Maryland Department of Natural Resources
Forest Service

Riparian Forest Buffer Design and Maintenance

June 2005

Riparian Forest Buffer Design and Maintenance

Maryland Department of Natural Resources
Forest Service
580 Taylor Ave., E-1
Annapolis, MD 21401
www.dnr.maryland.gov
Toll free in Maryland: 1-877-620-8DNR, ext. 8531
Out of state: 410-260-8531

Compiled by Anne Hairston-Strang
Supported by USDA Forest Service, Northeast Area State and Private Forestry
Through the Chesapeake Bay Program Forestry Work Group
June 2005

DNR Publication No. 02-5312005-31

Cover photos:
Alliance for the Chesapeake Bay forest buffer on Kilby farm, Cecil Co. (Rob Northrop, MD DNR)
Cunningham Falls SP LWD (RH Wiegand, MD DNR)

Table of Contents

List of Figures

List of Tables

Acknowledgments:

I am indebted to a large number of people for information and assistance with this effort in accumulating buffer restoration wisdom from around the Chesapeake Bay region, including:

- Phil Pannill, especially for invasives control and herbicide information;
- Rob Northrop, Phil Pannill, David Kazyak, Riley Smith, and Mike Herrmann for new photos and figures;
- Presenters at regional workshops: Bern Sweeney, Rachel Egolf, Eric Burkentine, Mark Southerland, Lane Heimer, Tina Alban, Pat Cornman, Brett Sage, Matt DiBona, Jonathan Kays, Joe McCue, Phil Pannill, Dr. Hailu Sharew, David Wise, John Galli, Brian LeCouteur;
- Foresters willing to share tips and tools of the trade over the last several years; and
- Reviewers, including Casey Schraeder, Barbara McWhorter, George Eberling, Lane Heimer, Dr. Hailu Sharew, Wade Dorsey, Jonathan Kays, David Wise, Patrick Meckley, Dr. Judy Okay, Dr. Sara Tangren, Sally Claggett

Particular thanks go to Al Todd, USDA Forest Service Northeast Area State and Private Forestry, for ideas, encouragement, and patience, the Chesapeake Bay Program Forestry Work Group for support and coordination, and USDA Forest Service for grant funding through Grant # 01-DG-11244225-244.

Introduction

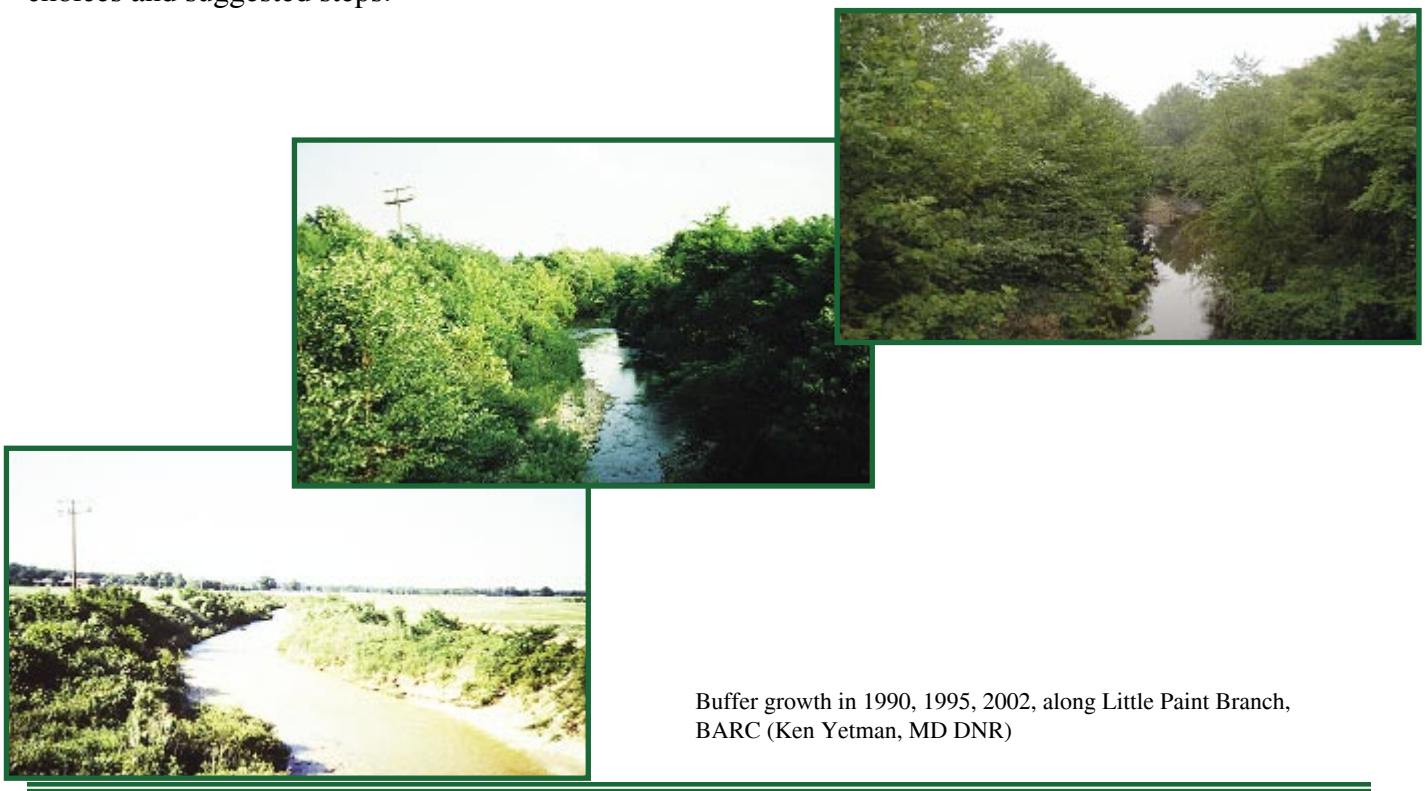
Riparian forest buffers (RFBs) are essential components of maintaining long-term stream and watershed health and resilience in the Chesapeake Bay region. RFBs also provide valuable ecological functions for wildlife habitat and biodiversity. This guide has been prepared as a resource to the many who wish to establish a forest buffer efficiently, effectively, and with a minimum of maintenance.

The best way to minimize maintenance is to do an excellent job designing the planting and preparing the site. Ask most foresters how you should plant a buffer site, and you'll most likely hear, "Well, it depends". It depends on the landowner's objectives, site and soil conditions, prior land use, adjacent land use, budget, available labor, and acceptable levels of risk. This guide is meant to help match these circumstances with suitable techniques designed to avoid or minimize some common problems. It is no substitute for years of experience, but should help speed the learning curve.

Developing a buffer plan will include making choices about:

- Purpose of the buffer
- Site preparation steps
- Species choices
- Density/Spacing of trees and shrubs
- Post-planting protection
- Maintenance tasks and timing

Information to help guide choices follows. Checklists are included in Appendix A and B to record choices and suggested steps.



Buffer growth in 1990, 1995, 2002, along Little Paint Branch, BARC (Ken Yetman, MD DNR)

1. Objectives for the buffers

Riparian forest buffers have been encouraged because they offer a wide suite of environmental benefits for water quality, wildlife habitat, and aquatic health. They are one of the cornerstones for long-term protection of the Chesapeake Bay watershed, and are the natural cover for most streams in this region.

Most landowners who plant a forest buffer recognize the environmental benefits, but also have additional preferences or desired long-term uses. Species choices and design start from these basic objectives. Information for some common objectives is below, with the greatest detail offered for water quality.

Water quality

A literature review of buffer research (Straughan Env. Service, 2003) found that riparian buffers removed between 18-55 lbs/ac/yr of nitrogen. Forests were found to reduce up to 99% of nitrogen loading, grass buffers up to 85%. Efficiency was lower, only 20-30%, during storm events, when water moved through the buffer faster. Root uptake functions only during the growing season, but denitrification in the soil occurs year-round, albeit slower at colder temperatures. Forest buffers were found to function reasonably (about 50%) after 5 to 10 years, but buffers older than 15 years were measurably better. Some buffer attributes contribute to relative higher nutrient reduction in the buffer:

Taller is better. Forests average higher nutrient reduction than grass, provided that concentrated flow like ditches, storm drains, and field tiles (drainage pipes) can be avoided. Adjacent grass buffers and edge of field practices like level spreaders can help disperse concentrated flows. Trees add elements of diverse aquatic food sources, large woody debris for cover, and pool/gravel bar formation. The gravel bars and woody debris are major areas of stream invertebrate habitat, supporting the base of the food chain and the biota that provide the stream's natural ability to capture nutrients already in the water. Nutrient reduction doesn't stop at the stream edge, and native tree cover helps streams build the most efficient in-stream processes.

Wider is better. Water quality functions on year-round streams generally are well served by a 30 m (100 ft) buffer, although site conditions will dramatically affect actual function. Narrower buffers can function to reduce nutrients, but generally less thoroughly. Thirty-five feet is used as a minimum width, below which it is difficult for a buffer area to effectively reduce nutrient loading delivered from upslope. Buffers of 100 m (300 ft) and wider offer significant benefits for wildlife and biodiversity. Buffers can be expanded to encompass particular features critical to protecting water quality, such as seeps and floodplain/slope edges where trees can intercept upwelling groundwater and steep slopes near water sources where risk of erosion and delivery to water is high.

Wetter is better. Plant uptake and denitrification are the two major pathways for reducing nitrogen. Denitrification can remove nitrogen more rapidly and in greater quantities, transferring it to gaseous forms like N_2. It occurs, generally, when soil pore spaces are 60% or more full of water and abundant organic matter (carbon) and nitrogen are available. Saturation should not be constant. Areas where water accumulates during storms are important to have in permanent vegetation, preferably with deeper

rooting and greater contribution of organic carbon. Rates are highest at microbial "hotspots" but these are hard to identify from surface features and may be related to organic matter level.

