vertical growth. Trees with similar growth rates are planted together in small pure clumps to encourage their long-term survival, thus maintaining species diversity over time. Species typically found in a late successional forest are planted in the center of the pods with early successional trees and

Figure 2: Pod Planting

shrubs planted along the perimeter. Areas between the pods are planted with native ground cover to deter the establishment of invasive, non-native grasses and weeds and to promote biodiversity.

As the site matures, the late successional species are intended to compete with each other promoting straight growth with the early successional trees growing faster and shading the sides of the pods (minimizing side branching on the late successional species). The early successional species are expected to eventually invade the areas of native ground cover, connecting the pods and forming a continuous forest.

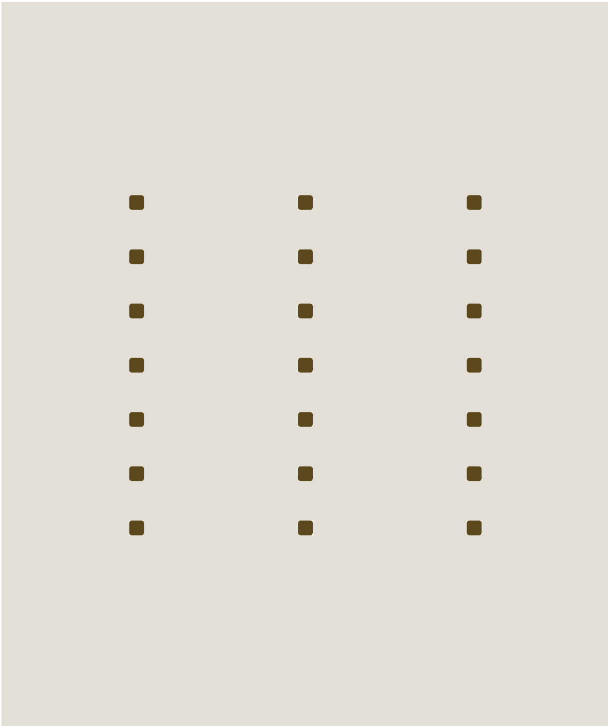
3.1.2 SCATTER PLANTS

Scatter planting activities incorporate the planting of native ground cover throughout the site with trees planted randomly (although similar growth rates and moisture requirements are considered in selecting the species mixes) at a spacing of roughly 1.8 by 2.4 m. The random spacing and arrangement of species is intended to emulate the arrangement of naturally established seedlings, but also serves an aesthetic function for owners who object to the artificial appearance of rows. There are later challenges related to follow-up tending as discussed earlier.

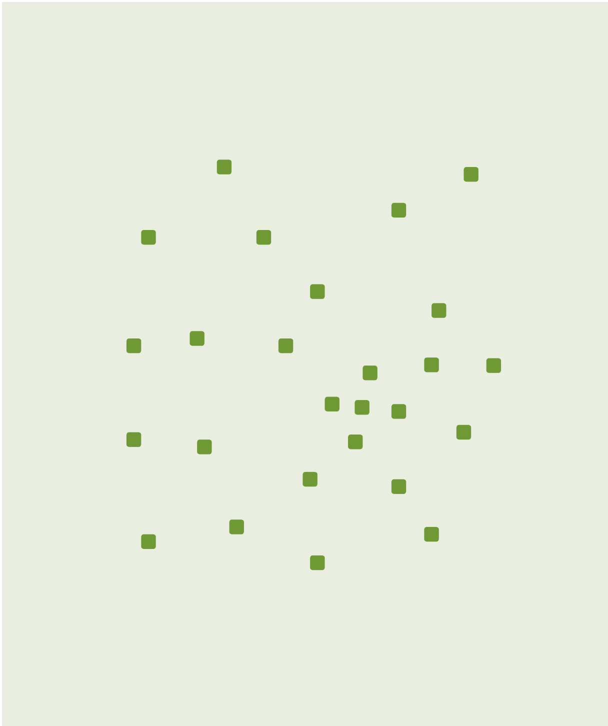
In both pod and scatter planting designs, species such as white pine may be planted in small clusters to maintain a native conifer presence in the restored landscape while avoiding the creation of a monoculture. Longterm maintenance includes spot spraying of sod forming cool season grasses and other invasive species (e.g. dog strangling vine) to minimize their spread, and manually removing vines (vetch, bindweed, grape etc.).

3.1.3 SEEDING

Direct sowing of desired species is a mechanism used on some sites to reduce cost and increase effectiveness of large-scale planting. The same concerns related to the control and restriction of invasive exotics, the establishment of a wide range of native tree species with a focus to those species not expected to arrive on the site by natural means, and the establishment of native cover are built into the program, as with other restoration efforts. Appendix A provides a more detailed description of one such effort. Of interest is the implementation of agricultural cultivation and chemical competition control prior to commencement of the project, and further efforts to restrict invasives from entering around the perimeter of the site.



Conventional Row Planting



Scatter Plotting

3.1.4 HYDROLOGICAL RESTORATION

Tile breakage, removal of drains or dams, and recreation of oxbows in streams are common approaches used to restore more naturally occurring moisture conditions to the landscape. Tile breakage has been implemented prior to many conventional afforestation efforts as well.

Pit and mound (Figure 3) may be created in order to re-establish the type of micro-topography characteristic of a natural forest environment (naturally occurring pit and mound are typically levelled out during decades of cultivation and agricultural use). Both the spacing and depth of the pits will vary from one jurisdiction to another, but a typical treatment in the Essex Region Conservation Authority is to enter the site after soybeans or winter wheat have been harvested (weed control a by-product of crop production) and establish approximately 200 to 250 pits per hectare with each pit 15 to 45 cm deep and 1.8 by 2.5 m square. The mound piled to the side of the pit is usually .65 m high. In the following spring, an herbaceous cover (native grasses, wildflowers and sedges) is seeded over the site (wetland species in the pit, a drier seed mix on the mound), after which a mix of nuts (acorns, hickory nuts, walnuts, hazelnuts) and bareroot or plug stock are planted on each pit and mound complex. In other areas, deeper pits and higher mounds than those in Essex have been established. Some managers endeavour to focus the pit/mound work to sites where they would have been most likely to occur naturally (e.g. areas where root depth may be limited by a high water table or bedrock, and the incidence of windthrow would have been a more common occurrence).

The landowner/manager should consider whether potential operational problems may be encountered later in the life of the stand (e.g. increased hand tending and pest control costs, access challenges, thinning, etc.) that will result from the irregular topography, but it is recognized that these considerations will not be factors in all situations.

3.1.5 COMPETITION CONTROL

Most practitioners recognize the importance of competition control in the establishment and growth of hardwood seed or bareroot stock. In some cases, the landowner may be required to grow and harvest a crop of corn in year one, and then grow and harvest a crop of soybeans in year 2. Following that investment, the establishment of forest cover begins. This cropping schedule provides several advantages including the ease of mechanical tree planting in soybeans as compared to corn stubble and the added benefit of reduced residual nitrogen fertilizer after soybean harvest. Since soybeans are GMO Round-up ready there are fewer weeds (but some always remain). Vegetation management efforts vary according to site type.

Figure 3: Pit and Mound Establishment

3.1.6 FIELD PROCEDURES

The following text summarizes some of the restoration-focused field procedures that have been developed from experience in south-western Ontario. Included is a breakdown of the typical practice with respect to competition control, planting arrangement and site considerations on lands managed with a restoration focus by the Long Point Region Conservation Authority (LPRCA), and several recommendations related to the establishment of diverse hardwood conditions. Both may provide assistance to managers developing programs with similar objectives.

LPRCA Restoration Field Procedures

Site preparation is one of the key activities affecting the success of the project, and weed control is one of the most important measures to be taken prior to undertaking restoration. Weed control can be achieved with well-established farming practices that have good weed control programs (controls every year to minimize weed seed production and availability), herbicide applications prior to restoration (the fall before or early spring), or topography restoration (pit and mound, dune creation, bottomland oxbow etc.) to bury competing weed seeds and topsoil and expose sterile subsoil. Non-native cool season perennial grasses and vines are the competing vegetation types that cause most restoration failures. It is important to assess weed competition in the year prior to planting activities to ensure the proper treatments are implemented to maximize success.

As a general rule, nutrient rich clay loams and alluvial soils have higher weed competition than nutrient deficient sandy loams. After herbicide treatments related to pod or scatter plants have been completed, it is recommended that no further tilling be undertaken (thus avoiding opening up the seed bank and promoting new growth). Disturbing the soil is necessary when planting trees in rows on heavier soils and when undertaking topography restoration. An additional herbicide treatment may be required in these situations if early weed germination occurs.

The tree species utilized in the restoration project should be planted on favourable sites (soil texture, depth and moisture regime), and with other compatible species. To ensure slower growing species such as white oak, shagbark and bitternut hickory survive to maturity, they should not be planted in the same pod as faster growing species such as red oaks, black oaks and black cherry.

Clay Loams

Sites with clay loam soils have the potential to produce good growth as long as weed competition is managed and sufficient topsoil is present. Hill slopes that have been farmed for many years may have very little top soil and would be better suited for early successional species (aspen, grey dogwood) or planted into native grasses and forbs. Topography restoration on clay loams may include pit and mound (more in the lower wet areas and less in the uplands) and the creation of wetlands (shallow and seasonal in nature that promote the development of silver maple/red maple swamps). Any tiling or open drains in the site should be removed to restore the natural hydrology.

Sandy Loams

Sites with sandy loam soils generally have fewer nutrients, but due to the lack of competition still produce acceptable growth rates. With effective site preparation, planted stock can grow successfully with minimal weed competition (annual weeds such as Horseweed, Ragweed, Pigweed and Lamb's Quarters are not considered competitors to trees (Louter et al. 1993 & P. Gagnon. 2009. pers. comm.)). These sites are good candidates for native ground cover establishment prior to tree planting activities. Native perennials such as prairie grasses and forbs (butterfly milkweed, Brown-eyed Susan, bushclovers, lupine, flowering spurge etc.) are slow to establish, making them ideal for suppressing non-native weeds while not competing with planted trees in the first few years of restoration. Topography restoration on these sites can include pit and mound (generally restricted to lower areas with high water tables), sand ridge/dune creation (in dry locations) and wetland creation. Tiling and drains should be removed.

Alluvial Bottomlands (AB)

Sites with AB soils have the potential to produce the best growth rates of all restoration sites, but they also are the most challenging in terms of weed competition since sites may be inundated by flood waters two or three times per year depositing a variety of competing weed seeds during each event. Generally, traditional site preparation cannot be undertaken at these locations due to the potential for erosion and the timing of standing water on the site. AB sites located in sand plain watersheds drain well and do not remain flooded for long periods of time. Pod plantings seem to be a preferred option on these sites, with weed control methods limited to the pod locations. After spring runoff, Glyphosate can be applied to the dry pod locations (usually located between the watercourse and any floodplain swamps at the toe of the valley slopes) to control existing weed competition. Tree species are planted at closer spacing than in upland sites to promote the shading of competing weeds, and early successional species such as Balsam Poplar and Trembling Aspen are planted along the perimeter to promote the expansion of the pods. Additional treatments with Glyphosate or Simazine may be required in the second and third year.

If the topography has been altered in the past, restoration including pit and mound and wetland creation may be conducted. Floodplains are generally considered depositional in nature with larger particles (sand and fine gravels) being deposited next to the watercourse and fines being deposited closer to the valley walls. This characteristic has a tendency to create natural berms between the watercourse and the rest of the floodplain storing high flows in the bottomlands, depositing fines and creating seasonal/permanent wetlands. Bottomlands that have been in agricultural production have usually been levelled to allow rapid spring drainage thus removing this natural berm. Therefore wetland creation should include excavating material from the toe of the valley slope and moving it to locations near the watercourse or placing it against the valley wall. When undertaking this activity it is important not to remove any potential flood storage (promote the cut and fill method). In bottomlands with a high sand component, wetlands in combination with pit and mound creation can be excavated deeper and still support silver maple forests and other associated tree species. Bottomlands located in watersheds with primarily clay soils generally show uniform sediment deposition throughout the floodplain. Suggested topography restoration for these sites may be a combination of pit and mound and shallow wetlands at the toe of the valley slope.

Where an existing seed source is nearby, ingress of naturally established sycamores, cottonwoods and aspens is common on these disturbed sites, often surpassing those trees that have been planted.

Hardwood Establishment—Recommended Field Procedures

Both hardwoods and conifer species are utilized in afforestation programs, although restoration efforts in the southwest tend to emphasize hardwoods. Hardwood establishment can be more challenging. The following suggestions, as adapted from advice provided by M. Gartshore (2009. pers. comm.) may assist in dealing with some management issues:

· Identify reference sites to emulate, paying attention to enduring features (soil, landform, moisture),

· Plan on the project being adaptive, iterative and results-based,

· Use direct sowing. Minimal top growth while root development is occurring is the primary goal for up to the first three years, and this can reduce the likelihood of predation,

· Plant native strawberry plugs (*Fragaria vesca*, *Fragaria virginiana*). Strawberries often form an early matrix that permits native species but excludes exotics such as forage species. Excellent for pod plantings,

Source: Ed. J.T. Trowbridge, Lucy Larcom, Gail Hamilton: Our Young Folks;
An illustrated magazine for Boys and Girls (Boston: Ticknor and Fields, 1866) 491

· Avoid and eliminate Eurasian forage and lawn species including some biennial and perennial weeds. Focus on good site preparation and yearly exotic weed control (using backpack sprayer),

· Site preparation is important for weed management, hydrological function and easy establishment of native species,

· Once planted keep all vehicles, ATVs, mowers and farm equipment out of the site. This disturbance not only brings in more weeds but also negatively affects biodiversity levels,

· Match species to the eco-region and to specific site conditions,

· Use a diverse suite of species drawing from grasses, vines, wildflowers, shrubs and trees,

· Accept early agricultural native and non-native annuals (Lamb's Quarters, Pigweeds, Crabgrass, Horseweed, and Ragweed). They will control perennial weeds, provide water from shed dew, hide native plants from predators, bring nutrients to the surface and provide exceptional nutrition when they die. They will not grow from seeds if soil is not disturbed,

· Accept that native plants add value and even if they compete somewhat with new trees, the trees are adapted to such circumstances and the new forest will sort it out. Focus on controlling exotic species.

· Make efforts to accelerate succession of conventionally-established conifer plantations toward more natural conditions, using native plant seeds, and introducing native shrub species in openings, creating openings if none exist.

· The new forest should complement nearby natural forests. New plantings should be seamless with contiguous natural areas.

· Monitor project using census plots, photographs, faunal and floral surveys.

3.2 Conventional Afforestation

The objectives for the afforestation effort as undertaken in Ontario at various levels since the early 1900s are varied as indicated earlier in this paper and the accomplishments have been significant. Those efforts have demonstrated over time the ability to include an economic/timber product component (where that was the owners' objective) while realizing many other overall objectives.

The knowledge gained during the implementation of those programs has been significant as well. Conventional planting has a long history of documentation and research dating back to E. J. Zavitz's experimental tree planting trials starting in 1905 at the Ontario Agricultural College in Guelph. Over the years, numerous researchers in Ontario (e.g. Fred von Alton, C. Larson, etc.) in addition to researchers in the northeastern and central United States have experimented with and outlined successful practices for establishing trees. The results of these trials have lead to the development of conventional tree planting approaches by forestry professionals.

White et al. (2005) provides a summary of the necessary considerations and approaches for conventional plantation establishment in southern Ontario, including:

· crop planning,

· species and site compatibility,

· site preparation,

· stock handling,

· planting methods and tending.

Those principles have been developed over time and are generally understood by managers in southern Ontario.

3.2.1 SPECIES CHOICE AND SITE CONSIDERATIONS

Site suitability is the major determining factor in species selection. Within the bounds of a variety of biological constraints, species choice is further influenced by the priorities of the landowner, treatment cost and likelihood of establishment success. Figure 4 provides a typical decision key used by managers in southern Ontario when considering species/site compatibility.

Planting sites are typically stratified according to soil texture, depth, moisture regime and drainage. Within a stratum, one to three conifer species most suited to the area may form the bulk of the planting with an additional two to four species sometimes added as a minor component. Both hardwood and conifer species are included in conventional afforestation programs, but for a variety of reasons, conifers are usually emphasized.