Shallow soils (10 ft or less) and flatter slopes (<12%) are better. Roots are better able to contact groundwater flows carrying nutrients in shallower soils and gentler slopes. Nutrients carried in groundwater in very deep soils have more limited opportunities to be treated by vegetation. On steep slopes, groundwater tends to drain more rapidly, again reducing contact time with soil and roots. Only the areas immediately adjacent to or in the water body are in a good position to reduce nutrients for these types of watersheds, making the provision of forest cover right next to streams even more critical to optimize nutrient processing capacity within the stream itself.

Some harvesting maintains functions over time. Rapidly growing trees support higher rates of nitrogen removal, with the vegetation able to take up more nutrients than they return in leaves and twigs. Carefully planned and implemented harvesting can maintain function over time (e.g., after 30-80 years depending on species, or intermediate operations like thinning). The trees immediately adjacent to the waterway should be left to optimize shading, streambank stability, and large woody debris important for instream habitat. State harvesting rules usually set minimum standards for retaining some riparian trees (e.g., Maryland requires leaving 60 sq.ft./ac. of basal area in 50-foot or greater buffer zones).

Multiple species are better. Different trees and shrubs offer different advantages for wildlife, water quality, and aesthetics. Many hardwoods have higher nutrient uptake rates, but some with readily degraded leaf litter, like maples, have been found to more readily release nutrients as well. Hardwoods with leaf litter that doesn't break down as quickly, such as oaks or beech, seem to keep nutrients in recalcitrant forms less likely to reach streams. Conifers, with year-round foliage, can have a longer season for plant uptake, even year-round in mild climates, although nutrient uptake rates usually are lower than hardwoods. Conifers can block wind, odors, and protect privacy year-round. Mixed species with multiple canopy layers are more resilient in the face of numerous potential threats to survival and function, such as insects, disease, storms, ice, and fire. Stroud Water Research Center recommends eight to ten species in a planting to restore a range of stream functions.

Continuous is better. A continuous forest buffer helps maintain stream function as it drains larger areas, minimizing undesirable trends like temperature rise that are hard to reverse even in a substantial forest corridor further downstream (Goetz et al., 2003). An ounce of prevention working better than a pound of cure holds true for forest buffers. Small breaks (less than 100 ft) do not seem to adversely affect fish abundance (Sweeney et al, 2004).

The most widely used incentive programs are targeted at achieving water quality benefits, with some attention to wildlife habitat benefits. Programs like the Conservation Reserve Enhancement Program (CREP) have made practices like RFBs very attractive financially, trading public money for important environmental functions on private land. The landowner is obligated to establish the practice successfully in order to receive the payments. Usually, adequate stocking needs to be established within 2 years. Reinforcement planting costs may not qualify for continued cost-share, so the landowner has a strong incentive to establish plantings quickly and with high certainty of tree survival. Design would include the considerations listed under nutrient removal, modified by what is practical for maintaining efficient and profitable farm operations around the buffer.

Recreation

Recreational goals can affect the layout and extent of the planting area and species selection. Plan for water access for fishing or other water-based recreation. If trails are nearby, a diversity of species can be important for visual and botanical interest, with varying leaf and bark texture, flower color and timing, and mature size. For recreational deer hunting, landowners may want to plan access to deer trails down to watering spots. Hunting can be for personal/family use, or as an annual income source ($5-15/acre per year or more). Hunting is an important way to keep deer herds at healthy levels and prevent browsing from eliminating the natural understory and young trees.

Wildlife

J&K Hollingsworth (USFWS)

Specific recommendations depend on which species or types of wildlife are of interest. In general, a mixture of species that provide hard mast (like oaks, beech, hickory) and soft mast (like plum, serviceberry, crabapple) will support a range of common wildlife species. Other considerations include cover, nest or den sites, winter shelter, and perches. Groves of conifers can be included for winter thermal shelter. Greater diversity in tree species selection is generally an advantage, as long as species selected are appropriate for soil, moisture, and light conditions.

Forest Products

Many landowners rely on income from the land to support their family and ownership costs long-term. Landowners should plan on leaving trees immediately adjacent to waterways for long-term stabilization and stream protection. Harvesting and buffer requirements vary by state, and good implementation of harvesting best management practices are critical for protecting water quality. Maryland's forest harvesting guidelines currently call for a minimum 50-foot riparian management zone, expanded for slopes, where only limited harvests should occur. Beyond that, some removal of forest products can help maintain nutrient cycling capacity, as well as provide important periodic income. Species choices for timber and future income are commonly loblolly pine on the Coastal Plain and oaks or walnut farther west. Timber markets thirty years or more in the future are uncertain, and many other species may have greater value than they do today. While markets may change over time, major species with desirable wood properties like pines, oaks, and yellow poplar are expected to maintain their utility and value into the future. Other income-producing products from buffers include willow cuttings, nuts, or berries, which can be important for niche markets.

2. Reading the site - Background for design

Once objectives are identified, you need to evaluate the site for limitations and opportunities. Major factors are prior land use, soils, drainage, and adjacent conditions. These usually determine site preparation steps.

What is the prior land use?

Crop - You have the opportunity to establish a cover crop that can help control weeds during early years of establishment without competing too vigorously with trees. Watch for herbicide carryover, and weed seeds previously suppressed by annual herbiciding.

Pasture - Weeds and rodents are more likely to already have a foothold and more vigorous measures to control them are often warranted prior to and during the early years of establishment. This may include delaying planting a year to apply herbicide to control the worst weeds without fear of damaging young trees and shrubs.

Lawn/Park - Fescue provides very strong root competition, and damage from mowers and weed-eaters is common. Weed mats, mulch, or tree collars can help block grass growth immediately adjacent to the newly planted tree. Damage from deer browse and rub may be particularly challenging since hunting is limited in populated areas and deer density can be high. Invasive species can be a problem because there are so many different kinds and seed sources nearby in the form of some commonly used landscaping plants.

Are there noxious or invasive weeds?

Noxious weeds or exotic invasive weeds can be real challenges for tree survival and growth. They usually spread without the herbicides applied every year with crops. Noxious weeds must be controlled according to state law, so landowners have particular interest in preventing them on their property; requirements vary by state.

Good field identification guides for invasive species in forests include Huebner et al. (2004) for the Northeastern U.S. and Miller (2003) for the Southern US (see web links in references). Other invasives information can be found in publications like Sweringen et al. (2002), state Native Plant Societies, regional Exotic Pest Plant Councils, and state Invasive Species Councils.

Beyond the commonly listed noxious weeds (Table 1), problematic exotic invasive species for tree establishment in the Mid-Atlantic US include:

- Japanese honeysuckle (*Lonicera japonica*),
- Bush honeysuckles (Tartarian, Amur, Asiatic (bella) especially),
- Tree-of-Heaven (*Ailanthus altissima*),
- Multiflora rose (*Rosa multiflora*);
- Canada thistle (*Cirsium arvense*) and bull thistle (*Circium vulgare*);
- Mile-a-minute (*Polygomum perfoliatum*);
- Kudzu (*Pueraria lobata*);

- Japanese stiltgrass (*Microstegium vimineum*);
- Autumn olive (*Elaeagnus umbellata*)
- Japanese hops (*Humulus japonicus*)
- Tall fescue (*Festuca arundinacea*).

In areas with some residential development nearby, common invasive problems are:

- Oriental bittersweet (*Celastrus orbiculata*),
- Norway maple (*Acer platanoides*);
- Porcelainberry (*Ampelopsis brevipedunculata*);
- Privet (*Ligustrum spp.*);
- English ivy (*Hedera helix*);
- Garlic mustard (*Alliara officinalis*);
- Japanese knotweed (*Polygonum cuspidatum*)
- Japanese barberry (*Berberis thunbergii*).

Gary Stolz/USFWS

Table 1: Noxious weeds by state for Delaware, Maryland, Pennsylvania, Virginia, and West Virginia (from PLANTS database, http://plants.usda.gov)

Latin name	Common name	DE	MD	PA	VA	WV
Ambrosia trifida	giant ragweed	X				
Cannabis sativa	marijuana			X		X
Carduus acanthoides	plumeless thistle		X			X
Carduus crispus	curled thistle					X
Carduus nutans	musk thistle		X	X		X
Cirsium arvense	Canada thistle	X	X	X		
Cirsium vulgare	bull or spear thistle		X	X		
Datura stramonium	jimsonweed			X		
Galega officinalis	goatsrue			X		
Heracleum mantegazzianum	giant hogweed			X		
Elaeagnus umbellata	autumn olive					X
Lythrum salicaria	purple loosestrife			X	X	
Lythrum virgatum	Eu. wand loosestrife				X	
Papaver somniferum	opium poppy					X
Polygonum perfoliatum	mile-a-minute			X		
Pueraria lobata, P. montana, P. thunbergiana	kudzu			X		X
Rosa multiflora	multiflora rose			X		X
Sicyos angulatus	burcucumber	X				
Sorghum bicolor	shattercane		X	X		
Sorghum halepense	Johnsongrass	X	X	X		X

Are deer common?

Deer populations are generally increasing regionwide, most rapidly in suburban areas where the patchwork of developments, farms, and woods provides their preferred habitat in abundance and hunting is limited. If woods are adjacent and have an understory, a distinct browse line can indicate high levels of deer. When deer levels have been high for many years, there may not even be a browse line anymore, just very sparse understory with little regeneration of new trees or shrubs. Other possible information sources are local foresters, landowners, and hunters, who may know where deer populations are dense. Deer densities over 20 per square mile can be a problem for regenerating trees, depending on species and palatability. Controlling deer damage includes managed hunts, tree shelters, or fencing.


Tom Darden, MD DNR

Are voles common?

Generally sites on pastures or with any established grasses are likely to have voles, especially where there is cover from predation by hawks and owls (tall grasses, thickets). This includes sites where warm season grasses are being established as an adjacent practice. Voles tend to prefer sites with high grasses rather than forbs (broad-leaved herbaceous plants) and wetter conditions. Look for tunnels in soil, burrows, or droppings. Sites can be checked for vole populations in September using apples or peanut butter bait under covers (see vole fact sheet at www.naturalresources.umd.edu). Damage to roots and the base of trees usually occurs in winter, when other food sources are low. With several generations a year, vole populations grow quickly. When a site has a vole problem, voles can lower survival to 10% or less even with repeated replanting. Vole prevention includes mowing in early fall.

Are there seed sources nearby that could naturally regenerate trees?