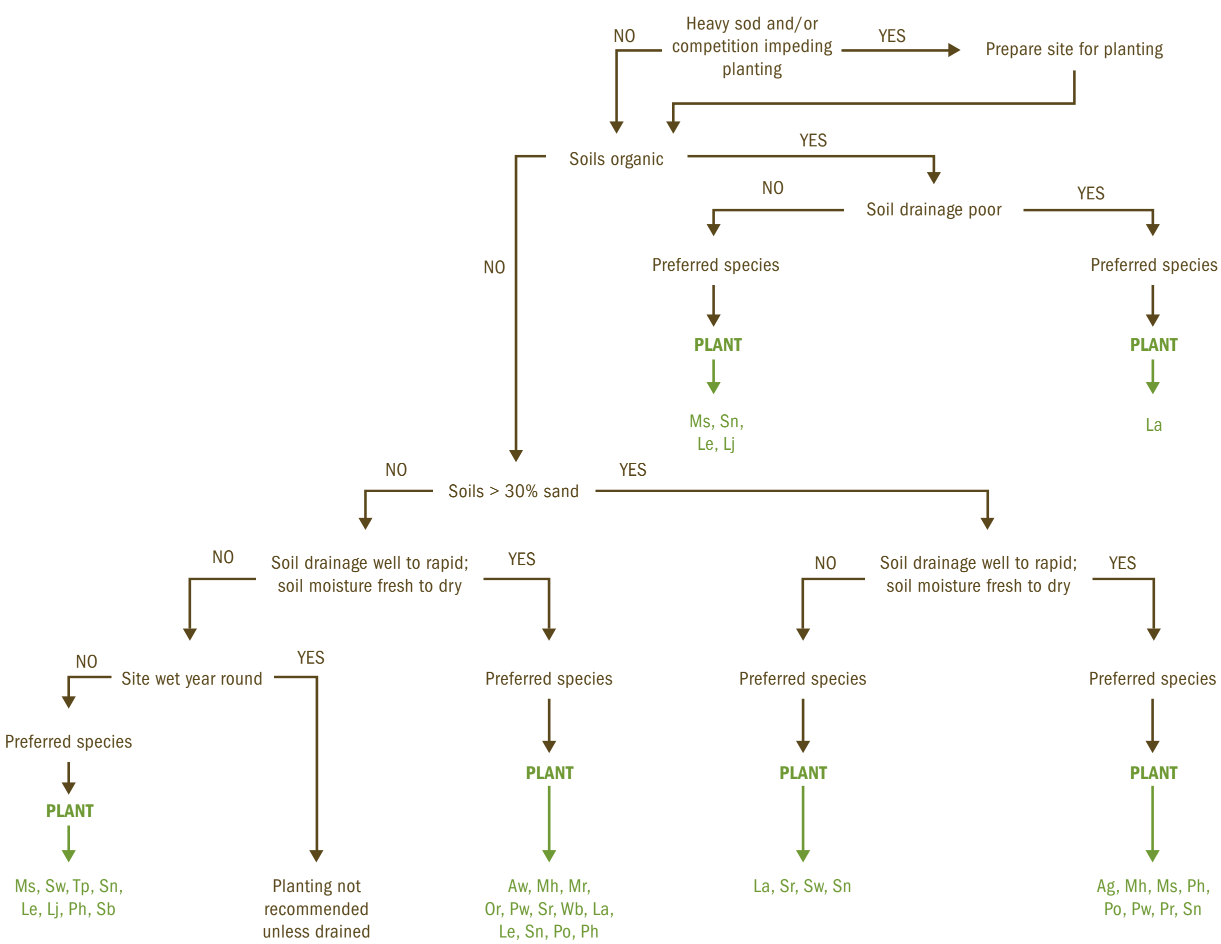


Figure 4: Silvicultural key for identifying preferred species in relation to soil and site characteristics (White et al. 2005)

Many of the sites available for afforestation have been degraded by past agricultural activity and are characterized by reduced fertility, soil profile simplification and sometimes topsoil loss (McPherson and Timmer, 2002). Where those site productivity limitations exist, coniferous species are typically the best option, therefore species such as red pine (particularly on infertile, well drained soils), white pine, white spruce and several others have been most commonly used.

Most late successional and some mid-successional tree species are adapted to establishment under a forest canopy. Conventionally established conifer plantations create forest conditions relatively quickly due to uniform spacing and rapid achievement of crown closure, and thus can later provide an overstory condition suitable for the natural establishment of many native hardwood species. Species like beech, sugar maple, hemlock etc. are challenged by numerous issues in open fields not the least of which are the missing microclimate conditions of a forest.

Besides being more demanding for soil nutrients and moisture, hardwoods are highly susceptible to herbaceous competition and rodent damage. Von Althen (1977) listed several requirements for successful hardwood plantation establishment, including the following:

· a deep, moist but well-drained planting soil,

· ploughing and disking the total area,

· effective weed control for the first two or three years after planting,

· rodent control where necessary.

Some planting agencies restrict the proportion of hardwoods included in their operational programs because of the competition and predation issues (G. McLeod, pers. comm.). Ecoregion 7E is an exception—suitable sites for hardwood establishment are available and landowners are often willing to accept responsibility for the additional costs of site preparation and several years of follow-up tending. In the most south-westerly portions of Ecoregion 7E, there are few native conifers other than Eastern Red Cedar for managers to consider and with little forest industry, management must be done with the assumption that later thinnings will not occur.

3.2.2 SPECIES MIXTURES

Conventionally established plantations have often been of a single species, but may incorporate several species depending on site and landowner interests. Usually the other species are planted in alternate rows, or in uniform blocks, their locations dictated by local soil characteristics. Block planting can increase operational efficiency and survival, facilitating weed control, protection from browsing, and thinning to favour the best individuals (von Althen, 1988), but where species are compatible in their growth characteristics or when specific objectives are to be targeted (e.g. using white pine to train red oak), they may be intermixed, typically by row.

Alternate row planting (for example black walnut and white pine, or white pine and red oak) has often achieved very satisfactory results. When species selection and distribution is random with little accommodation for different growth patterns or site variability, results have been disappointing and subsequent management efforts, especially 25 to 40 years later, more challenging.

3.2.3 SPACING

Where timber production is one of the objectives for the plantation, the maintenance of regular spacing permits crop tree development that is relatively predictable and uniform. Tree spacing may vary from one block to another but is usually dictated by the desired density at the time of the first planned thinning, thus it will vary with species and anticipated product. Adjustments can be made to meet specific objectives (e.g. higher densities to promote early pruning of side branches and the development of clear boles; lower densities where larger material must be available to warrant thinning activities).

3.2.4 COMPETITION CONTROL

Both woody and herbaceous vegetation can impact tree survival and growth on old field sites through direct competition for light, water and nutrient resources, and the cover provided to rodents. Managers have several options when managing competition, including brush cutting followed by a herbicide application when undesired species are too tall to manage effectively with a chemical treatment alone, use of a post-emergent herbicide followed by cultivation when dealing with perennials, mechanical site preparation alone if annual vegetation has not gone to seed, or Simazine applied in strips or over the entire site when managing heavy sod (White et al. 2005). Cover crops such as barley, wheat, rye grass or Dutch white clover have been established in conjunction with herbicide on some sites with the objective of reducing the requirement for subsequent herbicide applications or mowing. This type of application has been employed operationally in several areas (e.g. Essex Region Conservation Authority, Upper Thames Conservation Authority). The choice of cover crop type sometimes requires a trade-off between overall effectiveness, seed availability and cost. For instance clover is relatively inexpensive but may contribute to browsing damage in areas where deer populations are high, or could provide habitat for rodents unless mowing is done through the growing season and into the late fall. Cover species such as native clump forming grasses or wildflowers can be very effective but the seed may be more costly to purchase initially.

Boom sprayers (mounted on farm tractors or ATVs) and spot spraying are the most common approaches when chemical tending. In very competition prone areas of southern Ontario, up to three separate chemical applications are considered necessary to ensure successful plantation establishment. Mechanical tending (mowing or roto-tilling) is an option as well, but is generally less effective than chemical approaches. For large scale operations, both chemical and mechanical competition control are facilitated by regular spacing and distribution of the crop trees.

3.3 Knowledge and Experience Gained

The availability of post–establishment data is limited for more recent restoration efforts, and the protocols for plot establishment and measurement vary. This is a serious knowledge gap. Despite this, efforts to understand the ecological processes and species silvics, using reference ecosystems and site-based understanding of successional trajectories continue to aid in predicting success rates and future trajectories. Many development patterns may be inferred by examining past successes and failures. Adaptive management and monitoring are critical.

Several steps are critical to afforestation success, from determining species/site suitability, most appropriate competition control approach, selection of stock type or seed, stock handling and planting approach, tending and sometimes subsequent pest management. Each step is important and there are many examples of a newly established forest subsequently failing because of a lack of timely tending or pest control. Following is some of the information gained from past experience and experimentation that may help in ensuring a successful afforestation program, regardless of the programs' motivation.

3.3.1 HARDWOOD ESTABLISHMENT

Bareroot Stock

Hardwood plantation establishment efforts have often been disappointing because managers had insufficient knowledge of the site requirements of the various species, and planting techniques developed for planting conifers had proven to be unsuitable for hardwood planting. Successful hardwood establishment requires intensive site preparation and tending for at least three years to maintain a relatively weed free site, while conifer species require less intense management, usually for only one to two years (White et al., 2005).

Many potential planting sites in southern Ontario are not amenable to cultivation prior to establishment (usually considered a prerequisite to hardwood planting programs). Where cultivation and competition control were not carried out adequately, survival, growth and form were unacceptable. Where sites were suitable, the high cost of cultivation and subsequent weed control sometimes exceeded the capacity of the landowner or the planting agency over the long-term, again leading to less than satisfactory results.

Inappropriate or misapplied competition control efforts have led to difficulties as well, particularly when dealing with Eurasian cool season grasses, which can be introduced by equipment, and which respond positively to successive mowing.

The use of high quality seedlings is critical. Red oak has been studied extensively and research has shown that in order to match the stand development following natural processes in oak ecosystems associated with repeated ground fires, seedlings chosen for planting must have attained the following attributes (as summarized by Dey and Buchanan, 2005):

- A well-developed root system with large carbohydrate reserves, a balanced root: shoot ratio, and a well-branched root system with a framework of permanent lateral roots. First order lateral roots are strongly related to field survival and early growth performance.
- A minimum stem diameter near the root collar. Many authors recommended stock with root collar diameters of at least 7.4 mm, and suggested a minimum diameter of 4.6 to 6 mm when measured 2 cm above the root collar (with smaller trees culled).
- A minimum shoot length – seedlings that are initially taller performed best after outplanting. Some authors recommended a shoot length of 50 cm, and set 30 cm as a minimum.
- Stock age – size of nursery stock is more important that stock age. Two-year old seedlings outperform 1+0 seedlings because they are generally larger and have better developed root systems. Very young but fast growing hardwood plugs show promise for the same reason.

Some of these criteria, particularly that related to root collar diameter, will likely be relevant for other hardwood species as well.

Good growth in plantations established from bareroot stock has been achieved where proper site selection, good quality planting stock, adequate site preparation and necessary tending operations have been factored into the program. McKenney et al. (2008), in their report on the development of hardwood plantations established by von Althen in the 1970s and 1980s recorded MAI (m^3/ha/yr) values for several species ranging from 2-5 m^3/ha/yr. Higher values were shown for basswood (5.09) and red oak (6.76), and lower values for white oak (.43), shagbark hickory (1.39) and black walnut (1.97). While poor on average, black walnut growth was closely related to site condition, with lowest productivity expressed on pure clay soils and good growth on loamy and silty soils.

Direct Seeding

The experience with direct seeding of hardwood species in open field conditions in southern Ontario is rather limited and results are not well documented, although it is an important component of many restoration projects. There have been obvious successes, often on sandy sites, and poorer results observed on heavier soils (J. Enright, per. comm.). In general, resultant stocking levels have been highly variable when compared to bareroot planting.

Direct seeding trials of black walnut, northern red oak, white oak, bur oak, swamp white oak, sugar maple, and shagbark hickory in Wisconsin showed black walnut with the most consistent stocking (many sites developing more than 1235 sph) while red oak germination was more variable (several sites having very low germination rates), and direct seeding success rates for white oak were very low (Edge, 2004).

The experience with light-seeded species such as ash, maple and birch is very limited as well, and suggestions range from treating the approach as experimental until more field research is completed (Edge, 2004) to observations that relatively small seeds such as ash and birch are simply unsuitable for direct seeding (von Althen, 1977). It is worth noting that direct seeding of yellow birch has been successfully carried out in shelterwood understory conditions where a cool, shaded and somewhat moist environment can be maintained during the germination and early development stages.

Mechanical or spot seeding is a more efficient use of seed than broadcast methods, allowing better control over final stand density and lowering planting costs (Edge, 2004). Seed desiccation on the soil surface has resulted in poor germination and regeneration failures following broadcast sowing of red oak acorns (Dey and Buchanan, 1995). Seeding depths for acorns of between 2.5 and 5.0 cm reduce the risk of desiccation and are recommended.

Table 1 provides an estimated seed to seedling ratio based on Ontario nursery records, assuming site preparation and competition control are carried out as required. This table may assist managers in estimating the number of seeds required to produce a single one year old seedling, and thus develop specific afforestation plans.

Table 1: Estimated seed required to produce a year old seedling (Swaile B., 2009. Pers. comm.)

Species Name	Seed:Seedling Ratio Bareroot
Yellow birch	15 to 1
White birch	15 to 1
Green ash	9 to 1
White ash	9 to 1
Butternut	4.5 to 1
Bitternut hickory	5 to 1
Shellbark hickory	5 to 1
Pignut hickory	5 to 1
Shagbark hickory	5 to 1
Black cherry	10 to 1
Hard maple	**12.5 to 1**
Red maple	10 to 1
Silver maple	5 to 1
Bur oak	3 to 1
Red oak	3 to 1
White oak	5 to 1
Black oak	5 to 1
Swamp white oak	5 to 1
Black walnut	2.5 to 1

Direct seeding of some hardwood species, particularly the large-seeded species, has advantages. Seedlings arising from planted seed will develop more natural root systems, root injuries typically associated with planted bareroot stock are avoided, there is the potential to more easily regenerate shallow sites, and cost savings can be realized. Competition control is critical, as with bareroot stock. While there are several reports related to the seeding of black walnut and red oak, information on other species of oak or the hickories is limited, so expectations with respect to predation, germination rates and long-term development potential are still being fine-tuned.

3.3.2 SITE CONSIDERATIONS

Any manager initiating an afforestation program must consider the site characteristics and make necessary adjustments to their management approach. As an example, von Althen (1977) cautioned that hardwoods will not produce high-quality timber when planted on dry, exposed slopes and ridges, or in areas where the topsoil is shallow and the subsoil consists of heavy compacted clay. The production of high quality timber will not be an objective for some landowners/managers, but the implication is that survival, growth and general forest health can be affected on some challenging sites. Site conditions that are unfavourable to certain species can challenge a forest establishment program by extending the length of time it takes to achieve crown closure and the efforts required to maintain trees as the primary dominant vegetation. These efforts in turn affect treatment costs. In the von Althen example poor survival and growth leads to wider spacing, an extended period of required competition control and ultimately poorer tree form and height growth.

Attention to site constraints or species/site compatibility varies across southern Ontario, but information on species/site relationships is available for many of the species in question with some of the pertinent information provided in Taylor and Jones (1986) and summarized in OMNR (2000). These reports show species performance by site class for red and white oak (Table 2), bitternut hickory and black walnut, as well as the conifer species typically included in afforestation programs, but there is a challenge related to the availability of similar information for the other oak and hickory species commonly used in planting programs in the Carolinian area.

The species performance tables help the manager by ranking species potential on different site conditions, identifying best and poorest local site conditions and likely problem areas, and predicting variation in species performance due to local changes in soil site quality (OMNR, 2000). The tables will be of use in grouping species that have similar growth potential on given sites and should therefore provide assistance when deciding upon species mixtures. The use of appropriate reference sites is another important tool available to the practitioner, and ideally these should contain examples of the desired future forest condition.

Ecological Land Classification (ELC) for Southern Ontario is another tool that will gain importance in southern Ontario as it is made available and gains familiarity among managers. The ELC provides a common language for the organization of ecological and forest management knowledge of the landbase.