Most of the Eastern U.S. gets enough rainfall that trees eventually will grow in most sites where they are not kept out by mowing, cultivation, browse, or chemicals. Generally sites with mature forests of desired species adjacent will see significant amounts of natural regeneration, volunteer trees that grow without planting. Natural regeneration is the least costly approach to restoring trees by streams, and should work well where deer populations are hunted, invasive weeds are limited, desirable tree seed sources are nearby, and the site is not thick grass like fescue. Where some natural processes like landscape-level fire no longer operate and other conditions like deer browse are at historic highs, some important native species like oaks may not regenerate well. Interplanting among natural regeneration can be used to fill in gaps or establish desired species that do not volunteer successfully. Perches can be used to some extent to encourage seeds spread by birds (McClanahan and Wolfe, 1993).

What is your physiographic region?

Coastal Plain. Gentle slopes, alluvial soils, and high water tables are common. Pines can be part of a native species mix; on very wet sites, bottomland hardwoods or other conifers like bald-cypress and Atlantic white-cedar are better adapted. Common weeds include Johnsongrass, thistle, trumpetvine, and burcucumber.

Piedmont. Rolling hills are characteristic, and some valleys are limestone with high pH soils. The area tends to be more developed, offering more deer and greater variety of exotic invasive plants. Hardwoods dominate riparian species, although hemlock and white pine also occur. Thistles, multiflora rose, and *Ailanthus* are problematic.

Mountains. Temperature tolerances and aspect come more into site design and species selections. Issues with bears and coyotes are more common in damaging trees and shelters. Natural regeneration is more commonly used.

Figure 1: General physiographic regions in the Chesapeake Bay watershed

What are the soil types?

Soils maps are published by NRCS, usually available on the web (soils.usda.gov/survey/online_surveys/), in libraries, or at local Natural Resources Conservation Service or Conservation District offices. Soils are rated for productivity, usually both for agriculture and woodlands. Higher quality sites often can be regenerated more easily, since growing conditions are better for the young trees. Weed competition can be very high on good sites as well. Soils can be tested through commerical labs to identify potential problems with nutrition or texture.

Sandy- Tend to be droughty and well-drained, lower fertility. Voles will like looser soils like this.
Loam- Good growing conditions and fertility, adaptable for many species, can be easily eroded.
Clay- Usually poorer drainage, wetter conditions at least seasonally, can be fertile but difficult to access in spring and difficult to work in. Thistle prefers clayey soils.
Rocky- Hand planting is more likely than machine planting in rocky soils, but voles may be lower.

Check organic matter levels (darker is usually more), compaction (50% pore space is ideal), and moisture level. General data is available in soil survey descriptions, but a riparian zone may have substantially different conditions than the general soil unit. Putting a shovel in the soil in a few places can help identify some conditions that will affect site preparation and planting (e.g., wet soils just below the surface, buried old roads or dump piles).

What is adjacent to the site?

The best recommendations for appropriate species to plant often can be found by looking at the sites nearby. Learn and avoid the exotic species like *Ailanthus* (esp. Piedmont) and Paulownia (esp. mountains), and the remaining trees will often tell you what native species are thriving in the area. Good information resources include the NRCS PLANTS database, native plant society lists, and Chesapeake Bay conservation landscaping handbook (see resource list after references section).

Some of your future problems can be found here too. If you have mile-a-minute or multiflora rose on a wood's edge nearby, you should count on planning a strategy to discourage it in a new planting. Adjacent woods, thickets, and existing grass cover are signs to look for existing vole populations.

What is your budget?

Natural regeneration is cheapest as long as there are few invasive plants already present or in adjacent areas. For planting approaches, bare-root seedlings are by far the cheapest planting stock to buy and the easiest to plant. In rural settings with appropriate techniques, seedlings generally work well, especially if protected from deer browse by shelters or fencing. In urban areas where they are more frequently damaged by mowers, weedeaters, and unmanaged deer populations, seedlings have been less reliable. Containerized plants are a good option where greater immediate visibility is needed, but usually cost at least 10 times as much. Larger stock remains noticeably larger than bare-root stock for several years, but the head start in height is paired with greater adjustments necessary for the root system to regrow in the new planting location. After 5 to 7 years, it often can be difficult to distinguish between trees from container versus seedlings. Judge your level of patience along with your budget. Larger saplings can be used on edges of planting areas for visibility, with seedlings used beyond for a cost-effective compromise. Tree protection devices like tubes/shelters cost more than seedlings themselves, but can avoid planting failure in areas with heavy deer browse or other survival challenges. Cost-share may be available for initial planting costs, but replanting expenses are rarely covered except in the event of a severe drought or flood.

Are there resources for replanting and maintenance?

Plan on paying attention to new hardwood buffers for up to five years, controlling weeds, checking survival, and replanting some areas if needed. Tree protection devices can give new seedlings better chances for survival and rapid growth, but cost several times as much as the seedling, especially with installation costs. Reinforcement plantings can be used to replace dead seedlings, a time-intensive process. Alternatively, natural regeneration can eventually result in forested conditions in many situations at low cost, but with little control over species, density, or timing. Some temporary control of herbivores like deer and voles and elimination of noxious weeds may be needed in any case to allow establishment of trees in current conditions. Planting with tree protection offers the advantages of prompt establishment, some control of species composition, and fewer follow-up replantings.

3. Buffer Establishment Techniques

Planted pine-hardwood buffer in Somerset Co. (John Jordan, MD DNR)

Comparison of Establishment Approaches

Buffer establishment involves preparing the site, selecting species, choosing planting density and locations, and protecting the new trees. Several techniques are available, with advantages and disadvantages to each (Table 2). Planting is the most commonly used technique in Maryland because it generally gives the most predictable results, can be used with many different site conditions, and supplies are readily available. In more mountainous areas with abundant suitable seed sources, natural regeneration is used with good success.

Because the site preparation and maintenance needs depend so much on existing site conditions, recommended practices here are divided by existing land use. A section on conditions that best support natural regeneration is below, with some additional details by land use. Recommendations concentrate on bare-root seedling planting (hand or machine) in detail because that currently is the most widely used technique in riparian forest buffer establishment in this region.

Hand planting (Ayton Nursery, MD DNR)

Machine planter (Ayton Nursery, MD DNR)

Table 2: Comparison of riparian forest buffer establishment approaches

Techniques	Advantages	Disadvantages	Site prep considerations
Natural Regeneration	Locally adapted native species No transplant shock Low cost Natural appearance Does not depend on good access to site for equipment	Stocking density varies (too few or many) Noxious/invasive weeds difficult to control Little control over species Can be longer time to stand establishment/crown closure May require fencing to protect from deer browse or cattle	Needs nearby (300 ft) desirable seed source May need to disc soil to encourage trees in sod Control existing weeds and those released by scarification May need precommercial thin or reinforcement planting
Direct Seeding 	Some control over species selection and location No transplant shock Denser stands (1000s/acre sown) and early crown closure	Higher cost than bare-root seedlings Need for large numbers of seeds Inconsistent seed availability Variable density Predation by squirrels, rodents	Herbicide and mechanical till if discing in large seeds, raking light seeds Can place shelters over selected planting sites (e.g, hand-planted acorns) or install fencing
Seedlings-Hand Planting 	Good control over species selection and location Generally good availability of planting stock Cost-effective method Low equipment cost Predictable densities (seedling spacing) Can use on steep or rough sites without good tractor access	Higher labor cost than machine planting Risk of poor seedling handling (drying out) Densities can vary if spacing not controlled (may take more or fewer seedlings than ordered) Roots can be bent in planting slit (J-rooting)	Control noxious and invasive weeds, mow for easier access, herbicide to control noxious weeds prior to planting Tree shelters are prudent options if high deer density Typically planted in rows to give good access for maintenance mowing
Seedlings-Machine Planting	Good control over species selection and location Good availability of seedlings Cost-effective method with low labor and combined herbicide/ planting step Most predictable stocking densities (spacing of seedlings) Packing wheel evenly tamps seedlings in planting trench	Need access to machine Risk of poor handling (drying) Roots can be bent in planting slit (J-rooting) Furrows can favor vole travel, esp. on sandy soils Clay soils can be difficult to work, especially when wet Some hardwoods have too large a root mass to work well	Use on gently sloping sites accessible to tractor and plow Use foam markers at front of tractor to mark rows/planting sites Can apply desired herbicides on same pass as planting rows Planting rows allow good access for maintenance
Containerized tree planting	More visible (taller trees) Longer planting season Materials generally available Less susceptible to trampling	Higher cost for materials and labor Pot-bound roots Transplant shock	Need planting holes dug and weeds controlled
Ball and Burlap tree planting	Suitable for street tree plantings Most difficult to steal Starts with heights above most competing plants	Very high cost (materials and labor) Transplant shock while rebuilding root system	Need large planting holes, may need machinery to handle larger trees Invasives control most critical for vines, simpler for others
Live staking	Excellent for bank sites	Limited species (must be able to sprout from cuttings)	Can minimize damage to top of stake by tapping guide hole with rebar; use wood mallet

Conditions for Natural Regeneration Success

Natural regeneration of a stand of desirable native trees should be evaluated as an option on most sites since it is by far the least expensive option under favorable conditions and draws on locally adapted native trees. Generally it will take longer to reach mature forest conditions through natural regeneration, but the cost efficiency may be worth the exercise of some patience on sites where it will work well. Site conditions that tend to favor a viable stand of native trees are:

Good seed sources nearby:

- Look upwind in the direction of prevailing winds for light-seeded species like maple, sycamore, ash, pine, and yellow-poplar (can be fairly far away);
- Look upslope for heavy-seeded species like oaks and hickories (should be close by if you want these in your new stand, at least within 300 ft.);
- Look for perches (snags, fenceposts, utility poles etc.) for seeds spread by birds like dogwood and serviceberry;
- Look for existing trees that produce root sprouts like aspen, black locust, or persimmon.