Table 2: Species performance by site class

Red Oak/7e (predicted species performance by Site Class[1]

	Depth to Distinct Mottles (cm)						
TEXTURE GROUP (TG)	>150	100-150	80-100	50-80	30-50	15-30	<15
VGR–Very Gravelly							
All textures with >50% of particles >2 mm	-5	-4	-3	-3			
GSY–Gravelly Sandy							
All sandy textures with 20-50% of particles >2 mm	-4	-3	-2	-2	-3	-3	
SDY–Sandy	-3	2*	1*	1	2*	2	-4
vcS, cS, mS, fS, LvcS, LcS, LmS, LfS		25.5	26.9	26.4	24.8	25.4	
GLY–Gravelly Loamy	2*	-2	-2	-1	-2	-3	-4
All C.LMY textures with 20-50% of particles >2 mm	25.3						
C.LMY–Coarse Loamy	2	-2	3*	1	2	3	-4
All SL and L (including vfS amd LvfS)	24.8		23.9	27.6	25.4	23.6	
SIY–Silty	2	-1	-2	-3	2*	1*	4
SI and SIL	24.1				25.2	28	21.4
FLY–Fine Loamy	3*	-3	3*	2*	2	2	2
CL, SCL, SICL	22.5		22.5	25.8	24.6	24.7	25.1
CYY–Clayey		3*	-3	3*	3	2	3
C, SC, SIC, HC		23.2		22.8	23.8	24.2	23.9
SHA–Shallow			2*	-2	4*	-5	-5
All textures where depth to bedrock ≤50 cm			25.6		21.9		

SITE CLASSES (SI-50 yr): 1: ≥26.0 m 2: 24.0-25.9 m 3: 22.0-23.9 m 4: 20.0-21.9 m 5: ≤19.9 m

White Oak/7e (predicted species performance by Site Class[1]

	Depth to Distinct Mottles (cm)						
TEXTURE GROUP (TG)	>150	100-150	80-100	50-80	30-50	15-30	<15
VGR–Very Gravelly							
All textures with >50% of particles >2 mm							
GSY–Gravelly Sandy			-5	-4	-4	4*	-3
All sandy textures with 20-50% of particles >2 mm						17.1	
SDY–Sandy			-4	-4	-3	2	1*
vcS, cS, mS, fS, LvcS, LcS, LmS, LfS						21.5	24.4
GLY–Gravelly Loamy							
All C.LMY textures with 20-50% of particles >2 mm		-5	-4	-4	-3	-2	-2
C.LMY–Coarse Loamy		-4	-3	3*	-2	1*	-2
All SL and L (including vfS amd LvfS)				20.5		23.2	
SIY–Silty		-4	-2	3*	-2	1*	-3
SI and SIL				20.2			
FLY–Fine Loamy			-3	2	1	3*	-4
CL, SCL, SICL				22.2	23.3	20	
CYY–Clayey			-5	3*	2	2	4*
C, SC, SIC, HC				20.3	21.7	21.9	18.5
SHA–Shallow				-5	-4	2	-5
All textures where depth to bedrock ≤50 cm						22.6	
SITE CLASSES (SI-50 yr): 1: ≥26.0 m 2: 24.0-25.9 m 3: 22.0-23.9 m 4: 20.0-21.9 m 5: ≤19.9 m							

3.3.3 MULTIPLE SPECIES

Some managers have expressed concern related to the practicality of intermixing large numbers of species on a planting site (as opposed to block planting of more than one species on a site) from a cost and from a silvicultural point of view. However several reports provide observations of mixed species tree plantations (von Althen (1977); McKenney (2008); Pedlar et al. (2006 and 2007); Kelty (1992, 2006) with most recording superior growth rates when compared to single species plantations. Pedlar et al. (2006) summarized findings from 110 growth plots in hardwood plantations in southern Ontario; after controlling for soil conditions, mixed hardwood plantations were found to grow at a rate about twice that of hardwood monocultures.

There are conditions, however – Kelty (1992): "There is no evidence to indicate that a mixture of randomly selected species would generally out yield a monoculture of the most productive component species. Species that are used in mixtures must have good ecological combining ability – significant differences in growth characteristics that will reduce competition or foster facilitation. Furthermore, the species interactions must increase efficiency of use of a resource that is a limiting factor to productivity". So for instance, component species in a mixture should occupy different strata in the canopy (e.g. a fast growing intolerant species in the overstory with a shade tolerant species in the understory) or different rooting zones in order to maximize production.

Combining species that differ in characteristics such as shade tolerance, height growth rate, crown structure (particularly leaf area density), foliar phenology (particularly deciduous versus evergreen habit), and root depth and phenology is important in designing highly productive mixed-species stands Kelty (2006). Where species' crown or root structures are complementary, Kelty recommends mixing the species on a tree-by-tree basis to maximize interspecific interactions.

On the other hand, von Althen (1988) recommended that when a small number of one species is planted with a large number of another species, group planting may be more successful as the chances of survival and adequate growth are greater. He further observed that while the random mixture of many species may be the most desirable arrangement ecologically (most closely resembling the arrangement in natural stands), the management of random mixtures for high quality timber production requires greater expertise than management of plantations in which a row of one species alternates with a row of another species.

Hardwood plantations established for timber production should contain species with comparable growth rates (von Althen, 1988). Edge (2004) went further, noting that species with very different juvenile growth rates (such as walnut and oak) may not be compatible.

Many situations have been observed where a mixture of species (often white pine and white spruce or white pine and red oak) were planted, with the dominant species eventually showing good growth, better spacing and good form because the less dominant species slowed and eventually succumbed to suppression. With better spacing and larger diameter residual trees, windthrow and wind damage were less of a concern. So while the slower growing and eventually suppressed species did not make up a significant component of the final stand, they performed a role in canopy closure, spacing and promoting good growth. A manager who understands and can predict the interaction of different species on a particular site may use that knowledge to achieve a variety of goals.

Managers should consider both the cost of establishment and the cost of future management. The initial plantation design in terms of species arrangement, row width and density will affect the future forest condition. Some multiple species plantations have such a complex arrangement that future opportunities to adjust density or obtain intermediate revenues will be compromised by inoperability. The profitability of future operations will be influenced by the value and volume of wood as well as the cost of extraction.

3.3.4 CONSISTENT SPACING

Control of spacing at the time of plantation establishment and through the life of the stand can make stands less susceptible to insect and disease build-ups or windthrows and stem breakage (Oliver & Larson, 1996). The uniform age and spacing of single-cohort plantations allows control of species composition, manipulation of more uniform stands, growth of more uniform tree sizes and wood properties and attainment of quicker financial returns. While offering more efficiency of management, managers must also accept the need for more careful thinning to avoid stagnation.

The timing of crown closure and slowing of diameter growth is controlled by initial or early spacing of trees. Trees at uniform spacing and equal vigour are less likely to differentiate than those at an initially irregular spacing. Regular spacing is more likely to yield trees of uniform, predictable size.

Image: Consistent Spacing

3.3.5 HYDROLOGICAL RESTORATION

When trees fall over creating the pit and mound condition, the root environment is altered, changing the soil potential to support growth. Raised, aerated soil conditions are created on the mounds while adverse soil processes are disrupted, allowing certain tree species to establish and grow in areas where they otherwise could not. On the mound, mineral seedbeds suitable for germination of light-seeded species are made available. Advance regeneration or stump sprouts survive on the undisturbed soil between new pit and mound. The pit itself often becomes saturated with water making the soil anaerobic and unsuitable for root growth. Subsequent accumulation of organic matter can further discourage growth (Oliver and Larson, 1996). On some sites however, the pit can become a permanent storehouse for water, allowing an accumulation of organics, in turn supporting tree growth. The potential positive and negative effects on eventual tree density and growth should be factored into the managers' plans for the area.

The forest floor will retain the pit and mound relief and variations in soil condition for several hundred years. With farming these hummocks are levelled out and are usually not present on sites scheduled for afforestation. Where not recreated artificially, pit and mound will eventually develop naturally after the forest is re-established, trees mature, and are again blown over.

Image: Hydrological Restoration

3.3.6 RESTORATION AND CONVENTIONAL AFFORESTATION

Succession in conventionally established conifer plantations toward more natural forest conditions has been noted in many areas as those stands develop, particularly where managers have been actively engaged in thinning programs over time. Examples from the LPRCA which illustrate this progression are provided in Figure 5. Some work has been done to document this transition and to suggest management approaches to further accelerate that restoration. Parker et al. (2001 and 2008) have provided a series of management approaches based on their work with southern Ontario conifer plantations, including underplanting and direct seeding options, earlier and heavier thinning (to a residual basal area of 16-21 m^2/ha), and the arrangement of thinning operations (rows for access plus canopy gaps of 1.5 to 2.0 times the height of the overstory). They have demonstrated that managers have the option of commencing thinning operations at 30 to 35 years and allowing natural regeneration to become established over time, or of speeding up the process significantly by thinning earlier and planting and seeding at the time of the first thinning in gaps of a suitable size, recognizing that a combination of both artificial and natural regeneration will result.

Soil amelioration is also a critical aspect of site restoration after agricultural abandonment. McPherson and Timmer (2002) examined soil conditions on degraded sandy outwash areas of the Oak Ridges Moraine that had been planted to red pine. They noted several major ameliorative processes that had taken place since plantation establishment, including:

- the cessation of erosion,
- soil horizon redefinition on non-eroded fallowed sites,
- bulk density reductions due to soil organic matter accretion and increased root and faunal activity, and
- substantial recovery of soil fertility during plantation development on fallowed soils.

Soil remediation “close to corresponding natural forest conditions was achieved within 75 years of initial reforestation”. These degraded sites would have been unsuitable for the successful establishment of hardwood species at the time of the first afforestation effort yet those plantations that were mature (>60 years) provided understory conditions supportive to the natural establishment of a vigorous, more shade tolerant deciduous understory.

A

White pine plantation, 35-40 years old, unthinned; stem exclusion stage.

B

Red pine plantation, 60-70 years old, two thinnings to date, two more scheduled, dense hardwood understory up to 6 m in height composed of tuliptree, sugar and red maple, white and green ash, red oak, beech, bitternut hickory, yellow birch, sassafras; stand reinitiation stage.

C

Red pine plantation, with small component of Scots pine, white spruce and white pine. 70 years old, thinned four times, overstory removed in 1993. Naturally established understory composed of red and white oak, shagbark hickory, sweet chestnut, sugar and red maple, largetooth aspen, sassafras. Hardwood understory has been evident for 30 years.

Figure 5: Stand development following conifer plantation establishment

3.3.7 TREATMENT COST

Treatment cost will be a consideration in deciding upon management approach. Some of the costs that are typical for conventional and restoration focused afforestation as experienced by the Long Point Region Conservation Authority, the Essex Region Conservation Authority and Northumberland Stewardship are provided in Table 3 as examples. It is clearly difficult to compare costs across jurisdictions in different parts of southern Ontario. Costs associated with nursery stock production are set by the supplying nursery and vary from one facility to the next. Planting costs are generally lower in areas with a predominance of sandy areas than they are for those with a higher proportion of clay sites. Nevertheless some costs are directly related to the afforestation effort focus.

Cost comparisons should include all the costs, including cash and in-kind. For example volunteers and/or students are a useful resource particularly when implementing a relatively small treatment, but they generally cannot be depended on when delivering on-going, large-scale forest establishment programs. It is necessary to include all of the human resources and travel/field costs for planning, project management, delivery and monitoring for 3 to 5 years in order to fairly indicate realistic expenditures.

Hardwood nursery stock can cost 70% more to produce than conifer stock which will influence a hardwood focused conventional program depending on the proportion of hardwood involved, and will certainly affect restoration focused work with its emphasis on hardwood species. Although not reflected in Table 3, some managers may choose to plant larger potted native hardwood stock such as sycamore, aspen, ash or elm (150cm bareroot ranging from $3 to $10/tree, depending on quantities produced) to speed the restoration process and permit fall planting, and to utilize rodent guards and weed blankets (@$2/tree combined, not including installation) where other competition control measures may not be effective or appropriate.

Hand planting is required when bareroot are established during a restoration effort in order to ensure random spacing or to facilitate the establishment of pods. Hand planting costs are often 50% higher than those for machine planting, which at this time is typical of most, but not all, conventional afforestation. Note that soil texture, drainage and property size issues may preclude machine planting on conventional afforestation sites as well.

Collecting and direct seeding of hardwood species is less expensive than growing and planting of bareroot stock, although eventual species composition, density and stocking are more difficult to predict.

Tree planting density is a major factor affecting eventual costs. Most conventional tree plants target a planted density of between 1500 and 2200 stems per hectare. Restoration focused afforestation may emphasize a lower density (some managers recommending less than 1600 stems per hectare to permit the natural in-seeding of local tree, shrub and wildflower species). This of course will lower the planting cost, but depending on the degree of natural ingress, lower density planting can lengthen the period before crown closure (extending the stand initiation phase as described below) and affect tree form and growth. Where the treatment has been successful in encouraging rapid ingress of natural regeneration, some allowance for higher establishment costs may be accommodated.

The establishment of groundcover may be a very effective means of competition control. Costs can vary significantly depending on the proportion of wildflower seeds included in the mix.

The amount of information that is required before, during and after planting of a restoration project is substantial. There is need for close monitoring of the planting site during the first few years and perhaps for many more years to come because of the range of species involved and because many of the approaches are still being fine-tuned. The restoration approach has many more variables to consider and hence monitoring the results and taking appropriate corrective action should be reflected in the associated costs.

Hydrological restoration costs are variable as well depending on the type of work required, and can be very expensive. Note that they are not necessarily a component of all restoration efforts.

A cost aspect that landowners must consider regardless of approach taken relates to taxation status of the property. In order to qualify under the Managed Forest Tax Incentive Program (MFTIP), and therefore allow the landowner to receive a 75% reduction in property taxes, there must be a minimum of 1000 trees per hectare (approximately 3.1 X 3.1 m. spacing). This may be a concern in lower density efforts, particularly if survival is low, or if artificial regeneration is not augmented by natural regeneration.

The treatment costs shown in Table 3 reflect average situations within three jurisdictions, but some of the cautions noted above must be considered. The major factor dictating cost will be the suite of species prescribed for planting. Conifers require a lesser degree of site preparation and subsequent competition control than the hardwood species as discussed previously, and the stock is often cheaper to produce. On a per hectare basis, costs for conifer establishment and early management (the Northumberland Stewardship example) may be only 60% of that required for conventional plants with a hardwood component or for hardwood based restoration work (the Pit and Mound operation detailed by ERCA).

In these examples, the LPRCA costs per hectare are somewhat lower than the ERCA conventional hardwood plant because the ERCA example reflected a 100% hardwood plant while LPRCA prescribed a mix of conifer (1/3) and hardwood (2/3), and ERCA's site conditions (often dominated by clays) are more challenging, requiring a heavier investment in chemical tending. LPRCA's planting density is somewhat higher than ERCA's which would increase their costs somewhat, bringing them more in-line with the final ERCA costs.

As illustrated, restoration costs can be comparable to those costs experienced in traditional hardwood plantings. When hydrological restoration is required (LPRCA – Pit and Mound & Ox-bow), treatment costs can increase dramatically.

Table 3: Treatment cost examples

Conventional Efforts	Conventional Conifer		Conventional with Hardwood Component			
Conventional Afforestation	Northumberland Stewardship		LPRA		ERCA	
Trees/ha	1730		2200		1500	
Activity	Cost/tree	Cost/ha	Cost/tree	Cost/ha	Cost/tree	Cost/ha
Plant						
Seedling cost	$0.39	$680.76	$0.73	$1,613.33	$1.00	$1,500.00
Tree Planting (machine)	$0.37	$640.10	$0.32	$704.00	$0.50	$750.00
Shipping and Handling	$0.05	$86.50			$0.02	$25.00
Site Preparation						
Fall plow			$0.02	$49.42	$0.03	$49.42
Spring disc			$0.03	$59.89	$0.04	$59.89
Groundcover (red clover)					$0.04	$55.60
Seeding of groundover					$0.02	$34.59
Fall strip spray	$0.10	$173.00	$0.08	$173.00		
Broadcast glyphosate			$0.03	$65.80		
Tending						
Mowing (4 treatments)					$0.10	$148.26
Simazine (broadcast or spot spray)*	$0.15	$259.50	$0.17	$374.00	$0.40	$600.00
Treatment cost	**$1.06**	**$1,839.86**	**$1.38**	**$3,039.45**	**$2.15**	**$3,222.77**

* ERCA Warranty Program: 70% woody stem survival gaurantee or replant the following spring (for first two growing seasons)

Restoration Efforts	Pit and Mound		Pit and Mound & Ox-bow	
Restoration focused afforestation	**ERCA**		**LPRA**	
Trees/ha	988		2200	
Activity	Cost/tree	Cost/ha	Cost/tree	Cost/ha
Plant				
Seedling cost	$1.00	$988.00	$0.73	$1,606.00
Native grass seed mixture	$0.63	$617.75	$0.05	$100.00
Nuts for hand planting	$0.08	$74.13		
Tree Planting (hand)	$0.50	$494.00	$0.44	$968.00
Hand Planting of native seed	$0.04	$34.59		
Hand Planting of nuts	$0.04	$34.59		
Shipping and Handling	$0.03	$25.00		
Site Preparation				
Pit and Mound Excavation	$0.40	$395.36	$0.31	$680.00
Ox-bow creation			$3.36	$7,400.00
Broadcast glyphosate			$0.02	$54.75
Fall plow			$0.02	$49.42
Spring disc			$0.03	$59.89
Warranty Program*				
	$0.40	$395.20		
Treatment cost	**$3.10**	**$3,058.63**	**$4.96**	**$10,918.06**

04

Ecological and Habitat Implications over Time

4.1 Back to the Future Forest

The forest manager has an opportunity to profoundly influence the future forest. Based on the objectives, the site, and the available resources (trees, other plants, money, human resources), the manager can send a forest on a "trajectory" into the future that can meet a number of different objectives. Three case studies are presented, illustrating the application of principles, practices and potential for restoration. We start with a review of some of the principles that have been established by some leading restoration organizations.

The desired future forest condition can range from fibre production to a complex restoration of rare ecosystems. Various organizations have attempted to provide guidance on how the objectives can be set, and how to achieve them.

4.1.1 PRINCIPLES

All of the organizations involved with restoration have developed principles to guide their decisions.

Trees Ontario Principles

The vision of Trees Ontario is to enhance the health and integrity of the environment through tree planting and sustainable management of Ontario's forests. Trees Ontario has developed principles to set direction for afforestation and restoration:

- To promote the use and application of scientifically-based forestry practices for sound forest establishment and management,
- Pesticides will not be used unless necessary to ensure the survival of forests,
- To continue to establish and foster partnerships with agencies, associations and sponsors interested in the sustainable management of Ontario's forests,
- To promote the importance of long-term planning to ensure the success of reforestation efforts,
- To promote forest establishment at a landscape level in order to maximize ecological and social benefits,
- To promote the use of native species appropriate for the site and local conditions,
- To promote the importance of species diversity in maintaining ecological processes.

The Society for Ecological Restoration International (SERI)

The Society for Ecological Restoration is a leader in the development of restoration techniques. Their online Primer (SERI Science and Policy Working Group, 2004) for restoration provides several management principles. Four examples are provided here.

Often projects have difficulty because the objectives are soft and lack measurable milestones to judge progress. This will be illustrated later in the case studies, but SERI refers to this process often.

> *SERI 27. Prepare a list of objectives designed to achieve restoration goals. In order to achieve restoration goals, explicit actions are undertaken to attain specific end results. Each end result is called an objective.*

SERI also recommends the use of public agencies. When public funds are available, it can free up other resources to improve the project.

> *SERI 29. Establish liaison with interested public agencies. Ecological restoration is necessarily an endeavour of public concern, even if it is conducted on privately owned land without public expenditure."*

The use of a reference ecosystem as recommended by SERI makes a great deal of sense. However in some areas of southern Ontario, there may be some practical limitations to locating a reference ecosystem that is fully functioning and contains examples of the desired future forest condition.

> *SERI 23. Establish the reference ecosystem or "reference." The reference model represents the future condition or target on which the restoration is designed and which will serve later as a basis for project evaluation. The reference can consist of the pre-disturbance condition if it is known, one or more undisturbed sites with the same type of ecosystem, descriptions of such sites, or another document, as described in Section 5 of the SER International Primer. The reference must be sufficiently broad to accommodate the amplitude of potential endpoints that could reasonably be expected from restoration.*

SERI also stresses the need for adaptive management. Based on the reference ecosystem, and even more sweeping issues like climate change, managers need to think adaptively. When resources allow, and there is an opportunity for a mid-course correction, some projects may need additional interventions. Invasive species are an example.

SERI 47. Implement adaptive management procedures as needed. Adaptive management as a restoration strategy is highly recommended, if not essential, because what happens in one phase of project work can alter what was planned for the next phase. A restoration plan must contain built-in flexibility to facilitate alternative actions for addressing underperformance relative to objectives. The rationale for initiating adaptive management should be well documented by monitoring data or other observations.

Determining Success—Monitoring

Managers need a basis for identifying measures and the range of acceptable or desirable targets for those measures. The following nine attributes are abridged from the Society for Ecological Restoration International Primer[5]. A restored ecosystem should have:

1. the same characteristic assemblage of species and community structure as the reference ecosystem.
2. indigenous species to the extent practicable.
3. all functional groups necessary for continued development and/or stability.
4. a physical environment capable of sustaining reproducing populations.
5. no signs of dysfunction.
6. integration into a larger landscape.
7. reduced or eliminated threats from the surrounding landscape.
8. resilience to endure the normal periodic stress events.
9. ability to self-sustain and evolve with environmental conditions as its reference ecosystem.

Parks Canada and the Canadian Parks Council

The National Parks Directorate of Parks Canada has assembled a working group of experienced restoration experts to provide *Principles and Guidelines for Ecological Restoration in Canada's Protected Natural Areas* (Parks Canada, 2008). Applicable concepts from their report are abridged here.

Ecological restoration is effective when it:

· Restores the natural ecosystem's structure, function, composition and dynamics,

· Strives to ensure ecosystem resilience over time,

· Endeavours to increase natural capital,

Ecological restoration is efficient when it:

· Strives for consistent and timely results,

· Is mindful of limited resources and creative in seeking novel means for accomplishing objectives and partnerships,

· Fosters creativity, innovation and knowledge sharing to ensure best future science and practice,

· Is responsible to the individuals, communities and institutions upon which the project(s) depends for success.

Ecological Restoration is engaging when it:

· Integrates the heritage value of cultural resources, especially where these are highlighted in the protected area's designation,

· Provides opportunities for people to more deeply connect with nature and enhances their understanding and appreciation of the relationships between cultural and ecological patterns and processes,

· Offers Canadians opportunities to discover and experience Canada's nature in ways that help to broaden their sense of attachment to the protected areas,

· Provides opportunities for community members, individuals, and groups to work together towards a common vision.

In the document prepared by Parks Canada there is detailed discussion of the framework for restoration in Canadian Parks, and many of these topics relate to restoration in southern Ontario on private land. The principles of ecological effectiveness, practical and economical efficiency and socio-cultural engagement were developed for Parks but are generally good advice.

It brings in the concept of "cultural practices" which in this context refers to ecologically sustainable traditional practices of long-standing application (i.e., usually, one thousand years or more; e.g., traditional use of fire by Aboriginal people). Regard for preserving the cultural evidence of our First Nations is an important consideration for forest managers.

5 For the unabridged list see Society for Ecological Restoration International Science and Policy Working Group 2004: http://www.ser.org/pdf/SER_International_Guidelines.pdf

4.1.2 ECOSYSTEM FUNCTION AND BIODIVERSITY

When a manager implements a restoration plan, they set in place the ecological process that can take a field to a new condition that will provide habitat structure for hundreds or even thousands of other species. We have enough examples in place now that we know replacing even rare and unique ecosystems is possible (but potentially costly).

Almost all land owners in Ontario have a biodiversity objective. For restoration projects, one of the most rewarding short term benefits is the number of species that moves into the developing ecosystem. In the case studies we will illustrate the basic structural development of a habitat using the following measures with basic descriptors of ecosystem structure like canopy height, species number.

4.1.3 APPLICATION OF THE PRINCIPLES

Before considering the case studies, there are some sources of information that may be useful for managers in applying the broad principles described above.

Fitting into the Landscape

In 1852, it was a brave new world for Susannah Moodie (Moodie, S., 1852) (inset), but how times change. Susannah had a vision for her own property which involved a large view of the nearby lake with no trees to intervene.

As the pendulum swings back to the desire for a more natural landscape in southern Ontario, managers and owners have a hard time defining exactly what is natural. Owners rely on the knowledge of forest managers to guide them towards a robust natural condition. Painting a picture of the early forest landscape of southern Ontario can help in developing objectives for a small woodlot. For forest managers seeking a vision for their future forest, the use of studies and examples of the pre-settlement forest can be informative, and may help in providing some direction. There are not many explicit descriptions of the southern forests from long ago.

Table 4 lists some of the few sources of information that describe the forests at the landscape level in the pre-settlement condition. These general historical overviews are a good source for general direction, but they are not suitable for specific guidance related to a particular site without knowledge of the local soil, moisture and richness. Local expertise is necessary to interpret the landscape information at the site level. Studies are arranged so that local references are at the top, and broader areas are at the bottom.

“A few years afterwards, I looked about for the dreadful cedar-swamp which struck such a chill into my heart, and destroyed the illusion which had possessed my mind of the beauty of the Canadian woods. The trees were gone, the tangled roots were gone, and the cedar-swamp was converted into a fair grassy meadow, as smooth as a bowling-green. About sixteen years after my first visit to this spot, I saw it again, and it was covered with stone and brick houses; and one portion of it was occupied by a large manufactory, five or six stories high, with steam-engines, spinning-jennies, and all the machinery for working up the wool of the country into every description of clothing. This is civilisation! This is freedom!”

Susannah Moodie

Table 4: Sources of information about pre-settlement landscape conditions in southern Ontario.

Location of study	Author	Title
York Regional Forest	Puric-Mladenovic	Puric-Mladenovic, D. 2003. Predictive vegetation modeling for forest conservation and management in settled landscapes. Ph.D. Thesis. Faculty of Forestry, University of Toronto, 281 + 112
Bancroft Minden	Pinto	Pre-industrial forest composition of the Bancroft-Minden Forest. Southern Science and Information, Ministry of Natural Resources, North Bay, Ontario
Muskoka	Pinto	Pre-industrial forest composition of the French-Severn Forest. Southern Science and Information, Ministry of Natural Resources, North Bay, Ontario
Eastern Ontario	Pinto	Pre-industrial forest composition of the Mazinaw Lanark Forest. Southern Science and Information, Ministry of Natural Resources, North Bay, Ontario
Southern Ontario	Suffling, Evans Perera	(2003) Presettlement forest in southern Ontario: Ecosystems measured through a cultural prism. Forestry Chronicle.
Southern Ontario	Larson, B.M., J.L. Riley, E. Snell and H.G. Godschalk.	(1999) The woodland heritage of southern Ontario: a study of ecological change, distribution and significance. Federation of Ontario Naturalists, Don Mills
Southern Ontario	Uhlig, P., A. Harris, G. Craig, C. Bowling, B. Chambers, B. Naylor and G. Beemer	(2001) Old growth forest definitions for Ontario. Ont. Min. Nat. Res.
New England	Abrams	(2001) Eastern White Pine versatility in the presettlement forest. Bioscience 51: 967-979.
Eastern North America	Lorimer, C.G.	2001. Historical and ecological roles of disturbance in eastern North American forests: 9,000 years of change. Wildlife Society Bulletin 2001, 29(2)425-439.
Eastern North America	Frelich, L.E	1995. Old forests in the Lake States today and before European settlement. Natural Areas Journal 15(2): 157-167.
Eastern North America	Frelich, L.E. and C.G. Lorimer	1991. Natural disturbance regimes of hemlock-hardwood forests of the upper Great Lakes region. Ecological Monographs, 61(2): 145-164.
Eastern North America	Seymour, A.S., White, P.G. and P.G. deMaynadier.	2002. Natural disturbance regimes in northeastern North America – evaluating silvicultural systems using natural scales and frequencies. Forest Ecology and Management. 155: 357-367.

The descriptions that these reports provide are broad. For example, Suffling recommended a systematic restoration of eastern hemlock and beech stands for conservation purposes; and restoration of pine forests on sandy and rocky areas in southern Ontario. He reviews the abundance of pine and its iconic status. Although he found the historical distribution was lower than the common perception of pine on the landscape, the loss of the large old growth on the landscape through logging and fire has had an impact. Further he notes, when using historical information for management "we should be aware of the cultural, economic and emotional prisms through which we receive information."

Abrams in New England stated "White pine was widely distributed in colonial forests of central New England, averaging 20% (with a range of 16% to 22%) of the witness trees in the Connecticut River valley, Pelham Hills, central uplands, and eastern lowlands, where it was an important member of the hemlock–northern hardwood, oak–pine –hemlock, and oak–pine–chestnut forest types."

"In other regions, governments, land companies and many pioneers failed to recognize or ignored the severe limitations of poor soils. The same settlement pattern occurred, but was followed by soil exhaustion and erosion, farm abandonment and subsequent reforestation (e.g, Norfolk County). In other areas, ostensible settlement was really a logging operation, with occupants moving on after they had high-graded the most profitable timber. These loggers often sold land to gullible settlers who were obliged to destroy the woods and the soil, and abandon their properties when they no longer yielded even a meagre living (northern Bruce and Grey Counties exemplify this pattern)."

Evans Perera Suffling

Considering the Landscape Perspective

In the face of widespread development that rarely considers forest, grassland, wetland or naturally functioning ecosystems, managers have a clear challenge in attempting to make a contribution to the big picture on a small parcel of land. Is it worth considering the work that has been done on the historical landscape? We know that going back to the future in a substantive way is not possible. There are lots of gaps—extensive interior forest, early succession communities, and natural grasslands. All of these were much more extensive in the past in the absence of agriculture and roads. In many areas, managers are faced with conditions so drastically different from those in the past that the best we can often hope for is to re-establish healthy functioning ecosystems composed of species native to the region but not necessarily in the same patterns or percentages.

A popular concept in resource management has been the "diversity of diversities". Landscape diversity refers to the variety of distinct ecosystems within a given geographic area. Some landscapes in pre-disturbance southern Ontario were relatively uniform (for instance the areas of white pine forest that grew back after wildfire). Other landscapes were more varied with a mosaic of different plant associations in close proximity. A more diverse landscape combining a natural arrangement of relatively uniform and highly diverse ecosystems will usually support higher species diversity across that landscape.

It is normally the role of organizations with landscape level responsibilities to develop strategic plans for larger areas. Then even if the average landowner, like the Susannah Moodie of today, does not see the big picture or have any interest in it, the resource manager has access to and should be aware of those plans. By seeing all of the possibilities and bringing them to the owner, along with their professional judgement, the opportunities to move towards that full diversity of diversities are increased.

Managers need to be strategic in their afforestation efforts and informed by the best landscape scale plans in existence. Guidance on where not to plant forest is equally important since where we plant is as important as what (species mix and woodland composition goals) and how we plant (afforestation techniques).

Some of the programs that have been put in place at the provincial level include:

The Big Picture Project: Developing A Natural Heritage Vision For Canada's Southernmost Ecological Region.— Authors: Jarmo V. Jalava, Peter J. Sorrill, Jason Henson and Kara Brodri. Natural Heritage Information Centre, Ontario Ministry of Natural Resources, P.O. Box 7000, 300 Water Street Peterborough, ON K9J 8M5 ph: 705-755-2167; fax: 705-755-2168

http://www.carolinian.org/ConservationPrograms_BigPicture.htm

The Great Lakes Conservation Blueprint For Biodiversity. — **OMNR and the Nature Conservancy of Canada (NCC).** This shared vision for natural heritage conservation identifies a portfolio of sites representing high quality terrestrial and freshwater areas that can support a broad range of natural biodiversity, including species at risk. The Great Lakes Conservation Blueprint contributes to the goals of Ontario's Biodiversity Strategy.

http://nhic.mnr.gov.on.ca/projects/conservation_blueprint/Terr_Vol1_final_e-version.pdf (50 megabyte file)

A Greenway For Ontario—Ontario Nature's vision for the future of land conservation in Ontario. A Greenway for Ontario will keep Ontario's remaining natural spaces and working lands healthy, vibrant and ecologically sustainable.

http://www.ontarionature.org/pdf/Ontario_Nature%27s_Greenway_Vision.pdf

Natural Spaces: A Greenspace Program For Southern Ontario— encourages the conservation and restoration of healthy ecosystems across southern Ontario through the voluntary and cooperative efforts of landowners, diverse organizations and governments.

http://www.mnr.gov.on.ca/en/Newsroom/LatestNews/MNR_E004248.html

Matching the Species to the Site (Local)

Knowing the range of possibilities in the landscape helps but there is still more specific site information that is needed. The ecological potential of a site is the domain of professional managers. Landowners normally do not have enough experience to judge the environmental restrictions of moisture, productivity, and logistics.

Managers often establish the site type from prior experience. When uncommon sites occur or there is a need to verify a prescription, the use of the Southern Ontario Forest Ecological Land Classification (ELC) (OMNR, 2009) can provide additional information. Training in the use of the ELC is available from OMNR.

In the following case studies the ELC can be used to give some context to the site within the landscape. In other words, helping to provide answers to the questions like—"what are the options given the soil and environmental conditions?"

4.2 Case Studies

Our objective is to project new forest growth from point of establishment out as far as possible so that the major anticipated changes in species composition, stocking, structure, habitat condition etc. for a few selected management approaches and dominant site types can be illustrated and compared. Red and white pine plantation data (going back 80 years in some cases) is available and has been analyzed. Early observations and measurements tended to focus on the overstory, with little attention to the development of naturally establishing understory layers until the most recent data collection efforts. Data from more recent restoration work is more limited, with the oldest examples going back only 15 years or so. In either case, a level of interpretation and projection is required.

Three case studies are provided to illustrate some of the current options for restoration. They may assist managers in providing guidance to land owners about the range and natural variability of the future forest, and in likely successional trends. The case study descriptions include:

· site types and forest types using the Southern Forest Ecosystem Classification to scope the potential range of forest types or “reference ecosystems”,

· visualizing habitat development over time,

· some relevant silvicultural practices.