Lack of invasive weeds already established on or adjacent to the site:

- Some control of noxious and invasive plants should be expected when relying on natural regeneration. Spot spraying with a backpack sprayer or ATV-mounted tank may be used effectively, with careful attention to existing young trees. Focus on controlling only those weeds that interfere with height growth of desired regeneration or are state-listed noxious weeds as a cost-effective and practical approach.
- Existing weeds can be removed most easily prior to allowing natural regeneration, but the seed bank should also be taken into consideration since many problem species have seed with long-lasting viability for sprouting; check individual species profiles on invasives web sites in resource section. Control costs can be significant on sites with serious invasive species problems (planted or natural) and control is usually easier and less costly before trees are present.

Growing sites for new trees:

- Bare mineral soil that allows good seed/soil contact will allow the most rapid regeneration;
- Herbaceous plants and clump-forming warm season grasses generally allow some niches for tree seeds and sprouts to take hold, and may not need much site preparation;
- Sod-forming grasses like fescue and orchardgrass require treatment to release the seed bank and allow trees to seed in. Options include discing about 70% of the sod in early spring or early fall before seed fall, or broadcast herbicide.
- Established shrub cover like rhododendron, raspberry, or multiflora rose can resist tree invasion for decades, and will probably require control (mechanical and/or chemical) if conversion to forest is desired;
- Trees desired for wildlife (e.g., soft mast species like apples, serviceberry, persimmon, pawpaw) can be interplanted and protected with tree shelters to augment natural regeneration and expand species composition;
- Areas with high deer browse pressure or vole populations may need deer fencing or rodenticide.

Functional soils:

- Check soils for some potential problems: compaction, very shallow or very stony soils, very wet conditions (if even the weeds look stressed, check the soils):
- Soils that have been severely compacted are likely to need some treatment (tilling, deep ripping, and/or soil amendments) to support healthy plant growth quickly. This is more common in urban areas, but some cowpaths may also qualify. If the site is being disced to open up a sod-forming grass area, then that should address most compaction from animal use.

Stocking from natural regeneration can vary hugely. Initial germination of seed may yield thousands of seedlings/acre. Many of those will not survive to become over two feet tall, so seedling counts should include a minimum height to avoid counting stems with little chance of forming a tree canopy. Some of the same stocking standards as for planting (such as a minimum 200 trees/acre used for CREP in Maryland) can be applied for determining when natural regeneration has been successful in establishing forests if a minimum height is used (such as over two or three feet). Alternatively, a minimum percent cover can be used, such as 80% ground cover of primarily native vegetation that is likely to develop into a forest, a standard in West Virginia. Since natural regeneration typically is expected to take longer than planting, a longer time frame for evaluating survival success is appropriate, such as 10 years rather than 5 years.

Dense natural regeneration can be very helpful in preventing weed problems, and is likely to eventually thin itself as some trees outcompete smaller ones. While the dense regeneration may be desirable when young, canopy trees will grow more quickly and stands will develop more diverse structure more rapidly if they are thinned. If the new stand has more than 1000 trees/acre after several years, precommercial thinning can be used to reduce density closer to 4-500 trees/acre, although it can cost several hundred dollars/acre. The mature stand may have only 100 to 150 trees/acre. Thinning will encourage more rapid development of larger trees useful for wildlife habitat and timber, and of some understory and mid-canopy layers that create multiple habitat niches. Areas of otherwise suitable sites that do not develop a robust stand of young trees can be augmented with planting of desired species.

Pine natural regeneration (Jack Perdue, MD DNR)

Planting Configurations

Planting patterns can vary widely, and a brief comparison is provided below (Table 3). Rows are most commonly used for ease of design, installation, and maintenance. Random is rarely recommended because of lack of control. Some object to the lack of natural appearance of rows. While loss of trees to mortality and addition of trees from natural regeneration blur the row effect over time, rows are artificial in appearance, particularly during the early years. The most appropriate pattern will depend on desired functions. Mother-tree or clustered patterns may be suitable for maintaining a variety of wildlife habitats over a longer time frame, while rows may be the quickest path to full canopy closure and benefits of a mature forest; a combination may be used as well.

Table 3: Comparison of planting configurations

Pattern	Advantages	Drawbacks
Rows (grid pattern, such as 8 x 10 ft or 10 x 10 ft, often 400-600 trees/acre) 	Efficient to plan tree order from area to be planted Clear to communicate to planters and apply in the field Easy to maintain with mechanized equipment Likely to create closed canopy forest over the whole site	Lack of natural appearance Species distribution may be linear (e.g., all one species closest to stream), although species/site matches for soil moisture may call for this
Clustered (groups of trees/shrubs separated by less densely or unplanted areas, usually fewer trees/acre than rows) 	Can group commonly associated species More natural appearance Well-suited to accommodate soil and site variations and successional habitats Can use hardware cloth/ fencing to protect clusters in lieu of tree shelters	Better applied by staff experienced in species ID (esp. if dormant seedlings) Harder to locate trees during maintenance or survival checks unless all are sheltered or flagged Difficult to maintain with mowers
Random (may be a similar trees/acre as rows) 	Avoid artificial appearance Planters have flexibility Less need for layout	More difficult to monitor planting density Harder to locate trees during maintenance or survival checks unless all are sheltered or flagged Difficult to maintain with mowers
Mother-tree (planting larger trees at wide spacing) 	Natural appearance Mimics some natural conversion processes (perches, microsites) Lower cost Uses larger trees with greater early visibility and seedfall	Slow to reach mature forest conditions- experimental Areas needed to maintain more widely spaced Could limit use of prescribed burning to maintain warm-season grass habitat

Recommendations by Prior Land Use

Contour farming in Cecil Co., MD (Rob Northrop, MD DNR)

Crop Sites

Crop sites usually have good fertility and limited surface compaction, although there may be a compacted layer below the plow zone and organic matter content may be low. You can't necessarily tell all the weed problems you may have by looking at the field under cultivation, since weed seeds may be laying dormant in the soil. Weed problems may emerge the first year that herbicides are not sprayed widely, as they are with many crops. Some problems with residual herbicides can occur; check which herbicides were applied in the last two years to see if any would interfere with intended tree species (such as sulfentrazone (Authority®) and rose species). Some situations are more prone to problems with carryover, such as no-till crops, limestone soils, dry soils, and soybean crops. Practices that can offer more options for weed control, minimize need for control later, and can reduce problems with herbicide carryover include:

- Delaying planting a year to allow control of noxious or invasive weeds prior to planting, and
- Using cover crops.

Natural Regeneration considerations:

Crop sites usually start with bare soils that are likely to get good recruitment of trees, particularly of wind-borne seeds like poplar, ash, pine, sycamore, birch, sweetgum and maple. Recruitment may get so good that later precommercial thinning may be useful to avoid the "doghair" stand that can slow development of larger trees useful for timber and multiple sub-canopy layers useful for wildlife habitat and stand resilience for water quality. If invasive weeds are likely to be common (look in the field edges), consider a cover crop of non-sod forming herbaceous plants.

Recommended action for planting trees on crop sites:

- Control invasive weeds in fall
- Establish a cover crop (fall or spring).
- Plant trees in spring (can strip spray herbicide to create planting slot in cover crop).
- Mow at least twice a year for at least two years to assure seedlings are taller than competing vegetation, and at least once a year for 5 years for better survival of planted seedlings. If natural regeneration is abundant and invasive weeds are few, mowing can be suspended after 2 years.
- Check survival and presence of problem weeds and control before populations spread.
- If landowners wish to avoid herbicide, tree mats can be used, and have been shown to improve growth and survival on crop sites (Sweeney et al., 2002)

Sheltered trees with cover crop (Brent Harding, MD DNR)

Strip spray in cover crop (Brent Harding, MD DNR)

Table 4: Techniques for planting in crop fields

General Conditions	Type	First response for Crop sites	Further response
Deer abundant		Use tree shelters on susceptible species (100-400/acre)	Check options for increased hunting/crop damage permits Alternatively, use 8' deer fencing
Noxious weeds present	Johnson grass	Add clover to cover crop mix to allow herbicide use for grass control	
	Thistle	Early fall spray to control before planting (see App. A) Can use cover crop of winter wheat or oats to discourage weeds Use tree shelters to allow directed spray herbicide post-planting	Mow several times a year to prevent development of seed heads- does not generally reduce established plants
Exotic invasives present	Woody/non-woody	Establish a cover crop Control perennial weeds in the fall with herbicide Use tree shelters to increase options of post-planting herbicide use (can be 3' if don't have excessive deer browse)	Weed mats or tree collars to slow growth over trees Mow several times to minimize seed set (see App. A by species)

Rob Northrop, MD DNR

Restoration in progress (Riley Smith, MD DNR)

Pasture sites

Pasture sites often have established weeds with well-developed root systems as well as weed seeds from animal feed. Compaction from animal traffic often is present. Voles are generally common. Cattle or other animals grazing on adjacent land should be excluded from an area during tree establishment; animal rub and trampling, as well as browsing, can decimate a new forest.

Natural regeneration considerations on pasture sites

- If pasture is thick sod-forming grasses, the planting area should be disced to plow under about 70% of the ground cover or treated with an herbicide to allow trees to colonize;
- Spot scalping in sod is not recommended because of vole damage, and spot spraying may not open a growing site for long enough;
- Perches to encourage bird-distributed seed can be considered if invasive plants with bird-distributed berries such as multiflora rose are not prevalent;
- If the pasture already shows sign of tree regeneration, further disturbance should not be necessary except as needed for invasive plant control;
- Spot spray invasive weeds, particularly vines, which can easily topple and shade out young trees;
- If animals have not been removed from the entire site, fencing should be established to prevent trampling, browsing, and rub.

Recommended for planting all pasture sites

- Control noxious and invasive weeds prior to planting
- Check for voles and mice prior to planting
- Remove grazing animals from site or fence to exclude them from the planting area
- Mow regularly for 2-3 years to reduce weed competition and vole damage, with at least one mow in September to remove preferred winter cover for rodents.

Table 5: Techniques for planting in pastures

Conditions	Type	First Response on pasture site	Further response
No invasive weeds/low deer		Mow to make planting site easier to work in	Mats or collars and tubes to limit weed competition
Noxious weeds present	Thistle	Control thistle in fall prior to planting Avoid planting legumes like redbud or black locust	Survey and treat as needed in following years Mow prior to flowers setting seed
Invasive weeds present/low deer		Control weeds prior to planting, usually 1 year delay	Mats or collars and tubes to limit weed competition
Invasive weeds present/high deer		Control weeds prior to planting, usually 1 year delay Use tree tubes on selected trees (100-300/acre)	Spray for further weed control after planting if needed (some protection from spray provided by tubes)
Voles likely or confirmed	Meadow vole or pine vole	Mow in September Bait with apple slices or peanut butter shingles to check population levels	Consider control with zinc phosphide after baiting (need license) Use firmly embedded tubes and poison inside tubes
Grazing adjacent		Fence buffer	Establish stabilized livestock crossing

Turf or other sites

Turf is a common ground cover in our urban and suburban areas, including parks and lawns. Planting sites that have been primarily turfgrass are generally easy to access, but have a generous set of challenges. Soils may be compacted from foot or vehicle traffic, composed of rubble fill, low in organic matter, and/or high in weed seeds. Mowers and weedeaters can take their toll on new trees during well-meant but not sufficiently careful maintenance. Sites with public access may have problems with vandalism or plants being "relocated" for personal use. Deer populations can be very high as hunting pressure is usually low. Herbicide use may be restricted because of landowner preference or agency policy.

Rob Northrop, MD DNR

Natural regeneration considerations on turf sites:

- No-mow policies have resulted in natural succession on many but not all sites;
- As with pasture, discing or herbicide may help open up sites with heavy sod to more rapid tree establishment, but the likelihood of finding a wide variety of exotic invasives (especially landscaping escapees) is higher in developed areas, and should not be undertaken unless some followup weed control is possible to select for desired species and control invasive ones;
- If in a public area, post no-mow habitat restoration signs for public awareness;
- Control invasive weeds, especially vines, since they can overtop even larger trees.

Recommended for planting urban or suburban turf sites:

- Check soil suitability and arrange amendments like organic matter, gels, fertilizer if needed.
- Plant larger trees on edge of plantings to increase visibility and limit inadvertent trampling or mowing.
- Use weed mats or tree collars where herbicide is not desired and voles are few (or controlled).
- Do annual control of invasive weeds, particularly vines.

Table 6: Techniques for planting in turf

Condition	**Type**	**First Response on turf sites**	**Further response**
No invasive weeds/low deer		Mow to make planting site easier to work in	Mats or collars and tubes to limit weed competition
Noxious weeds present	Thistle	Control thistle before planting Avoid planting legumes like redbud or black locust	Survey and treat as needed in following years Mow prior to flowers setting seed
Invasive weeds present/low deer		Control weeds prior to planting, usually 1 yr. delay	Mats or collars and tubes to limit weed competition
Invasive weeds present/high deer		Control weeds prior to planting, usually 1 yr. delay Use tree tubes on selected trees (100-300/acre)	Spray for further weed control after planting if needed Deer control alternatives include fencing, Repellex® tablets in the soil and foliar sprays for immediate deterrent
Voles likely or confirmed	Meadow vole or pine vole	Insert tubes 1" + in ground Mow in September Bait with apple slices or peanut butter shingles to check population levels	Consider control with zinc phosphide after baiting (need license) Use firmly embedded tubes and poison inside tubes
Soil compacted/ infertile	compacted	Dig planting holes and use containerized stock	Amend soil with fertilizer, organic amendments like peat/ manure, sand, or water-absorbent gels and mulch or weed mat
	Rocks or other non-soil fill	Amend soil with organic matter (composts, peat)	Mulch

Establishment Techniques and Options

Establishment and maintenance techniques should be tailored to site conditions. The following sections cover options for different site conditions and planting options.

Limiting Soil Conditions

For most sites, soil conditions are sufficiently addressed by selecting species suited to the moisture and light levels. On crop sites, plowing to establish a cover crop should leave conditions suitable for tree growth. There may be a hardpan under the plow zone, which usually would change only slowly over time as tree roots develop macropores in the soil. Pasture areas usually would not be plowed, limiting exposure of the stored bank of weed seeds. If the compaction is severe enough to obviously limit existing vegetation growth (e.g., a well-used cowpath), plowing (surface tillage) or ripping (deeper tillage) could be considered in spots, if large enough to merit the expense. Ripping can be done on a grid pattern similar to the intended planting pattern (eases tree shelter installation), but care should be taken to avoid large air voids, particularly on heavier clay soils, so roots of new trees get good soil contact.


Terry Galloway, MD DNR

Urban sites sometimes have significant soil limitations. They can be on old fill without much actual soil, or be tremendously compacted. If the weeds are challenged, the trees will be too. Before planning the planting, stick a shovel in at the planting site; if it bounces back, try soil amendments. Soil testing can provide much better information with a modest investment: tests that could reveal significant limitations include particle size analysis, pH, total nitrogen, total phosphorus, and porosity. More than 55% clay or 95% sand can make soil impenetrable (clay) or droughty and infertile (sand). Soil amendments include fertilizer, composted manure, peat moss, sand, commercial potting mixture, mulch, water-absorbent gels, and decompaction agents. They add to the complexity of planning, but on a severely limited soil can greatly enhance moisture retention, fertility, and tree survival. Fertilizer can be added to soil, sometimes as packets inside tree shelters, and can stimulate early growth.

Mycorrhizal dips also tend to increase survival by jump-starting the beneficial soil fauna that live in symbiosis with most plant roots. They are not widely used because many soils already have existing suitable soil flora, and it is an added expense for which many people are not willing to pay extra. Mycorrhizal dips could be very important on some very difficult sites, particularly ones that have not recently supported vegetation such as reclaimed mine spoils, construction sites where topsoil has been removed, or wildfires that burned very hot and removed the litter layer.

Mulch is commonly used in urban plantings to encourage moisture retention and suppress weeds. It also provides a buffer against lawn mowers, a common cause of accidental mowing or damage to trunks that can open wounds for entry of disease.

Table 7: Soil Amendments and Uses

Soil Amendment	Use	Materials Cost/tree
Fertilizer	Infertile soil to increase early growth (sandy soils tend to have lower nutrients)	Depends on type used, usually < $1/tree
Composted manure or Peat moss	High clay or sand to improve structure and organic matter, peat acidifies soil	Depends on application rate, about $0.50/tree
Sand	High clay (takes large volume of sand to mitigate clay- organics usually more effective) or to increase infiltration	Depends on application rate, distance to supply
Potting soil	Very rocky or fill with no appreciable existing soil	$1/gallon in planting hole
Mulch (composted leaves, shredded bark)	Moderately compacted soil to improve infiltration (may need to fertilize as well)	Depends on application rate, about $0.50-1.00/tree
Water-Absorbent gel (gelatinized starch- dry flakes need mixing)	Droughty soils (high sand/rock content or low soil volume in planting area)	$0.20/dipped bare-root seedling Lasts several months
Decompaction agent	High clay compacted soil	About $0.25/tree, $100/ac.
Mycorrhizal root dip	Previously unvegetated or severely burned soils, mine spoils, other stressed sites	About $0.01/tree

Site preparation/ Weed control

Weed competition is probably the most common cause of problems in young plantations. Even with the use of tree shelters, weed control has been found to significantly increase seedling survival, with herbicide showing even greater effect than tree mats (Sweeney et al., 2002). Options include mowing, tilling and establishing a cover crop, and herbicides, and mats, often used in combination.

Example combination for first year preparation (pasture or fallow land): Mow the site several times during the growing season to minimize seed set on weeds and formation of grass clumps that shelter rodents. Complete the last mow in September, let grow for 4-6 weeks, and band/strip or spot spray planting locations (e.g., Oust®, Roundup®, Simazine, Pendulum®). If using herbicide, apply before mowing to allow good plant surface contact; may avoid mowing to allow dead vegetation to mulch site, minimize other weeds, and avoid stimulating resprouting of species like Canada thistle or crown vetch. Some herbicides used with site preparation include:

- Plateau® at 4 oz/acre after greenup with warm-season grasses/shrub, or
- Oust® at 3 oz/acre on pine to control undesired hardwoods, or
- Oust® at 1 oz/acre or less on oak/hardwoods (green ash) to control undesired hardwoods (e.g., sweetgum/red maple)

Mowing:

- Typically used on pasture sites
- CREP sites having mowing permitted anytime during first 2 years, afterwards, only outside of nesting season (see Table 10)
- Reduces weed competition, but should be done before weeds set seeds (May/June)

- Increases ease of planting
- Reduces vole habitat with an early fall mowing
- Easy to arrange and check for completion
- Don't mow just before a spray (reduces leaf area available to take up herbicide)
- Limit mowing around pines to prevent problems with tip moth
- Care should be taken to avoid accidentally mowing of trees and scraping of young bark

Plow and Cover crop

Typically used on crop field sites (may also be used to prepare for direct seeding option)
Establish a cover crop that will:

- minimize invasive weeds,
- not compete too vigorously with desired trees,
- produce green mulch to improve soil condition/organic matter, and
- act as "sacrifice" food for deer as an alternative to trees (Some suggest that rather than distracting deer from the trees, preferred food items as a cover crop will attract even more deer and browse damage).

A cover crop usually involves some herbicide and fertilizer during establishment. Strips can be sprayed at the time of planting to reduce competition along planting line, as long as weed seed sources are not so abundant that sprayed areas become major invasive weed problems (most commonly reported in mixed residential/rural areas rather than predominantly agricultural areas). If site has not been recently plowed (last 5 years), some practitioners plow at least three weeks before planting; others avoid plowing to minimize the exposed weed seed.