4.2.1 CASE STUDY 1: CONVENTIONAL AFFORESTATION (WHITE PINE PLANTATION)

This is an example of a white pine plantation similar to those established in many locations across southern Ontario. The management objective was to implement a low cost, long-term restoration to a white pine forest. It is in an area that historically had extensive pine forests.

Site Type

Table 5 summarizes ELC Vegetation and Site Type descriptions for typical white pine dominated forest conditions.

The table identifies the principal vegetation communities on this ecosite, but obviously the manager must then make the determination of what is appropriate (i.e., what was native) at the particular site; thus a Jack Pine dominated vegetation type might be appropriate on the Bruce Peninsula, but not in very many other places in Ecoregion 6E.

Table 5: ELC site information, white pine plantation

From the ELC for Southern Ontario Community Class = Forest; Physiognomic Class = Coniferous; Site Modifier = Non Calcareous

	FEC Code	Vegetation Type	Site type
Dry Pine Non-Calcareous Shallow Coniferous Forest Ecosite		- Jack Pine, White Pine or Red Pine separately dominant or in variable mixtures - Oak species, White Cedar, White Birch, and to a lesser extent Hemlock, Balsam Fir and Red Maple associates - Low Sweet Blueberry, Common Juniper, Wintergreen, Buffalo Berry, Serviceberry spp. and Sweet Fern - Bracken Fern, Gaywings, Bristle-leaved Sedge, Large-leaved Aster and Hairy Goldenrod	- dry (θ,0) to fresh (1,2) soil moisture regimes - occurs on droughty shallow soils over bedrock, rock, sands and coarse loams with rapid (2) to moderately well (4) soil drainage - conditions are extreme enough to limit the growth of other species - upper to middle slope (1,2,3) and tableland (7) topographic positions
Options (at the eco-element level)			
	FOCS2-1	- Jack Pine dominant - White Pine, Red Pine, Oak species and Red Maple more common associates	- xeric and moderately dry (θ,0) soil moisture regimes - typically on shallow soils over either non-calcareous, basic or calcareous bedrock; most extreme sites
Dry White Pine - Red Pine Non-Calcareous Bedrock Coniferous Forest Type	FOCS2-2	- White Pine or Red Pine separately dominant or in variable mixtures	- sands, coarse loams and shallow soils over non-calcareous, basic or calcareous bedrock, or rock; less extreme sites
	FOCS2-3	- Pitch Pine dominant, with White Pine, and Red Oak as associates	- xeric to dry soil moisture regimes - exclusive to the non-calcareous rock outcroppings associated with the Frontenac Axis in Frontenac County

Prescription

Landowner objectives:

· production of high-value wood products, enhancing non-timber values (wildlife habitat), creation of interior forest conditions,

· establishment of forest species suitable to the site (in this case, white pine).

Site condition:

· shallow, well drained, dry to fresh, non-calcareous sandy loam, FEC Code: FOCS2-2,

· currently under cultivation for soybean production, competing vegetation is under control at time of inspection.

Treatment schedule:

· field is already site prepared because of past land use. Plant bareroot white pine at 6'X8' spacing, with subsequent mowing between rows (years 1, 2 and 3) if competition warrants the treatment,

· ongoing monitoring for insect issues, branch prune to encourage clear bole production, commercial thinning at age 30 and again at age 50 for release of crop trees, encouraging development of large, high value white pine sawlog material.

Habitat Availability

The following projections are based on the work of DeGraaf et al (1992) and Hounsell (1989) who provided quantitative graphs of wildlife habitat development over time for White Pine. One of the types in DeGraaf's general category was "old field white pine", which is comparable to many of the conventional projects in southern Ontario. Hounsell also refers to the red and white pine forest unit.

> DeGraaf found that "Old field pine on fine-textured soils develop dense pure stands once the early successional species disappear. The understory and ground flora are almost non-existent until the canopy is broken by damage cutting or overmaturity (+150 years). Then a dense hardwood understory develops."
>
> He adds, "Old field pine naturally reverts to northern hardwoods, mixed oak-hardwoods or hemlock, a process that is hastened by thinning." (DeGraaf 1992)

After planting over 4000 stems per hectare, possibly to compensate for weevil problems in the first year, structure of the habitat develops quickly over the first 20 years as basal area and height of the planted trees increase.

Scenarios of White Pine Forest: Development over Time

The three scenarios provided in Figure 6 illustrate the development of vegetation over time and provide some basic measures of the change in structure for a conventionally established white pine plantation which is subsequently managed according to different objectives. The first scenario reflects conditions in a white pine plantation established conventionally but with no subsequent thinning. The second scenario reflects conditions that might develop if management of that white pine plantation focused on species diversity restoration. To accelerate succession and promote the earlier establishment of other native species involved, in this case the removal of approximately 30% of the pine basal area in large patches by creating 20 m diameter gaps. The third scenario assumes that the production of high quality sawlog material is of high priority, with a program of regular thinning in place.

Scenario 1 is a very basic treatment and perhaps not realistic in that no intermediate thinnings are planned. If thinnings were scheduled as in Scenario 3, the canopy openings created especially in the early operations would encourage diameter growth of residual pine and lead to brief and minor increases in shrub and herb growth. The early thinning would not however open the canopy sufficiently to encourage the height growth of the understory trees into the main canopy. Two or three successive thinnings are normally required before enough sustained light reaches the understory trees to permit that movement into the overstory.

The focus of Scenario 2 is to encourage early development of a naturally established understory in a conventionally established conifer plantation. The more open environment created by establishing openings throughout the stand allows for a rapid development of herbs and shrubs, as well as an understory tree layer. The herbs and shrubs eventually decline in terms of percent cover as the newly established understory tree layer develops and closes canopy within the openings. The transition from conifer plantation to mixed forest could in fact be further accelerated by earlier and more frequent gap creation or thinning operations.

These conceptual projections illustrate the importance of management to continue or expand habitat structure. In this example, if there is no attempt to provide openings in the stand then the early incursions of other tree species enter into a cycle of establishment, slow growth depending on light availability, mortality and re-establishment, with little movement into the main canopy unless a significant opening is created. Through a regular thinning program, the naturally established understory will develop over time and eventually replace the conifer overstory, as illustrated previously in the Figure 5 examples (as illustrated under Restoration and Convention Afforestion), but not as quickly as if there is a deliberate effort to accelerate succession by thinning heavier and more frequently and/or by creating gaps within the canopy for that purpose.

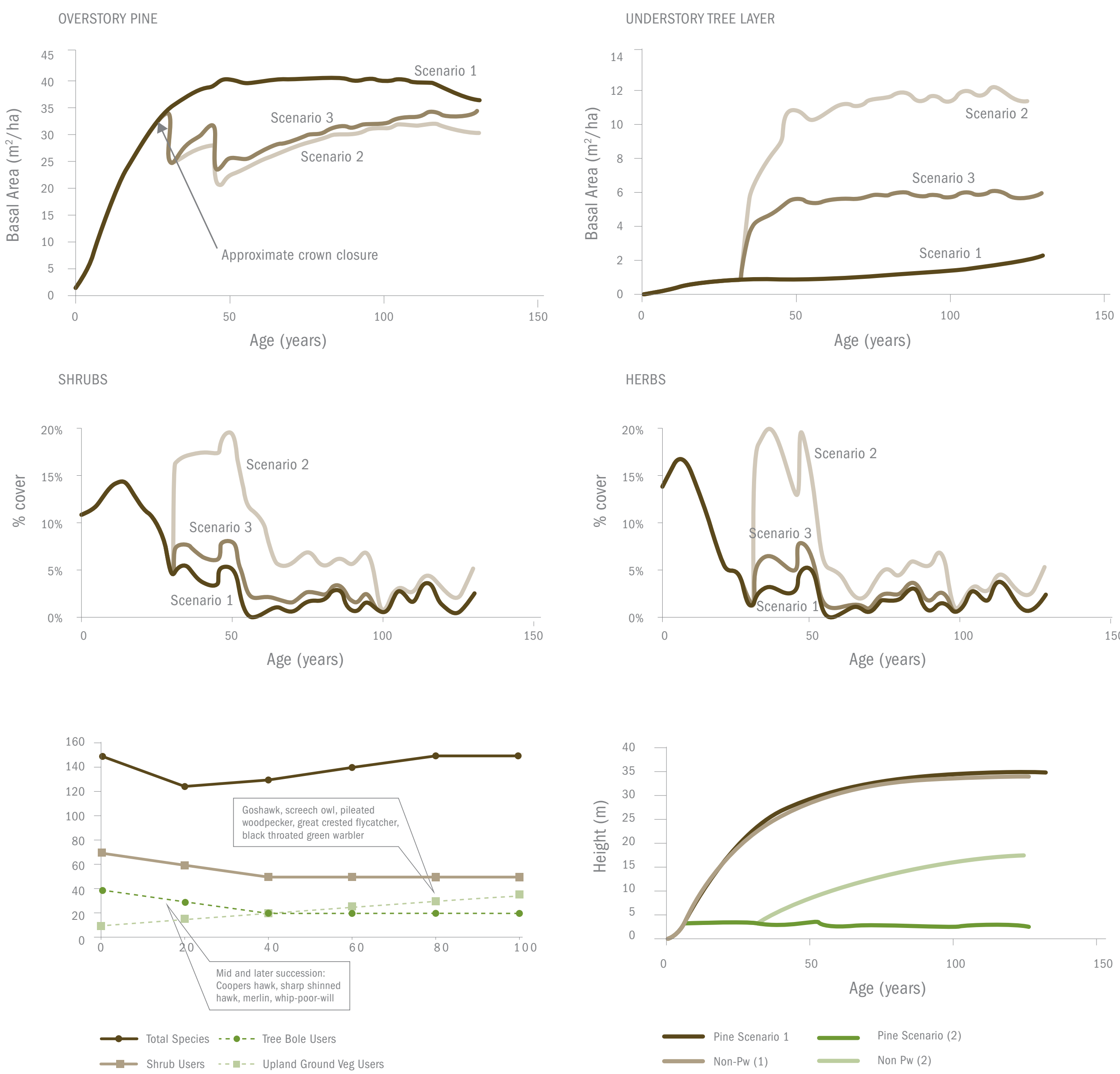


Figure 6: White pine forest, vegetation development over time

Scenario 1—wood production, no thinning. Scenario 2—wood production + species diversity acceleration. Scenario 3—wood production with thinning.

Table 6 provides a description of anticipated stand development, management and habitat trajectories over time for the white pine case study using the Scenario 3 situation with timely thinning as an important part of the management program.

Table 6: Stand development, management and habitat trajectories, white pine case study

Yr	Vegetation	Management	Biodiversity Targets And SAR & Rare Species Targets
0	Year prior to planting: agricultural field, promote soybean crop. Assess weed populations after crop harvest, treat field with herbicide (glyphosate) if excessive weed growth or if specific undesirables present (cool season grasses, vetch, bindweed).	Secure appropriate stock i.e. seed zone and species that best suit site conditions (wet, dry).	Not preferred habitat for many species in first few years, so some artificial management may encourage use. A number of birds can use the open area for feeding such as swallows and small raptors.
1	Re-assess weed populations prior to planting activities in the early spring. Treat site with another application of herbicide (glyphosate) prior to planting—if required. Annual agricultural weeds (both native and non-native) will dominate site and grow to large size and to a certain extent provide shade and moisture and some nutrients to seedlings. Some native annuals such as Horseweed and Ragweed, and the non-native lambs quarters, will flower & set seed. Seedlings generally grow well in the first year (transplanting stress), weather dependent.	Trees planted in rows by machine (6' between trees x8' between rows). Landowner mows between rows if undesirables present.	Once there is some ground vegetation, some birds actually prefer the low level of structure in the open area: Northern Flicker, Eastern Towhee, Chipping Sparrows. Mice and voles are generalists and can make do with very basic habitat resources.
2	Woody plants will remain small—below height of annuals. Annuals still present as a large component of the planting site. Seedlings are still below the free to grow stage but are growing well.	Landowner mows between rows if undesirables present.	Increase in grassland & edge birds including American Woodcock, Wild Turkey, Common Yellowthroat, Whip-poor-will. More use by wild life as species become accustomed to site conditions. Increase in aerial insectivores (swallows). Grasshoppers and other insects are common, early-successional species in high numbers.
3	Some self seeded native perennials present. Seedlings reach free to grow stage. Native annuals and biennials (Horseweed, Ragweed, Venus' Looking Glass much reduced). Trees and shrubs begin to appear at or above native vegetation.	Landowner communicates with local manager regarding any concerns and general updates with site's progress. Landowner mows between rows if undesirables present.	
6	Trees and shrubs well-established. Herbaceous plants fewer with open patches of mossy sand. Contribution of wild seed to site noticeable with increasing numbers of strawberries, raspberries, grapes, sumacs & sedges. Airborne species appearing (maples, ashes, willows, aspens, tulip-tree, birches, white pine, witch-hazel) where seed source exists.	Landowner monitors for grapevine. Mowing not usually required.	Scrubland bird species becoming common: Yellow Warbler, Blue-winged Warbler, Eastern Towhee, Brown Thrasher, Indigo Bunting and Field Sparrow. Forest birds using edges and parts of planted area to feed.
11	Trees reaching 5 m and canopy closure occurring within the next few years. Seedlings from adjacent forest trees starting to germinate.	Landowner continues to monitor for weevil and blister rust. Landowner consults with local managers if there are concerns.	Bird diversity rising with many edge, scrubland and field species combined including Chestnut-sided Warbler, Alder Flycatcher, Rose-breasted Grosbeak. Restoration no longer presents a barrier to forest birds.
16	Crowns closing, although full site occupancy may not be achieved (dependent on planting density, survival and site). Increase in vertical growth. Ground cover reduced due to acidic conditions from needle drop.	Grapevine should be gone by this point. Can do corrective pruning for double tops caused by weevil. Landowner continuing to monitor and relay any concerns to local managers.	Bird species singing in and using planted area as post-fledging areas.

20	Interspecific competition among pine is causing some weaker individuals to die. A pre-commercial thinning could take place at this point, or it could be delayed to age 30 to make it commercial.	Assess for timing of pre-commercial thinning. Prune for deformities.	Additional forest birds begin to breed in young forest including American Redstart, Wood Thrush.
30	Time for a commercial thinning. If thinning is relatively uniform (e.g., 1 row in 4 removed for access combined with selective thinning in the leave strips to promote crop tree growth), white pine will continue to dominate the overstory and the understory trees, shrubs, and herbs will continue to be relatively minor components. If the thinning is patchy (patches of 1 tree height or more in diameter), the effect on the white pine overstory will be very much diminished (little effect on crop tree growth) but should result in the patches becoming dominated by hardwood trees, shrubs and an increase in herbs.	Crop tree selection and basal pruning to improve value.	There are reports of Redbelly Snakes starting to use these stands for breeding during immature age class and after. As well the Whip-poor-will uses these stands for breeding and feeding during the immature phase. The Red-breasted Nuthatch likes a wide range of conifer in this age range including white pine, for breeding, feeding and wintering.
50	Time for a second thinning if white pine sawlogs are the objective. Commercial thinning has occurred. Tolerant hardwood becoming more apparent between rows where more light available, reaching into the lower canopy (some understory hardwood up to 15 m.).	Monitor vegetation and wildlife.	Mid and late succession: Hounsell reports use by some small raptors like Coopers Hawk, Sharp Shinned Hawk, Merlin, for nesting. Hermit Thrushes use this forest when there has been some establishment of undergrowth, after a thinning. Blue-headed Vireos use this site type for breeding once the stand passes the immature stage.
80	Possible second thinning has occurred. Hardwoods make up a small portion of the canopy. Over time it will continue succeeding from Pine to tolerant hardwood. This succession can be accelerated by harvesting patches (group selection) or delayed by continuing with a uniform shelterwood silvicultural system which maintains enough canopy cover to favour semi-tolerant species like white pine and actively discourages other species either by maintaining a moderate level of shading or through removal of non-pine species during interventions.	Monitor vegetation and wildlife.	In the mature and old stage of this stand Hounsell lists Goshawk, Screech Owl, Great Crested Fly Catcher, Black Throated Green Warbler, Pileated Woodpecker using these stands for feeding, breeding and even wintering.

Bird Habitat

Examining habitat structure by bird species for four phases of stand development provides a different view of habitat development. Figure 7 is an illustration of a possible scenario for the development of biodiversity in the white pine plantation case study based on the work of DeGraaf (1992). There is no equivalent work from southern Ontario. It shows 10 species guilds[6] as they respond to habitat changes over time. Habitat or available niches[7] increase with stand development. Some of the structures are fairly subtle and need to be considered during the initial planting. For example, overstory inclusions are places in the plantation where one or a few deciduous trees occur in a conifer stand. Even in relatively young stands these can have a very positive benefit. Some niches, like tree boles and high exposed perches are not possible until later stages.