Common cover crops with trees include winter wheat and clover**.** Winter wheat is not sod-forming; not too competitive with trees; and can regerminate for renewed cover. It is also short enough to plant over. Clover can act as sacrifice crop for deer, improves soil nitrogen, can use herbicides to control Johnsongrass without harming cover, and is good where warm season grasses are managed in adjacent areas. Avoid fescue and other large cool season sod-forming tall grasses; these are very competitive for nutrients and water, and attractive to voles if not close-mowed. Tree have been planted into orchardgrass with some success since it lays down later in the year. Warm season grasses are more clumped in growth habit, and less competitive with roots. Cover species can be seeded alone or as a mixture; with a nurse crop being added to a more long-lasting seed type (e.g., rye and clover):

-Annual rye nurse crop at 10 lb/ac planted in August through April
-Perennial rye (varieties such as Virginia, Canada, silky, or riverbank wild)
-Wheat nurse crop at 40/acre planted in August through April
-Barley nurse crop at 40 lb/acre planted August through April
-Oats nurse crop at 40 lb/acre planted August through April
-Millet nurse crop at 7-10 lb/acre planted in June to August
-Winter wheat at 60-120 lbs/acre planted in October
-Oats at 30-60 lbs/acre, 1st year of establishment in March-April
-White clover at 5-7 lbs/acre, 2nd year of establishment in March-May
-Wildflower mix of species native to region/physiographic province
-Orchardgrass or ladino clover with switchgrass and Indian grass (2 lb/ac each)

Herbicide

Herbicides are generally a very effective and rapid means of controlling competing weeds, particularly invasive species. Choice of chemical and application method and timing is critical. Table 8 identifies chemicals and timing for common invasive weed problems on buffer sites in Maryland, and more detailed information is in the appendices. Response to mowing is also listed, since for some weeds, close attention to mowing may be sufficient to solve the problem. However, some species such as multiflora rose sprout vigorously following mowing and may even spread in response, rather than diminish. Properly applied herbicides were found to be generally more effective than mats in trials by Stroud Water Research Center.

Herbicide label instructions are the law and must be followed, both to assure product effectiveness and to avoid undesirable effects for the environment or human health. Mention of trademarked products does not constitute endorsement.

Typical uses are:

- Site preparation in fall, broadcast spray or spot spray broad-spectrum herbicide like glyphosate;
- At time of planting in band or strip (2-3 ft) to reduce competition using a preemergent herbicide;
- After planting to control competing vegetation and noxious weeds, usually directed spray if sensitive species are in tubes, spot spraying if species are sensitive and unprotected, or broadcast spray if planted species are not susceptible.

Notes on herbicide use:

- Use selective herbicides where possible; broad-spectrum herbicides like Roundup® or Rodeo® kill all plants, leaving dead spots that allow invasion of problematic exotic invasive plants from seed stored in the soil or deposited from adjacent areas. Weed seed sources generally are most abundant in mixed rural/residential landscapes.
- Less costly than mats, generally most cost-effective
- If planting hardwoods that would be susceptible to damage from herbicides needed to control competition and noxious weeds, solid tree shelters can shield young trees and allow the use of directed spray herbicides
- Often will require follow-up treatments. Early treatment is critical. For example, Canada thistle can be easily controlled with Transline® if treated in the first year, but if allowed to go to seed the first year, it usually takes two successive years of treatment to control.
- Grass control has been well-documented to increase survival and growth of young trees.

Table 8: Control Methods for Invasive Exotic Plants in Riparian Forest Buffers Plantings

Species	Type of Plant	Mowing	Post-Emergent Herbicide			Pre-Emergent Herbicide		
		Cutting	Best	Okay	Best Timing	Best	Okay	Best Timing
Biennial Thistles	Annual Forb	Good	4, 5, 6	1, 10	C	9	8, 10	A or G
Canada Thistle	Peren Forb	Poor	6	4, 5, 1	C or F	9	8, 10	A or G
J. Stiltgrass	Annual Grass	Fair	1, 2, 3, 10	-	C - D	8, 10	9	A or G
Tall Fescue	Peren. Grass	No	1, 10	2, 3	B, F	8, 10	9	A or G
Johnsongrass	Peren. Grass	Poor	2,3	1	D	8, 10	9	A or G
Japanese Hops	Annual Vine	Poor	1,4,5,7,10	-	C - E	9, 10	8	A or G
Mile-a-Minute	Annual Vine	Fair	1,4,5,7,10	6	C - D	9, 10	8	A or G
J. Honeysuckle	Peren. Vine	Poor	1, 5	4, 7	C - E	-	-	-
O. Bittersweet	Peren. Vine	Poor	1, 5, 7	4	C - E	-	-	-
B. Honeysuckle	Shrub	Fair	1, 4, 7	5	C - E	-	-	-
Multiflora Rose	Shrub	Poor	1, 4, 7	5	C - D	-	-	-
Tree-of-Heaven	Tree	Poor	4, 5, 7	1	C - E	-	-	-

Mowing/Cutting: Comment indicates the feasibility of controlling the species through repeated mowing or hand cutting in a planted RFB site (Good, Fair, Poor, No).

Herbicides: 1=glyphosate; 2=clethodim; 3=fluazifop; 4=metsulfuron; 5=triclopyr; 6=clopyralid; 7=imazapyr; 8=pendimethalin; 9=simazine; 10=sulfometuron.

Timing: A=March-April; B=April-May; C=May-June; D=June – July; E= July-August; F=September-October; G=Combined with or following post-emergent application.

Include a non-ionic surfactant for foliar herbicide applications unless it is included in the product (as for some glyphosate products), except for some selective over-the-top applications as per label.

It is essential that the label for a particular product be checked prior to purchase or use, and that the information on uses, target species, application rates, and precautions be followed.

Mats, collars, and mulch

Black mats (many mats such as Vispore™ allow water percolation; install shiny side up)

- Alternative to herbicide use, useful particularly where herbicides are not being considered for use and on crop sites with less tendency to support voles;
- Decreases weed competition immediately adjacent to tree for 1-2 years;
- Increases light levels to tree shelter (can improve timely photodegradation of shelter)
- 1-2 times cost of seedling to buy materials and install

Potential problems:

- Dark color increasing sun scorch damage, decreasing frost hardiness because of earlier greenup and later dormancy, an effect that can be lessened with mulch or as weeds grow,
- Vole habitat in protected zone under mat can greatly increase mortality,
- Staples can come up, decreasing mat effectiveness and possibly damaging mowers (Fold under mat corners, insert staples through double thickness and push in at an angle away from the tree to minimize problems. Mat should be flat against the ground.).

Mulch mats (such as 4xTreemats™)

- Incorporate fertilizer, weed repellent, and deer repellent;
- Would avoid problems with black color in Vispore™ and similar mats
- 40-50% more costly, manufacturer says they last two years

Tree collars (such as Tassu)

- Decreases weed competition immediately adjacent to tree (smaller than mat)
- Not currently designed to fit with tree shelters, but product still in development
- Easier to install than mats, similar price for product
- Natural rodenticide impregnated in fibers to limit vole/mouse damage
- Can be used surrounded by mulch to increase weed-free area and minimize blowing

Potential problems include:

- Vulnerable to blowing off especially if not installed in contact with bare ground (scalped of sod),
- Weeds grow up in slit used for installation
- May not last even two years in warm, humid climates

Mulch (average 3” depth, 4-ft diameter, no mulch against stem, less near tree, more in outer portion)

- Readily available as shredded bark or bark nuggets, composted leaves is good if available;
- Aids moisture retention and blocks weeds;
- Pine bark mulch adds acidity, but avoids manganese buildup and pH rise of repeated hardwood mulch;
- Aesthetically accepted in park and urban settings.

Drawbacks include:

- Labor-intensive to apply over large areas
- Needs to be replenished after a year or two to maintain benefits
- Can harbor rodents

Spacing

More densely spaced trees develop forest conditions more quickly. Crown closure of a forest canopy is reached earlier and the shading can reduce some problem weeds more quickly. The density of the tree planting depends on landowner objectives, budget, cost-share program requirements, and intentions for management. Higher planting densities (e.g., over 500 trees/acre) usually should be thinned later to improve stand quality (larger trees, better habitat). If active forest management is not intended, lower planting densities can be used, since only 100-150 trees/acre usually survive to make up a mature forest stand. Lower planting densities will take longer to reach crown closure and establish forest conditions on the site, and leave less margin for loss if a minimum stocking is needed for cost-share or incentive programs. More widely spaced trees also mean that maintenance is likely to be needed for an additional few years as abundant light reaches competing vegetation longer.

Table 9: Some commonly used planting densities

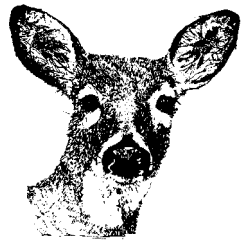
Species and State used	Spacing (feet)	Equivalent trees/acre
Pine, MD, VA:	8x10 ft	544 trees/acre
Hardwood, MD, VA	10x10 ft	435 trees/acre
Hardwood, MD and PA	12x12 ft	302 trees/acre
Hardwood, DE	11x11 ft	360 trees/acre
Hardwood, DE	9x11 ft	440 trees/acre
Hardwood, WV and VA (CREP)	20x20 ft	110 trees/acre
Forested wetland establishment	30x30 ft	48 trees/acre
Shrubs	8x8 ft	680 trees/acre

Species Selection

Select multiple species that are well suited to site conditions to improve resilience in the face of future insect or disease epidemic (like pine bark beetle, emerald ash borer, or sudden oak death). Species like sycamore, river birch, black walnut, or white spruce are less palatable to deer, although at high population levels, almost any tree will be browsed. Shelters are used less often on sycamore, and have not been found to improve growth. Green ash are browsed by deer, but grow above the browse line quickly if given the chance; sheltering at least a third of the ash is often recommended. Oaks are initially slow-growing as they build a strong root system, and generally benefit from shelters; they often resprout readily if damaged by mowing, browse, or moderate drought but will continue to need care until they grow above weeds and browse pressure. See the Planting Design checklist in Appendix A for some species choices by physiographic region and soil moisture status, along with short lists of resistance to deer, voles, salt, and selected herbicides.

Deer Control Options

Options range from fencing, tree shelters, and tree cages to repellents, including in-soil systemic tablets, foliar sprays of many types and active ingredients, and home remedies like deodorant soap, dog hair, urine, and blood. Fencing can be effective, but is usually costly, and needs continued maintenance to repair from treefall or overgrowth. Tree shelters are generally effective, but cost more than the seedling and planting; they are often less than fencing. Shelters also need periodic maintenance to remove bird nets, keep clear of wasps, straighten, and tighten ties, replace broken or rotted stakes, as well as final removal to avoid bark damage. Clustered or mother-tree planting configurations allow a group of trees to be encircled by tall hardware cloth fencing at multiple locations per acre, avoiding fencing the entire planting area.



Deer repellents:
Systemic repellent tablets like Repellex™ have had mixed reports, with general effectiveness at moderate deer densities. Tablets should be inserted in the containers prior to planting out or the trees should have an alternate means of protection such as temporary fencing or foliar spray until systemic repellents take effect (two weeks). At high deer densities, damage just from initial sampling can be substantial, even if an individual deer quits browsing after the first bite.

Foliar deer repellents seem best suited for short-term (8-12 weeks) protection from browse. Trent et al. (2001) found that repellents emitting sulfurous odors, topically applied, were the most effective (especially animal proteins such as egg, meat byproducts, blood). Of the repellents tested, Deer Away® Big Game repellents, Bye Deer™ sachet, Deerbuster™'s sachet, and Plantskydd® were among the most effective, although none were completely effective, particularly at high deer densities, and none lasted much more than 12 weeks. See http://www.agnr.umd.edu/MCE/Publications/PDFs/FS810-A.pdf for more information.

Tree Shelters:
Tree shelters are intended to improve growth and survival, and experience in planting in areas with deer browse pressure tends to support those claims. Research results have been mixed: some trials have found little improvement, others saw improvement in growth but not survival, still others found marked improvement in both survival and growth. Often, the greater the competition, the greater the advantage from shelters, typically moister sites. Recent research on Maryland's Eastern Shore found four times greater survival and 19 times better height growth with the use of shelters, with the greatest effect being shelters in combination with herbicides or mats (Sweeney et al, 2002). In the Maryland Piedmont, height growth of oak and ash seedlings in translucent tubes was three times that of unsheltered seedings after 3 years, although sycamore showed no advantage with tree tubes (Sharew and Hairston-Strang, 2005). Generally, tubes with lighter color, ventilation, and higher light transmission performed better. In practice, tree shelters are seen as almost essential components for tree survival where deer populations are high, often the mixed rural/residential landscape.

Diameter growth usually is poorer inside shelters. Tops should be well above shelters and subject to wind action for several seasons to gain sufficient strength to allow removal of the shelters without bending over, usually five to eight years after planting and an inch in diameter. Different species of trees

are likely to grow out of shelters at different rates, so more than one trip to remove tubes is likely to be needed for multi-species plantings. Removing shelters avoids problems with stem damage, girdling, and rot that has been seen when tree stems grow to fill the tubes without removal. Although tree tubes are designed to break down and/or split open, experience has not shown this to work without avoiding tree damage, especially when weeds shade the tubes from the ultraviolet light responsible for the plastic breakdown. Even if most of the tube splits, the stronger sections at the top or bottom of the tube may remain to constrain or girdle the tree. More recent design changes such as more readily degraded plastic are still under evaluation. Small-leaved trees like black locust or ash are more likely to trap leaf litter inside the tube, where it can decay and create rot-prone conditions.

When using tree shelters, the bottoms may be inserted a couple inches below the ground to limit access for mice or voles, easier with stiffer double-walled tubes. Some evidence suggests that lighter color tubes discourage voles, increasing survival. Spraying or mowing weeds around shelters is important to decrease root competition for moisture and nutrients, increase light around trees, and decrease attractive habitat for voles and mice.

Tree shelter comparison

Figure 2: Photograph showing various tree shelters: (1) Miracle Tube® (2) Tree-Pro®; (3) Protex®; (4) Tubex® brown; (5) Mesh Guard; (6) Blue-X®; (7) Tubex® green

(For light transmission characteristics of Tubex®, TreePro®, MiracleTube®, Blue-X®, Protex®, Mesh Guard- see Sharew and Hairston-Strang, 2005)

Advantages:

- Protect against deer and rabbit browse and buck rubbing, usually at 4-ft height (taller are more expensive and harder to handle, 3-ft provide less protection but work where deer aren't epidemic)
- Accelerate height growth (but not necessarily diameter growth)
- Allow survival where deer populations are high, especially on species preferentially browsed (plum, apples, crabapple) and slower-growing oaks

- Shelters plants from herbicide spray, allowing more options for weed contol around hardwoods
- Increases visibility of rows, allowing mowing of weeds without losing seedlings
- Can balance cost with growth advantage by sheltering a portion of the trees (e.g., 100 trees/acre, density of a mature stand)
- 2-ft shelters can be used in floodplains to minimize washover problems during flooding and on shrubs (usually a minimum of 175/acre)

Disadvantages:

- High cost (4+ times seedling cost for materials; tube, stake, tie, net, and labor for installation)
- Shelters can be lethal for cavity nesting birds, especially if bird nets are not maintained;
- Requires maintenance to remove bird nets just prior to seedling emergence, straighten shelters if fall over, stakes or ties break;
- Can shelter wasps- minimize interference with tree growth by periodically inspecting beginning in June and remove wasp nests with spray such as Raid to avoid stings;
- Can require removal between 5-8 years if shelters have not photodegraded (leaving on can damage bark from physical injury and cause rot from trapped leaves/water); newer tubes tend to have scored lines to encourage splitting, and photodegradation may be favored by weed control around tubes.
- Problems from falling over in flood zone (can use 2-ft shelters to minimize problem)
- Can shelter voles/mice from predation (minimize by early fall mowing to reduce surrounding cover)
- Problems from bears, fox, and coyote tearing up/knocking over stakes in pursuit of prey (or fun?)
- Mesh shelters avoided excess heat but had problems with mechanical damage to twigs and leaves grow through the mesh.

Tree cage: metal or EcoDepot LLC BioBark™ biodegradable tree cage with deer repellent and fertilizer in pressed cellulose/starch

Homemade tree cages: wire fencing cut, wired together at approx. 2 ft diameter, and staked around tree- avoids stimulating height growth, labor intensive

Fencing:

Fencing can be used to exclude deer, as is often done in clearcuts in Pennsylvania. Deer fencing can be electric, woven wire, or wire/plastic, but usually should be 8 ft tall. Staggered fencing, using two lines of parallel fencing several feet apart, can be shorter and still effective in excluding deer. Slanted fencing (multiwire fencing stepping up over 8 ft of distance, 5 ft of height) is effective with high deer pressure but is more expensive, with 2 sets of posts (Onstad and Knight, 2001). When laying out fencing, plan access for animals, fishing, boat launching or other activity in the buffer or waterway.

Advantages:

- More cost-effective in acreas between 2-40 acres. If the area is smaller, fixed costs are high, and if larger, animals are more likely to find ways in.
- Limits browse without having whippy growth from shelters or having to remove shelters.

Disadvantages:

- Cost for initial installation.

- Electric fencing requires efforts to train awareness with baiting.
- Needs continued maintenance to keep functioning- weed control, fence repair, and replacement after washout.

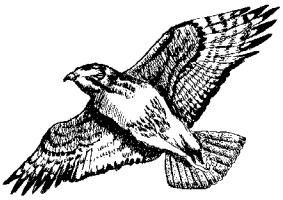
For 5-strand electric fence, problems include:

- Keeping electric fence charged
- Need to train by baiting periodically (metal bait holder with peanut butter or other bait)
- Need to spray twice a year to keep weeds down and preserve electric charge
- Need to clear fallen trees and repair fences periodically (some say continually)
- Have had porcupines eat batteries

For 8-foot woven wire fence

- Average installed price in PA was 1.70/ft in 2002
- Less maintenance, but cannot have interior corners less than 90 degrees
- Plow line to sink lower 4" in ground to keep deer from going underneath

Rodent Control Options



Small rodents can easily girdle and kill small seedlings as they forage for food. Mice are fond of nesting in tubes that are not inserted into the ground, and can encourage rot at the base. Voles have been problematic on numerous sites, attacking seedlings in the winter (usually after the survival check!) and girdling or consuming roots. Tall grass is preferred habitat, so pasture and old field sites are the most common sites with voles problems, particularly in moister areas. Other forbs also provide cover but are often less dense and less preferred. Voles often follow planting furrows as they establish runs, snacking on the trees right down the row.

Keeping vegetation low:

-Reduce preferred habitat by fall mowing, with a possible follow-up strip/spot spray along tree rows.
-Avoid scalping in grass sod, since this seems to promote vole activity near the trees.
-Maintain a mowed or cleared strip between planting and adjacent meadow to break up habitat continuity.

Vernon Burns/USFSW

Reducing populations:

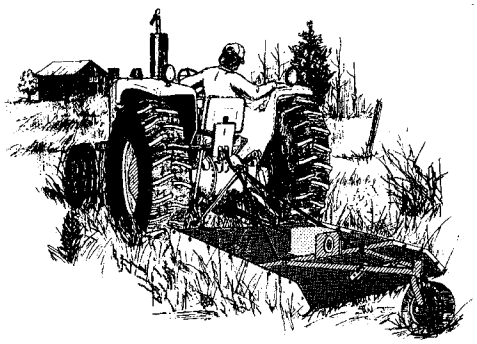
-Trapping can be used on small plantings (mouse traps on 10-ft grid);
-Raptor perches 15 to 20 feet high or snags can attract predators and keep populations contained;
-Rodenticides must be applied by commercial pesticide applicators; zinc phosphide is most commonly used because it does not bio-accumulate in the environment (do not apply in places accessible to horses). It is usually broadcast, in bait stations, or in tubes in the fall, when other food sources are declining and damage to trees becomes more likely.

Initial design can include elements to encourage predators that feed on rodents, such as establishing perches to attract raptors (hawks, owls) or enhancing fox habitat. While these may keep a population from becoming huge, they generally are insufficient to control rodents already at problem levels. More information can be found in the vole fact sheet at http://www.naturalresources.umd.edu.

4. Maintenance Techniques

Good maintenance is clearly linked to greater survival of planted trees and timely development of forest conditions and habitat. For hardwood plantings commonly used in RFBs, plan on 3 to 5 years of follow-up care. In general, trees can establish themselves more successfully among broadleaved plants like wildflowers, which grow in clumps. Sod-forming grasses like the cool-season fescues, are more competitive, and pose a challenge to tree survival, particularly through root competition for water and nutrients. Bushes that overtop seedlings and spread rapidly like raspberry and multiflora rose also can prevent development of tree cover through light competition. Exotic invasive weeds are a concern because they often are vigorous competitors that reduce tree survival. In addition, they build up the available seed source that can spread readily to adjacent natural areas and displace natural habitats. Notes on types of maintenance activities and an example schedule follow for trees planted in rows.