6 Guild – A group of organisms that exhibit similar habitat requirements and that respond in a similar way to changes in their environment.

7 Niche – The specific area where an organism inhabits.

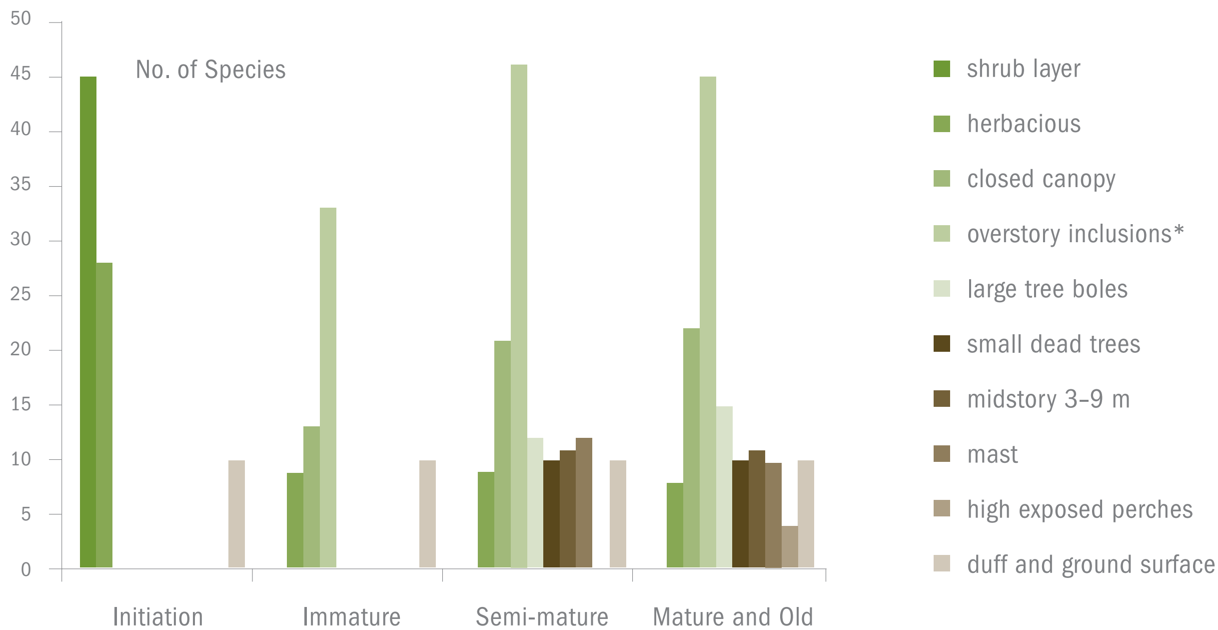


Figure 7: Bird species use of habitat niches with developing habitat structure – an illustration

(based on DeGraaf 1992).

Stand Development

The stand development conditions detailed in the case study are based on a composite of Permanent Growth Plot (PGP) measurements in white pine plantations from many locations in southern Ontario, and although those stands were generally untended but likely with concerted efforts to discourage hardwoods in the understory, trends are apparent.

Conifer plantations that develop as a result of conventional afforestation efforts will close canopy, transition to the stem exclusion stage, and eventually to the understory re-initiation stage. The length of each period will vary depending on:

· species,

· site,

· initial planting density and arrangement (clumps vs. uniform distribution), and

· subsequent management intervention.

Almost all of the conifers were planted and are present throughout the life of the stand. As the stands reach maturity and density-related mortality begins to occur, some self-seeding of conifers may occur, particularly of more shade tolerant species like white pine and white spruce.

Hard maple and white ash start to appear around age 30 which is when the basal area starts to level off, likely coinciding with crown closure and the beginning of density-related mortality of the overstory white pine. The hardwoods tend to remain in the understory and have a fairly constant quadratic mean DBH and erratic height patterns. As trees either grow or die, this constant DBH seems to indicate that individual trees are dying and being replaced.

Once canopy closure is achieved, understory and ground flora, though present, occur in limited quantities, grow very slowly, die and are replaced by other ground flora. The cycle continues with few naturally established trees able to move into the main overstory. This process generally continues until the canopy is eventually broken by thinning or harvest activity, or by overmaturity, and at that time a dense understory develops and moves into the overstory. The species composition observed in the understory is an excellent indication of the make-up of the future forest as crown thinning continues and succession proceeds.

4.2.2 CASE STUDY 2: AFFORESTATION WITH RESTORATION FOCUS —LAKE ERIE FARMS—SEEDING, DIVERSE SPECIES

There are biodiversity hotspots, where history and geography have come together to bring special attributes to a site that can lead to unique habitats or productive habitats. These are no longer as common on the landscape as they used to be. Case studies 2 and 3 represent two approaches that have been undertaken to implement restoration of some of those habitat conditions through afforestation.

Site Type

Table 7 provides site information for the Lake Erie Farms project:

Prescription

Lake Erie Farms is located on very dry sandy soils on the Norfolk Sand Plain just west of Big Creek and Venison Creek Valleys. The forested dunes on the property and adjacent properties of Wilson Tract, the Stead property and other aeolian dunes are similar. The agricultural portion of the property that was planted had not been reshaped much from its original land form. As reference conditions, the natural forest in the surrounding landscape was used. Planting what appears to be the climax dry oak forest on these sites would result in many of the forest species not surviving. Therefore the field edges of several older restored sites and other adjacent dry open areas were examined in order to identify the native species assemblages that were occurring naturally as the forest was developing. The St. Williams Conservation Reserve: Nursery Tract was also included as a reference system (some species that occur there are Wild Lupine, Slender Wheatgrass, Kalm's Brome and Dwarf Chinquapin Oak). The idea was to assemble all the species that would survive in open conditions that occurred nearby. Although the terrain on this site varied, the same mix could go everywhere and the species could sort themselves out.

Benefits to Wildlife

The concept was to introduce high plant diversity to the site early so that remnant insect, mammal, bird and reptile populations (at least those that are adapted to early successional conditions) could move into the fields immediately. The matrix of early successional native grasses and wildflowers may not survive when the canopy closes but they provide important ecological functions in the interim. They would be common in disturbed landscapes but can no longer get to sites being planted on their own because seed sources are too few and far between. An added benefit of common wildflowers and grasses was to help discourage exotic weeds such as Quack Grass that might otherwise damage seedling trees.

Table 7: ELC site information, Lake Erie Farms

From the ELC for Southern Ontario Community Class = Forest; Physiognomic Class = Deciduous

	FEC Code	Vegetation Type	Site type
Dry - Fresh Oak Deciduous Forest Ecosite	FODM also WODM3	- Red Oak, White Oak and Black Oak separately dominant or in variable mixtures - Red Maple, White Pine and Black Cherry are common associates - Bracken Fern - canopy cover variable; often relatively open (60 to 80% canopy closure)	- moderately dry (0) to fresh (1,2) moisture regimes - shallow soils over bedrock, rock, sands and coarse loams; absence of finer silts and clays; rapid (2) drainage; absence of gley; mottles > 60 cm in depth; subject to droughty conditions - typically on upper to middle slope (1,2,3) or tableland (7) topographic positions - site subject to some extremes in conditions or disturbance (e.g., fire, historical land use)
Options (at the eco-element level)			
Dry – Fresh Red Oak Deciduous Forest Type	FOD1-1	- Red Oak dominant - Bracken Fern, Lowbush Blueberry, Wintergreen and Starflower	
Dry – Fresh White Oak Deciduous Forest Type	FOD1-2	- White Oak dominant - Bracken Fern, Lowbush Blueberry, Wintergreen and Starflower	
Dry – Fresh Black Oak Deciduous Forest Type	FOD1-3	- Black Oak dominant - Bracken Fern	
Dry – Fresh Mixed Oak Deciduous Forest Type	FOD1-4	- more than two Oak species dominant - Red Oak >> White Oak > Black Oak - Bracken Fern	

Use of a Reference Site

In this project the manager used the reference site to provide focus and a reasonable assemblage for the client. The client wanted the species to be stratified into Sand Barrens, Oak Woodland and Mesic Forest. Although stratifying to specific habitats makes sense ecologically it does take more time to mix seed and to turn or shut off farm machinery during the planting operation.

There were three reference Vegetation types:

Sand Barren (Oak Opening): Black Oak, Dwarf Chinquapin Oak, Winged Sumac, American Hazel, Wild Lupine, New Jersey Tea, Butterflyweed, Flowering Spurge, Bicknell's Rock Rose, Intermediate Pinweed, Hairy Pinweed, Round-headed Bushclover, Arrow-leaved Violet, Panic Grasses, *Carex siccata, Carex muhlenbergii.*

Oak Woodland: Black Oak, White Oak, Red Maple, Trembling Aspen, Black Cherry, Red Oak, Sassafras, Largetooth Aspen, White Pine, Eastern Flowering Dogwood, Witch Hazel, Smooth Serviceberry, Pin Cherry, American Hazel, Choke Cherry, Maple-leaved Viburnum, Winged Sumac, Downy Arrowwood, Carolina Rose, Pale Blueberry, Summer Grape, Pennsylvania Sedge, Black-seeded Mountain Rice, Wood Rush, Sarsaparilla, Bracken Fern, Round-lobed Hepatica, Poke Milkweed.

Mesic Forest: White Oak, Black Cherry, Red Maple, Red Oak, White Pine, Black Oak, Sugar Maple, Trembling Aspen, Shagbark Hickory, Largetooth Aspen, Bitternut Hickory, Sassafras, Yellow Birch, Eastern Hemlock, White Birch, Summer Grape, Blue Beech, Witch Hazel, Ironwood, Wild Crabapple, Choke Cherry, Maple-leaved Viburnum, Poison Ivy, White Trillium, Red Trillium, Running Strawberry Vine, Sweet Cicely, Christmas Fern, Canada Mayflower, Starflower.

An extensive list of herbs, shrubs and trees was planted in this site and the list is provided in Appendix A.

Table 8 provides a detailed description of a project near Lake Erie including stand development, management and habitat trajectories. The actual project was started in 2006, so forecasts are based on practitioner experience.

Table 8: Stand development, management and habitat trajectories, Lake Erie Farms case study

Yr	Vegetation	Management	Biodiversity Targets And SAR & Rare Species Targets
0	Roundup-Ready Soybeans no-till sown into corn stubble. Grower said there is still enough fertilizer left over from corn crop to grow a good crop of soybeans. The crop was heavy given 2006 rains despite dry sand.	Develop a Management Plan that includes a restoration plan. Select and survey Reference Sites. Acquire, clean, store and assemble seeds from nearby sources. Line up research opportunities. Harvest soybeans on 1 Nov. Disk and pack soil. Machine Seeding native seed Nov. - Dec. (ideal) or May – June (not so ideal but different). Pack seed again. Packing important for establishment.	Monitor insects before seeding. SAR: Eastern Hognose Snake using edges but may be destroyed by farm equipment. Successful nesting not possible.
1	Site still 'hot' from disturbance and fertilizers. Seeded species that do not have germination inhibitions will germinate and remain small. Annual agricultural weeds (both native and non-native) will grow to large size and to a certain extent provide shade and moisture and some nutrients to seedlings. Some native annuals such as Sleepy Catchfly and Venus' Looking Glass will flower & set seed. Significant seeding in of maples (Acer saccharum, A. rubrum 1-2 seeds per sq m), Largetooth Aspen seed and new seedlings.	Use cool seasons to control perennial and biennial exotics. Herbicide edges, seed native plants 10 m or greater from edges. Install mixed conifers at interface between site restoration and non-conforming habitats (grassy road edges) Keep vehicles out. Monitor seedlings and wildlife. Establish photo stations to develop chrono series.	Grassland birds include Vesper Sparrow, Grasshopper Sparrow, Song Sparrow, and Field Sparrow. Heavy use of site by aerial insectivores. Increase in ground beetles, Tiger Beetles, Grasshoppers. SAR · American Badger · Eastern Hognose Snake · Antenna-waving Wasp · Native Bee *Halictus parallelus*
2	Cooling-off period less fertilizer available and disturbance reduced. Most early successional native perennials will flower and set seed. Woody plants will remain small – below height of wildflowers. Agricultural annuals will be almost non-existent, except exotic annual grass *Apera spica-venti*. Some early successional mosses, lichens and fungi will occur on soil surface.	Continue to control perennial and biennial exotics on margins during cool seasons. Monitor seedlings and wildlife. Place cover boards to monitor populations of reptiles.	Increase in grassland & edge birds including American Woodcock, Wild Turkey, Common Yellowthroat, Whip-poor-will. More use by wild life as species become accustomed to site conditions. Dramatic increase in pollinators[1] including bumble bees. Increase in aerial insectivores (swallows) and grasshoppers. Most insects common, early-successional species in high numbers. SAR: as in year 1

3	Native herbaceous plants will increase in number but be smaller, few weeds visible. Native annuals and biennials (Horseweed, Ragweed, Venus' Looking Glass much reduced). Trees and shrubs begin to appear at or above native vegetation.	Monitor at 5 years. Incidental observations and control of weed issues (backpack sprayer).	SAR: Central Ratsnake, Eastern Foxsnake (foraging).
6	Trees and shrubs well-established with some individuals reaching 1-2 m. Herbaceous plants fewer with open patches of mossy sand. Contribution of wild seed to site noticeable with increasing numbers of strawberries, raspberries, grapes, sumacs & sedges. Airborne species appearing (maples, ashes, willows, aspens, tulip-tree, birches, White pine, witch-hazel).	Begin serious control of invasive shrubs and trees such as Autumn Olive, Multiflora Rose, Tatarian Honeysuckle, Oriental Bittersweet, Scots Pine, Red Pine and Black Locust seedlings if they occur. Seed in more conservative sand plain species as required.	Scrubland bird species becoming common: Yellow Warbler, Blue-winged Warbler, Eastern Towhee, Brown Thrasher, Indigo Bunting and Field Sparrow. Forest birds using edges and parts of planted area to feed. Planted American Hazels, Carolina Rose, grapes, witch hazels, etc. producing seed. Snake populations rapidly increasing and utilizing cover boards. Insect populations stabilizing with conservative oak and hazel specialists becoming common such as Edward's Hairstreak. SAR: Small White Tiger Beetle colonizing sand barrens. Consider reintroducing Karner Blue butterfly under recovery plan.
11	Trees reaching 5 m and canopy closure common throughout site. Canopy openings with diverse native herbaceous species including some woodland species and numerous seedlings from adjacent forest trees. Trilliums begin to flower in shaded margins.	Continue monitoring invasive shrubs and trees and control during cool seasons. Close informal trails. Begin introducing seeds of common forest plants. Consider managing mosses in barrens areas to increase seed germination of barrens. Barrens may require managing to retain open character and increase sunlight on sand.	Bird diversity rising with many edge, scrubland and field species combined including Prairie Warbler, Chestnut-sided Warbler, Alder Flycatcher, Rose-breasted Grosbeak. Restoration no longer presents a barrier to forest birds. SAR: Eastern Hognose Snake exhibits aggregated nesting in sand barrens. Aggregation increases as young animals follow scent trails of older individuals. Woodland Vole begins using new habitat.
16	Canopy closure complete over 50% of site with major die-off of early successional sumac populations. Clubmosses and grape ferns begin to develop in partial shade.	Continue to control invasive shrubs and trees. Monitor vegetation and wildlife. Manage and monitor sand barrens.	Bird species singing in and using planted area as post-fledging areas including Red-eyed Vireo, Ovenbird, Hooded Warbler, Veery, Scarlet Tanager and Ruffed Grouse. SAR: Eastern Flowering Dogwood &Butternut near edges setting seed. Hooded Warbler using area for fledged young.
20	Canopy closure >80% complete with gaps filled with intolerant seedlings becoming free-to-grow. Trees thinning due to competition for light. Trout Lilies begin to flower along shaded margins (take 21 years to flower from seed).	Monitor and manage for exotic invasives. Monitor vegetation and wildlife.	Additional forest birds begin to breed in young forest including American Redstart, Wood Thrush. SAR: Eastern Flowering Dogwood no longer able to withstand anthracnose attacks due to shading. Great Plains Ladies-Tresses appear in clearings (take 20 years to flower). Jefferson Salamander using subterranean habitats and vernal pools.
30	Canopy closed, trees gaining apical dominance and height (10-12 m), understory composed mainly of forest plants.	Monitor vegetation and wildlife and manage forest exotic invasives.	Most forest and edge birds breeding on site. Forest raptors hunting in area.
50	Trees reach height of 12–18 m, and DBH of 30-50 cm. Some microtopography developing through fallen logs and tip-ups.	Monitor & control forest invasive exotics such as Garlic Mustard. Monitor vegetation and wildlife.	Complete use by conservative interior forest bird populations. SAR: Hooded Warbler, Louisiana Waterthrush, Cerulean Warbler.
80	Trees reach 20-30 m and DBH of 40-70 cm, microtopography developing. Forest plants develop large seed-producing individuals. Pteridophytes significant component of forest flora.	Monitor vegetation and wildlife.	Forest raptors nesting. Eastern Wood Pewee, Pileated Woodpecker, SAR: Acadian Flycatcher.

4.2.3 CASE STUDY 3 AFFORESTATION WITH RESTORATION FOCUS— LPRCA—POD PLANTING

Site Type

Table 9 provides ELC site information for the Long Point Region Conservation Authority pod planting case study.

Prescription

The prescription for this site is very similar to the approach described in the section dealing with Pod Plantings. The site has undergone agricultural cultivation and competition control prior to afforestation. Bareroot stock is planted in pods that range in size from 5 to 30 m, at a spacing of 1.2 to 1.8 m between trees. Native ground cover is seeded into the areas between pods.

Benefits to Wildlife

Pods are a variation on the theme of the direct seeding approach that is described above in Case Study 2. It tends to result in a more uneven age class for the stand than direct seeding, although in the long-term this would be difficult to discern. Table 10 provides a detailed description of a pod planting project within the Long Point Region Conservation Authority, including stand development, management and habitat trajectories.

Table 9: ELC site information, Long Point Region Conservation Authority pod planting project

From the ELC for Southern Ontario Community Class = Forest; Physiognomic Class = Deciduous

	FEC Code	Vegetation Type	Site type
Dry – Fresh Oak – Maple – Hickory Deciduous Forest Ecosite		- Oak species dominant (Red Oak >> White Oak) with Red Maple, Hickory, Sugar Maple, White Ash, Beech, Basswood, Ironwood and Black Cherry; Sugar Maple ≤ 25%	- sands and coarse loams with silt and clay components, along with fine loams and clays; moderate drainage; absence of gley; mottles > 60 cm in depth; less droughty conditions prevail - typically on upper to middle slope (1,2,3) or tableland (7) topographic positions - prevailing conditions limiting yet not extreme
Options (at the eco-element level)			
Dry – Fresh Oak – Red Maple Deciduous Forest Type	FODM 2-1	- Red Oak >> White Oak - either Oak or Red Maple can dominate	
Dry – Fresh Oak – Hickory Deciduous Forest Type	FODM 2-2	- Red Oak >> White Oak > Bitternut Hickory > Shagbark Hickory - either Oak or Hickory can dominate	
Dry – Fresh Hickory Deciduous Forest Type	FODM 2-3	- Bitternut Hickory > Shagbark Hickory	
Dry – Fresh Oak – Hardwood Deciduous Forest Type	FODM 2-4	- Oak dominant with Sugar Maple, White Ash, Beech, Basswood, Ironwood and Black Cherry associates; Sugar Maple ≤ 25% canopy cover - if Sugar Maple is close to, or in equal proportions to Oak (> 25%) see Dry – Fresh Sugar Maple – Oak Deciduous Forest Type”	

Table 10: Stand development, management and habitat trajectories, LPRCA pod planting case study

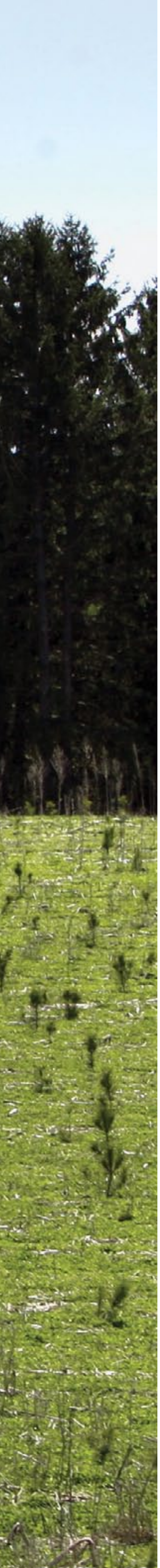
Yr	Vegetation	Management	Biodiversity Targets And SAR & Rare Species Targets
0	Year prior to planting – agricultural field, promote soybean crop. Assess weed populations after crop harvest, treat field with herbicide (glyphosate) if excessive weed growth or if specific undesirables present (cool season grasses, vetch, bindweed).	Develop a restoration plan. Select and survey Reference Sites. Harvest soybeans on 1 Nov. Disk and pack soil. Secure appropriate planting stock i.e. seed zone and species that best suite site conditions.	
1	Re-assess weed populations prior to planting activities in the early spring prior to planting activities. Treat site with another application of herbicide (glyphosate) prior to planting—if required. Annual agricultural weeds (both native and non-native) will dominate site and grow to large size and to a certain extent provide shade and moisture and some nutrients to seedlings. Some native annuals such as Horseweed, Ragweed, and lambs quarters, will flower & set seed. Planted native groundcover will germinate. Most native perennials will not mature in the first year (exceptions include some Indian Grass and Big Bluestem). Seedlings generally grow little in the first year (transplanting stress), weather dependent.	Seedlings are planted in pod locations. Native ground cover is drilled into areas between pods. Species planted will depend on site characteristics and project budget. Use cool seasons to control perennial and biennial exotics. Herbicide edges, seed native plants 10 m or greater from edges. Install mixed conifers at interface between site restoration and non-conforming habitats (grassy road edges) Keep vehicles out. Monitor seedlings and wildlife.	Use of site by aerial insectivores. Increase in ground beetles, Tiger Beetles, Grasshoppers.
2	Woody plants will remain small – below height of wildflowers. Annuals still present as a large component of the planting site. Native perennials are beginning to mature and set seed. Seedling are still below the free to grow stage but are good signs of growth.	Continue to control perennial and biennial exotics on margins during cool seasons. Monitor seedlings and wildlife. Place cover boards to monitor populations of reptiles. Monitor site for cool season grasses and vines. Treat cool season grass patches with glyphosate prior to warm season grasses/forbs/seedlings flush (herbicide application should be undertaken in early April after two or three days of above 10 degree weather). Generally landowner to undertake follow-up maintenance.	Increase in grassland & edge birds including American Woodcock, Wild Turkey, Common Yellowthroat, Whip-poor-will. More use by wild life as species become accustomed to site conditions. Dramatic increase in pollinators[2] including bumble bees. Increase in aerial insectivores (swallows) and grasshoppers. Most insects common, early-successional species in high numbers.
3	Native herbaceous plants will increase in number but be smaller, few weeds visible. Native annuals and biennials (Horseweed, Ragweed, Venus' Looking Glass much reduced). Trees and shrubs begin to appear at or above native vegetation. Seedlings reach free to grow stage.	Monitor at 5 years. Incidental observations and control of weed issues (backpack sprayer). Comparison with reference ecosystem. Landowner consults local manager with any concerns and general updates with site's progress.	
6	Trees and shrubs well-established with some individuals reaching 1-2 m. Herbaceous plants fewer with open patches of mossy sand. Contribution of wild seed to site noticeable with increasing numbers of strawberries, raspberries, grapes, sumacs & sedges. Airborne species appearing (maples, ashes, willows, aspens, tulip-tree, birches, White pine, witch-hazel).	Begin serious control of invasive shrubs and trees such as Autumn Olive, Multiflora Rose, Tatarian Honeysuckle, Oriental Bittersweet, Scots Pine, Red Pine and Black Locust seedlings if they occur. Seed in more conservative sand plain species as required.	Scrubland bird species becoming common: Yellow Warbler, Blue-winged Warbler, Eastern Towhee, Brown Thrasher, Indigo Bunting and Field Sparrow. Forest birds using edges and parts of planted area to feed. Planted American Hazels, Carolina Rose, grapes, witch hazels, etc. producing seed. Snake populations rapidly increasing and utilizing cover boards.

11	Trees reaching 5 m and canopy closure occurring within the pods. Numerous seedlings from adjacent forest trees. Early successional species planted around perimeter of pods beginning to invade early successional areas between pods.	Continue monitoring invasive shrubs and trees and control during cool seasons. Close informal trails. Begin introducing seeds of common forest plants. Consider managing mosses in barrens areas to increase seed germination of barrens. Barrens may require managing to retain open character and increase sunlight on sand. Landowner continuing to monitor and relay any concerns to local managers.	Bird diversity rising with many edge, scrubland and field species combined including Prairie Warbler, Chestnut-sided Warbler, Alder Flycatcher, Rose-breasted Grosbeak. Restoration no longer presents a barrier to forest birds.
16	Canopy closure completed in pods. Well established native perennials between pods with early successional species invading 10 to 20 percent of open areas.	Continue to control invasive shrubs and trees. Monitor vegetation and wildlife. Manage and monitor sand barrens. Landowner continuing to monitor and relay any concerns to local managers.	Bird species singing in and using planted area as post-fledging areas including Red-eyed Vireo, Ovenbird, Hooded Warbler, Veery, Scarlet Tanager and Ruffed Grouse.
20	Canopy closure >80% complete with gaps filled with intolerant seedlings becoming free-to-grow. Trees thinning due to competition for light. Trout Lilies begin to flower along shaded margins (take 21 years to flower from seed). Closure in pod planted sites dependent on distance between pods.	Monitor and manage for exotic invasives. Monitor vegetation and wildlife.	Additional forest birds begin to breed in young forest including American Redstart, Wood Thrush. SAR: Eastern Flowering Dogwood no longer able to withstand anthracnose attacks due to shading. Great Plains Ladies-Tresses appear in clearings (take 20 years to flower). Jefferson Salamander using subterranean habitats and vernal pools.
30	Canopy closed, trees gaining apical dominance and height (10-12 m), understory composed mainly of forest plants.	Monitor vegetation and wildlife and manage forest exotic invasives.	Most forest and edge birds breeding on site. Forest raptors hunting in area.
50	Trees reach height of 12–18 m, and DBH of 30-50 cm. Some microtopography developing through fallen logs and tip-ups.	Monitor & control forest invasive exotics such as Garlic Mustard. Monitor vegetation and wildlife.	Complete use by conservative interior forest bird populations. SAR: Hooded Warbler, Louisiana Waterthrush, Cerulean Warbler.
80	Trees reach 20-30 m and DBH of 40-70 cm, microtopography developing. Forest plants develop large seed-producing individuals. Pteridophytes significant component of forest flora.	Monitor vegetation and wildlife.	Forest raptors nesting. Eastern Wood Pewee, Pileated Woodpecker, SAR: Acadian Flycatcher.

Case Study Perspective

It is interesting to consider the expected condition of various treatment areas 100 years into the future, since that intended condition should play a role in deciding on the treatment approach. Will those case study areas eventually be quite different, or are they moving towards a similar condition (assuming they are on the same site type) or even a similar level of diversity, since it is unlikely that two areas even on the same site but managed in different ways will become the same in only a century? It can be assumed that they will all fill important niches even if they are quite different. If managers and scientists follow through with monitoring and observing change, we should have some of those answers in much less than a century.

These case studies are intended to help illustrate some of the concepts and potentials of afforestation and restoration. In the end, the onus is on the professional forest manager to set an ecosystem on a trajectory that will have natural resilience and provide ecological benefits. The landscape is large and the possibilities are infinite. According to Dunster and Dunster's *Dictionary of Natural Resource Management,* "one of the most important aspects of diversity is to retain a diversity of diversities in the landscape, thus leaving many options for the future, rather than maximizing one form of diversity that precludes other forms of diversity, possibly of equal or greater importance in the future." The role of forest managers is to establish an abundance and diversity of forest ecosystems on the landscape in the face of past and future whims of development.



05

Observations and Recommendations

5.1 Landscape Considerations

Managers should be strategic in their afforestation efforts and informed by the best landscape scale plans available, using them to identify features that are critical at the landscape level so that afforestation programs can be designed that will help fill the gaps, and to suggest for instance the appropriate balance of forest/savanna, or of hardwood/mixedwood/conifer forest representation. Examples of landscape level documents have been mentioned previously, but include:

- Municipal Significant Woodlands mapping or Natural Heritage Systems documents under the Provincial Policy Statements,
- Conservation Authority Watershed Plans,
- Carolinian Canada Big Picture Project Mapping,
- Priority Habitat Stewardship Landscapes and Conservation Action Plans as identified in the Carolinian Woodlands Recovery Strategy.

Recommendation 1: Trees Ontario and its partners should be aware of the strategic planning that has been completed or is ongoing in specific areas and make treatment recommendations to landowners based on that information.

5.2 Program Support

Both conventional and the more recently applied afforestation and restoration focused approaches are viable. Both have and will continue to contribute to positive ecological change across our landscapes. Ecosystem restoration can result from either approach over time, if that is the objective of the landowner and manager. An exception of course would be in the implementation of an afforestation project with a purely timber production objective, but such a narrow focus is rarely the case in southern Ontario. Indeed even when such single-focused objectives were identified as the original management intent for some of the earliest plantations in southern Ontario, subsequent management direction was adapted over time to newly identified needs and priorities.

The development of conditions of long-term biodiversity where restored areas are eventually able to sustain themselves ecologically is one of the long-term objectives for most managers. This objective may be achieved through a continuum of approaches (K. Elliott, pers. comm.) ranging from relatively straightforward one or two species conifer plantations to highly diverse planting and/or direct seeding efforts that incorporate scatter plants, pods and perhaps topographical restoration. The urgency in bringing an area to a restored state, the funding available, and the suitability of the particular site for the treatment under consideration, are three of the major factors to consider in determining management direction.

Recommendation 2: Trees Ontario should support investigated woodland ecological restoration projects where the primary goal is to restore biodiversity, where there is urgency in the establishment of the targeted ecosystem condition, and where the restoration plan matches the site conditions.

Recommendation 3: Trees Ontario should actively seek funding partners, and with them develop programs that will provide financial support in the implementation of afforestation programs with an immediate restoration focus.

5.3 Silvicultural Approaches

Innovative and promising afforestation approaches have been undertaken including high diversity plantings (tree and shrub species, wildflowers, graminoids, etc.), the use of ground cover, additional measures to discourage exotic species, and the direct seeding of hardwood species. Knowledge gaps affect our ability to predict treatment effectiveness. Some gaps can be addressed over time through long-term monitoring and adaptive management. In other situations, past experience may suggest that modifying the approaches would make them more effective. Neither situation should discourage managers from developing and fine-tuning new approaches.

Following are observations and suggestions for those implementing an afforestation program:

- Multi-species plantations can increase initial establishment costs, and later tending can be both more expensive and more technically challenging. However they also provide opportunities, particularly in mitigating the impacts of potential invasive insect or disease infestations, and potentially increasing overall productivity, etc. To take advantage of the potential for species mixtures, managers are advised to consider and come to understand the complexities involved and the implications related to later stand dynamics. Managers should focus on site potential and species compatibility, and consider establishing random mixtures, recognizing that some of the effort and expense (seed collection/stock production/planting, etc.) borne by the landowner may not make a contribution to the new forest or to its diversity in either the short or long-term.

- The establishment of native ground cover as a component of a broader competition control effort shows excellent potential and warrants more investigation on a broader range of sites.

- Guidelines for the establishment of hardwood forests from bareroot stock based on fairly extensive research are available. Managers should be cognizant of the recommendations which refer to careful site selection and the requirement for effective competition/rodent control, and maintenance of effective competition control for at least a three year period into their plans.
- Direct seeding may be an effective means of establishing hardwoods on light textured soils, particularly for large-seeded hardwood species. Caution should be taken when attempting a direct seeding program on heavier sites, or on sites where full cultivation and extensive competition control is not feasible, or where light-seeded hardwood species are targeted for regeneration.

Recommendation 4: Trees Ontario should consider direct seeding as one of the afforestation techniques eligible for subsidy through its supported programs. As part of this effort, Trees Ontario will work with its partners to ensure that appropriate technologies and measurable standards are recognized and in place.

Fine-tuning these techniques can be accomplished most effectively through the establishment of an on-going monitoring program from which detailed measurements and follow-up reporting can result. Managers need to be able to use that information in order to develop site specific plans (intensity of site preparation, direct seeding rates, follow-up tending requirements, treatment costs) from which reasonable expectations of the future forest conditions (eventual stocking levels, species composition, growth for various species, species diversity levels) may be derived.

Recommendation 5: Trees Ontario will encourage the implementation of long-term monitoring programs of afforestation efforts utilizing direct seeding, ground cover as competition control, and high plant diversity levels.

5.4 Assessment Procedures

Protocols for planting quality and survival assessment plot establishment and measurement must be developed in order to ensure consistency in the results provided by a wide range of Program Delivery Agents, and to address conditions of direct seeding or randomly spaced bareroot programs for which current assessment approaches are inadequate. Stocking and density measures may be more appropriate.

Recommendation 6: Trees Ontario should work with its' partners, including PDAs and MNR Science and Information staff to identify and establish consistent assessment approaches that will produce verifiable measures of establishment quality as well as long-term stocking and density.

5.5 Continuous Learning, Technology Transfer

Several partners have identified the need for more information sharing between practitioners (e.g. what is working and what isn't?) Of particular interest are site specific treatment variations, site preparation and competition control requirements, use of cover crops (native or otherwise), seeding rates and species choice. There is a need for practitioners to expand their areas of expertise, including species identification (e.g. native and non-native graminoids, shrubs), ecological processes, stand dynamics, and use that knowledge to fine-tune approaches in order to move forests toward a desired future condition, and reduce costs. These pieces of information could be incorporated into pre-treatment site plans and prescriptions.

Recommendation 7: Trees Ontario should organize workshops focused on site plans, prescription development and monitoring protocols for PDA's. These workshops should draw on the expertise of a wide range of practitioners, including those with experience in site assessment, direct seeding, use of ground cover, establishment of high diversity forests, writing prescriptions and monitoring.

Recommendation 8: Trees Ontario should encourage the development of a detailed site specific guide and monitoring protocol for practitioners wishing to implement alternative approaches.

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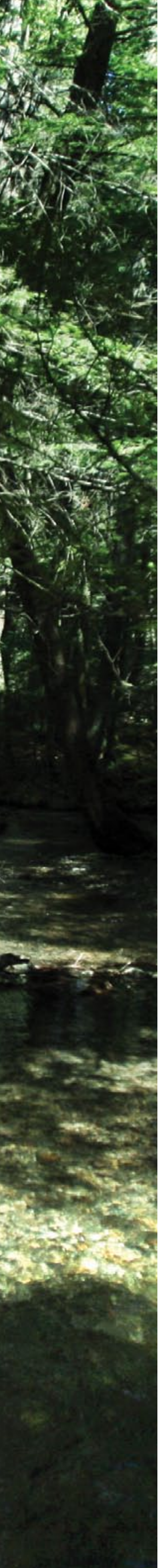


Appendix A

Restoration Plan: Lake Erie Farms

Site Name: Lake Erie Farms.

Location: 5 km west of junction of Hwy 59 and Hwy 24 on Norfolk County Rd 60.

Description of Property: Signed with parking lot and entrance. 160 ha with 74 ha of former agriculture and 86 ha of natural dry forest dominated by White Oak, Black Cherry, Trembling Aspen, Black Oak and Witch-Hazel. Plant Checklist and ELC classification has been completed for site. Management Plan in place.

WGS 84 Lat/Long Centroid: 42 39'10"N, 80 34'2"W.

Significance: this 160 ha parcel lies between Venison Creek Significant Natural Areas and South Walsingham Sand Ridges. It has similar habitats and similar significant species.

Owner: Nature Conservancy of Canada.

Funders: Nature Conservancy of Canada, Long Point Basin Land Trust.

Project Manager: Wendy Cridland, Mhairi McFarlane, NCC.

Ecological Advisor: formerly Heather Arnold, NCC.

Restoration Advisor and Contractor: Pterophylla Native Plants and Seeds: Mary Gartshore and Peter Carson.

Objectives:

1. Enhance natural habitats and ecologically restore agricultural areas for ecological integrity, biodiversity and function.

2. Reduce parameters of forest fragmentation and provide a significant corridor between Venison Creek and South Walsingham Sand Ridges.

3. Plant using locally collected species belonging to a diverse mix of species expected to occur on site.

4. Use both mechanized means and volunteers to direct sow all species required on site to reduce cost and increase effectiveness of large-scale planting.

5. Create high biodiversity of early and mid-successional species to serve the urgent needs of local species diversity (e.g. birds, insects) and Species at Risk.

6. Focus on planting those species not expected to arrive on the site by natural means. Many factors could prevent the arrival of the most appropriate native species to the site.

7. Establish all native cover to protect young trees and shrubs from the effects of invasive exotic species. Native trees and shrubs have a long evolutionary history with native plants. Once in the mix, native wildflowers and grasses will fill niches otherwise quickly filled with aggressive exotic weeds.

Year Started: 2006.

Timeline: 2006–2007.

Size in hectares: 53.6 ha.

Species at Risk on the Property:

Common Name	Scientific Name	Status
American Badger	*Taxidea taxus*	END
Woodland Vole	*Microtus pinetorum*	SC
Cerulean Warbler	*Dendroica cerulea*	SC
Hooded Warbler	*Wilsonia citrina*	THR
Golden-winged Warbler	*Vermivora chrysoptera*	THR
Louisiana Waterthrush	*Seirus motacilla*	SC
Acadian Flycatcher	*Empidonax virescens*	END
Eastern Hognose Snake	*Heterodon platirhinos*	THR
Grey Ratsnake	*Elaphe spiloides*	END
Eastern Fox Snake	*Elaphe gloydii*	END
Antenna-waving Wasp	*Tachysphex pechmanni*	S2
Native bee	*Halictus parallelus*	extremely rare
American Chestnut	*Castanea dentata*	END
Butternut	*Juglans cinerea*	END
Eastern Flowering Dogwood	*Cornus florida*	END

Planting cost per hectare: $1370.00/ha.

Plant Materials:

53.6 ha	Common Name	Scientific Name	Plant Type	Seed in kgs
1	Broomsedge	*Andropogon virginicus*	graminoid	0.51
2	Kalm's Brome	*Bromus kalmii*	graminoid	6.99
3	Muhlenberg's Sedge	*Carex muhlenbergii*	graminoid	0.12
4	Sedge	*Carex siccata*	graminoid	0.01
5	Awl-fruited Sedge	*Carex stipata*	graminoid	0.02
6	Fox Sedge	*Carex vulpinoidea*	graminoid	0.03
7	Slender Cyperus	*Cyperus lupulinus*	graminoid	0.47
8	Panic Grass	*Dicanthelium oligosanthes*	graminoid	0.01
9	Panic Grass	*Dicanthelium spp*	graminoid	0.03
10	Slender Wheatgrass	*Elymus trachycaulus*	graminoid	7.19
11	Little Bluestem	*Schizachyrium scoparium*	graminoid	13.39
12	Dark Green Bulrush	*Scirpus atrovirens*	graminoid	0.02
13	Sand Dropseed	*Sporobolus cryptandrus*	graminoid	1.34
14	New Jersey Tea	*Ceanothus americanus*	shrub	3.23
15	Silky Dogwood	*Cornus amomum*	shrub	0.15
16	American Hazel	*Corylus americana*	shrub	239.56
17	Sand Cherry	*Prunus pumila susquehana*	shrub	0.18
18	Choke Cherry	*Prunus virginiana*	shrub	2.87
19	Dwarf Chinquapin Oak	*Quercus prinoides*	shrub	51.58
20	Winged Sumac	*Rhus copallina*	shrub	1.62
21	Smooth Rose	*Rosa blanda*	shrub	0.42
22	Carolina Rose	*Rosa carolina*	shrub	0.37
23	Blackberry	*Rubus alleghensiensis*	shrub	0.43
24	Dwarf Dewberry	*Rubus flagellaris*	shrub	0.13
25	Maple-leaved Viburnum	*Viburnum acerifolium*	shrub	0.01
26	Yellow Birch	*Betula allegheniensis*	tree	0.16
27	White Birch	*Betula papyrifera*	tree	0.20
28	Blue Beech	*Carpinus caroliniana*	tree	0.05
29	Bitternut Hickory	*Carya cordiformis*	tree	52.65
30	Shellbark hickory	*Carya laciniosa*	tree	2.00
31	Pignut Hickory	*Carya ovalis*	tree	13.80
32	Shagbark Hickory	*Carya ovata*	tree	21.00
33	Alternate-leaved Dogwood	*Cornus alternifolia*	tree	0.20
34	Eastern Flowering Dogwood	*Cornus florida*	tree	2.80
35	Waxy-fruited Hawthorn	*Crataegus pruinosa*	tree	1.39
36	American Beech	*Fagus grandifolia*	tree	0.28
37	Witch-hazel	*Hamamelis virginiana*	tree	6.64
38	Red Cedar	*Juniperus virginianus*	tree	0.27
39	Black Gum	*Nyssa sylvatica*	tree	0.50
40	American Plum	*Prunus americana*	tree	8.75
41	Pin Cherry	*Prunus pensylvanica*	tree	1.30
42	Black Cherry	*Prunus serotina*	tree	6.00
43	Wild Crabapple	*Pyrus coronaria*	tree	0.14
44	White Oak	*Quercus alba*	tree	400.77
45	Swamp White Oak	*Quercus bicolor*	tree	1.50
46	Bur Oak	*Quercus macrocarpa*	tree	1.50
47	Red Oak	*Quercus rubra*	tree	133.02

48	Black Oak	*Quercus velutina*	tree	546.36
49	Staghorn Sumac	*Rhus typhina*	tree	0.43
50	Sassafras	*Sassafras albidum*	tree	1.30
51	Eastern Hemlock	*Tsuga canadensis*	tree	0.05
52	Nannyberry	*Viburnum lentago*	tree	0.10
53	American Bittersweet	*Celastrus scandens*	vine	0.05
54	Virginia Creeper	*Parthenocissus quinquefolia*	vine	0.02
55	Virginia Creeper	*Parthenocissus vitacea*	vine	0.49
56	Summer Grape	*Vitis aestivalis*	vine	0.60
57	Riverbank Grape	*Vitis riparius*	vine	0.22
58	Wormwood	*Artemesia campestre*	wildflower	3.10
59	Swamp Milkweed	*Asclepias incarnata*	wildflower	0.02
60	Common Milkweed	*Asclepias syriaca*	wildflower	3.52
61	Butterflyweed	*Asclepias tuberosa*	wildflower	1.25
62	Heath Aster	*Aster ericoides*	wildflower	3.40
63	Smooth Aster	*Aster laevis*	wildflower	4.59
64	Lance-leaved Aster	*Aster lanceolatus*	wildflower	0.81
65	New England Aster	*Aster novae-angliae*	wildflower	3.02
66	Sky Blue Aster	*Aster oolentangiensis*	wildflower	5.68
67	Frost Aster	*Aster pilosus*	wildflower	0.27
68	Purple-stemmed Aster	*Aster puniceus*	wildflower	0.03
69	Flat-topped Aster	*Aster umbellatus*	wildflower	4.37
70	Arrow-leaved Aster	*Aster urophyllus*	wildflower	1.16
71	Tall Bellflower	*Campanula americana*	wildflower	0.20
72	Showy Tick-trefoil	*Desmodium canadense*	wildflower	4.39
73	Panicled Tick-trefoil	*Desmodium paniculatum*	wildflower	0.72
74	Flowering Spurge	*Euphorbia corollata*	wildflower	4.37
75	Clammy Cudweed	*Gnaphalium mccounii*	wildflower	0.53
76	Sweet Everlasting	*Gnaphalium obtusifolium*	wildflower	0.49
77	Long-leaved Bluets	*Hedyotis longifolia*	wildflower	0.49
78	Bicknell's Rock Rose	*Helianthemum bicknelli*	wildflower	0.39
79	Woodland Sunflower	*Helianthus divaricatus*	wildflower	0.22
80	Great St. John's-wort	*Hypericum ascyron*	wildflower	0.20
81	Intermediate Pinweed	*Lechea intermedia*	wildflower	1.62
82	Pinweed	*Lechea villosa*	wildflower	0.76
83	Round-headed Bushclover	*Lespedeza capitata*	wildflower	5.49
84	Hairy Bushclover	*Lespedeza hirta*	wildflower	0.65
85	Indian Tobacco	*Lobelia inflata*	wildflower	0.06
86	Wild Lupine	*Lupinus perennis*	wildflower	1.74
87	Wild Bergamot	*Monarda fistulosa*	wildflower	2.18
88	Evening Primrose	*Oenothera biennis*	wildflower	0.20
89	Pokeweed	*Phytolacca americana*	wildflower	2.82
90	Virginia Mountain Mint	*Pycnanthemum virginianum*	wildflower	2.45
91	Brown-eyed Susan	*Rudbeckia hirta*	wildflower	4.69
92	Carpenter's Square	*Scrophularia marilandica*	wildflower	0.20
93	Sleepy Catchfly	*Silene antirrinum*	wildflower	0.35
94	Carrionflower	*Smilax herbacea*	wildflower	0.35
95	Early Goldenrod	*Solidago juncea*	wildflower	0.08
96	Grey Goldenrod	*Solidago nemoralis*	wildflower	5.32
97	Venus' Looking Glass	*Specularia perfoliata*	wildflower	0.19
98	Arrow-leaved Violet	*Viola fimbriatula*	wildflower	0.05

Planting and Restoration Methods: Site consists of 53.6 hectare of planting area. Three blocks have been set aside as unplanted controls. A ten meter buffer has been established between forest edge and seeded area. This is to facilitate weed control as well as provide a barrier (gap) to forest mammals that may forage on planted seeds. Five hectare of farmyard footprint have been left unplanted so that exotics can be controlled. In addition, sections next to county road edges have been planted with three rows of White Pine and Red Cedar at one meter spacing to curtail the invasion of road-edge weeds. The site was in agriculture prior to planting with one section in corn and another section in Roundup-Ready Soybeans. Both sites were disked and packed before seeding.

All seeds of listed species were collected locally or grown by the contractor and prepared using prescribed cleaning and storage methods for wild seeds. Large-seeded species (hickories, oaks) were sown using a modified carousel plug planter. This set-up required three people to operate—two planters and one driver. Seeds were pre-mixed and sown at random in long diagonal rows, crossed to obscure any sense of a linear planting. A Truax Wildflower Seeder towing a culti-packer was used to sow small hard seeds and fluffy seeds. This equipment requires one operator. Small hard seeds were thinned 10X by volume with commercial white millet in order that seeds could be spread thinly enough. Immediately prior to seeding with Truax Seeder and culti-packer, medium-sized and difficult to sow seeds were hand broadcast. Packing the soil prior to and following seeding is essential to provide a firm seed bed for seed-soil contact. One area was seeded in May–June another area was seeded November–December 2006. Supplemental seeding of oak species was carried out in fall 2007 using volunteers. Additional acorns were hand-scattered in fall 2007. The site is fenced, signed and gated to exclude ATVs but not people on foot.

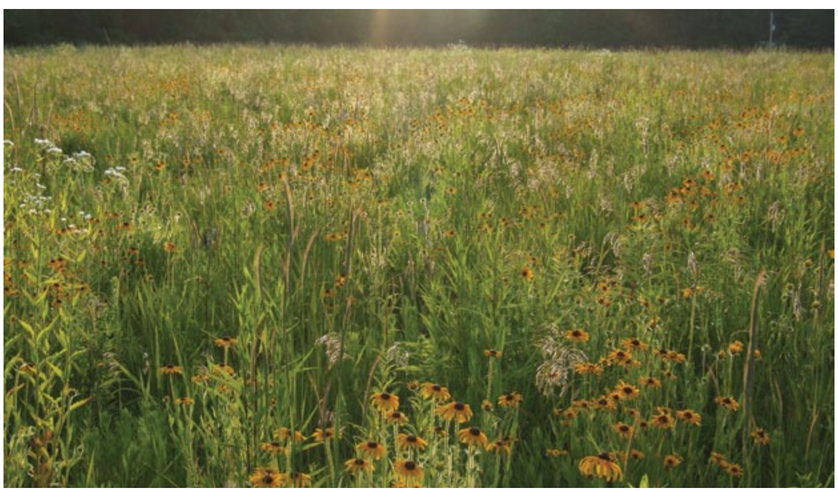
Monitoring and Research: Detailed scientific protocol was set up by NCC. Monitoring includes Breeding Bird Surveys carried out by Bird Studies Canada. York University PhD candidate is studying native bee populations. This study was started with sampling before restoration seeding had begun.

Management: Mostly exotic invasive management and research is carried out.

Management Issues: Exotic invasive plant species.

Results: Results of plot surveys and analysis carried out by NCC are not available yet. Early indications are that there has been successful establishment of the herbaceous layer. Tree seedlings of large-seeded species are visible throughout the site. In addition, some direct sown, small-seeded woody materials are also visible. Wild wind-borne species such as Sugar Maple, Red Maple, Largetooth Aspen and Tulip-tree are seeding in and beginning to establish.

A new restoration site in the first year after sowing in a former sandy agricultural field has a cover crop of agricultural weeds which protect the native plant and tree seedlings.



The same restoration site in second year is dominated by Brown-eyed Susan, Slender Wheatgrass and Prairie Brome. Grassland songbirds such as Grasshopper Sparrow, Vesper Sparrow and Savannah Sparrow are common breeding birds at this stage.

Lake Erie Farms site four years after sowing is showing growth of oak trees from seeds with native herbaceous cover. At this stage in ecosystem recovery, shrub land bird species such as Indigo Bunting and Eastern Towhee colonize the site.