Mow



Seedlings should be planted in rows at least 10 ft apart for tractor mower access, with mowing usually along rows (not always across rows). The first two years are most critical, and two or more mowings per year are recommended. Mowing every four to eight weeks, depending on the growth rate of competing vegetation, will help tree seedlings grow rapidly and usually prevents weed seedheads from maturing and making future problems. Mowing several times for the first two years helps keep the cut stems shorter and better distributed and avoids the large clumps of cuttings that can provide good rodent cover.

After the first two years, mowing is recommended less often, and only before or after the primary nesting season (Table 10). An early fall mowing (September) will reduce habitat for voles and mice, and is needed to minimize vole damage, which can occur even on larger saplings. Mowing at least once earlier in the year in addition to the fall mow can reduce weed competition better, and can prevent seedhead development. Where invasive weeds and voles have not been a problem, sites should be evaluated for natural regeneration. If significant numbers of local native trees and shrubs have established themselves, it may be more advantageous to let them grow than continue to mow.

Table 10: Nesting season dates during which to avoid mowing after the first two years of tree establishment (from http://www.fsa.usda.gov/dafp/cepd/crp/nesting.htm).

State	Nesting Season
Delaware	April 15 - August 15
Maryland	April 15 - August 15
Pennsylvania	April 1 – August 1
Virginia	April 15 – August 15
West Virginia	March 15 - July 15
WV, Lower Muskinghum/ Middle Island Ck watershed	April 15 – July 15

Problems with maintenance mowing include:

- Potentially better access for deer to seedlings,
- Accidental mowing of seedlings, especially where shelters or markers are not used,
- Not eliminating some strong competitors like Canada thistle, and
- Increasing extent of root sprouting shrubs like multiflora rose, although height and fruiting are controlled.

Herbicide

Herbicides are a valuable tool for eliminating noxious weeds and reducing vegetation that would preclude development of tree cover. It is generally the most cost-effective means of controlling invasive weeds and competing weeds, particularly on larger planting areas where some other approaches become impractical. Appendix C has details on controlling several exotic invasive weeds commonly encountered in RFB establishment in Maryland. The herbicide used will depend on the species posing a problem and the species being released from competition.

Hand clearing

Hand clearing is most frequently used to control invasive species in relatively small areas, often with volunteer labor. This can work well to eliminate some species in a limited area, but can be a great deal of work with little long-term impact for others. If exotic invasive species are found on the site, consulting resources like Swearingen et al., (2002) or the Weeds Gone Wild website can identify whether the species present are able to be controlled well by pulling or cutting. Sometimes root systems need to be pulled out and removed from the site to achieve control, and some areas on steep slopes or near water may not be suited to extensive physical disturbance. For most invasive species, plant parts pulled out should be bagged and removed from the site or burned to limit recurrence.

Notes on Maintenance Techniques

The best way to avoid real maintenance headaches often is to control problems with noxious or invasive weeds prior to planting. The planting can be delayed a year if needed to control weed problems without harming trees. Options for control are more limited and can be more labor intensive once the trees are planted throughout the site.

Weeds grow quickly and small trees can be hard to find. Rows can be flagged with fluorescent flagging to help locate trees and prevent accidental mowing of trees. If tree shelters are being used to protect from deer browse, they also help locate planted trees.

Methods for checking survival include:

1. Row count. Walk planting row for 100 ft+, counting live trees (click counter is useful), divide by expected number for walked distance. For 10 x 10-ft spacing, 7 live trees in 100 ft would be 70% survival. Repeat throughout the planting to sample the extent of the planting and detect areas of localized tree death. Notes on trees that are above the weeds (free to grow) as well as alive can help determine likely future survival or maintenance needs. Usually quickest method if in rows.

2. Plot survey. With random distance start, sample 1-5% of planting area using 1/100th acre plots (11.7 ft radius) on a fixed grid (e.g., every 50X300 ft), counting number of live trees. Can count both planted and naturally regenerated trees as separate tallies. Takes a little longer than row count, but can get a better count of natural regeneration/ volunteer trees.
3. Complete tally. Walk entire planting area, tallying live trees (click counter useful). Marking counted trees with paint spray can will avoid double-counting, especially in irregular planting site or where trees are not planted in rows. Divide live trees by total number planted for percent survival. Most time-intensive method.

Table 11: Example maintenance schedule to optimize survival of planted trees

Maintenance Activity	***Year 1***	***Year 2***	***Year 3***	***Year 4***	***Year 5***
Evaluate for grass and noxious weeds; strip spray in May to control if needed.	X				
Mow between rows at least twice (up to every 4-8 weeks) between June and October to prevent weeds going to seed, reduce grass and brush competition.	X	X			
Strip spray in late summer if needed to control perennial noxious or invasive weeds.	X	X	X		
Mow after Aug. 15 (end of growing season or early Sept.) to reduce rodent habitat .			X	X	X
Check tree shelters (straighten, clear out wasps, tighten ties, replace stakes or ties as needed).	X	X	X	X	
Remove bird nets for trees near top of shelter	X	X	X	X	
Check survival in late fall, noting survival problems, invasives, insects, or disease (e.g. 200 tree/ac minimal survival). Check for natural regeneration. Where abundant, limit further mowing unless site is prone to voles or invasive plants.	X	X	X	X	
To encourage hardening off in fall, raise and block up tree tube. If tree is still entirely within the tube, push back down in spring to avoid drying chimney effect.	X	X	X	X	
Replant in failed areas in spring if needed to reinforce tree stocking to desired levels; check natural regeneration for potential free recruitment of trees.		X	X		
Spray in 24-36” strip overtop dormant seedlings in March if needed to control weed or grass competition.		X	X		
Remove shelters if trees grown well outside the shelters (8ft) and diameters over 1”. If all tubes removed at one time, keep stake for whippy trees and use biodegrable ties to secure tree to stake.			X	X	X

Trouble-shooting before a Reinforcement Planting

If enough trees died to warrant reinforcement planting, the site should be surveyed to identify likely damage agents. Sources of damage should be controlled before committing more time and resources to repeating planting. It can be difficult to figure out what killed a tree, and it often may be more than one factor, but some physical evidence can help identify problems that could be mitigated before replanting.

Table 12. Trouble shooting survival problems before reinforcement planting

Condition	Source	Solution
Can't find the trees in all the weeds-look closely (easier to locate if planted in rows and/or in tree tubes)	Weed competition (most common cause of mortality)	Control perennial weeds prior to planting Mow or spray twice a year or more for 2 years (use mats if spraying is unacceptable)
Seedlings/branches nibbled down, often to ground (clean cut, not torn)	Deer	Tree shelters Deer hunt
Bark scraped up and down, seedlings can be pushed over or broken	Buck rub	Deer hunt
Base of trees girdled by gnawing, nests in bottom of tree tubes	Mice	Fall mow Rodent baits
Roots of trees eaten/girdled, trees can be pulled out of ground with little resistance	Voles	Fall mow Rodent baits Raptor perches/ fox habitat enhancement
Seedlings and larger trees nibbled, angled cuts (cone-shaped on larger trees), near beaver dam or lodge	Beaver 	Tree shelters Wire/hardware cloth Sand embedded paint on trunks
Trees present and visible but dry and brown	Drought, or poor handling prior to planting	Keep roots shaded and moist during storage and planting of bare-root seedlings Arrange for watering
Dead top or branch tips	insects	ID insect and control at Va. Tech or Home&Garden website*
Blotchy, brown, spotted leaves, or yellowing	disease	Don't replant the same species Consult tree disease expert or web site* for diagnosis and control
Seedlings and shelters flattened in same direction	Usually flooding	Use 2-ft shelters if needed Straighten following flood

* Insect ID Lab at Virginia Tech: http:/everest.ento.vt.edu/Facilities/OnCampus/IDInfo.html; University of Maryland, Home and Garden Information Center: http:/www.hgic.umd.edu.

Drought (David Kazyak, MD DNR)

Insects (David Kazyak, MD DNR)

Rodent (David Kazyak, MD DNR)

Browse lollipop (Riley Smith, MD DNR)

Weeds overtopping (David Kazyak, MD DNR)

Buck rub (Riley Smith, MD DNR)

Vole damage (Phil Pannill, MD DNR)

Figure 3: Photos of common damage to seedlings

References:

Goetz, S.J., R.K. Wright, A.J. Smith, E. Zinecker, and E.Schaub. 2003. IKONOS imagery for resource management: Tree cover, impervious surfaces, and riparian buffer analyses in the mid-Atlantic region. *Remote Sensing of the Environment* 88(2003): 195-208.

Huebner, Cynthia D., Cassandra Olson, Heather C. Smith. 2004. Invasive Plants Field and Reference Guide: An Ecological Perspective of Plant Invaders of Forests and Woodlands. NA-TP-05-04. USDA Forest Service, Morgantown WV. 88 pages. http://www.fs.fed.us/r9/wildlife/nnis/invasive-species-field-guide.pdf

McClanahan, T. R. and R. W. Wolfe. 1993. Accelerating forest succession in a fragmented landscape: the role of birds and perches. Conservation Biology 7(2): 279-288.

Miller, J. H. 2003. Nonnative Invasive Plants of Southern Forests: A Field Guide for Identification and Control. Revised. USDA Forest Service General Technical Report SRS-62. Asheville, NC. 93p. Available from the Southern Research Station, PO Box 2680, Asheville, NC. -A field guide to identification and control. Images of invasive plants by season, detailed descriptions, habitat, similar species, and control recommendations. http://www.invasive.org/eastern/srs/index.html

Onstad, C. and J. Knight. 2001. Fencing to protect stored hay from deer and elk. Montana State University Extension Service publication MT200108 AG. Bozeman, MT. 4p. http://animalrangeextension.montana.edu/articles/Wildlife/mt200108.pdf

Palone, R. S. and A. H. Todd, eds. 1997. Chesapeake Bay Riparian Handbook: A Guide for Establishing and Maintaining Riparian Forest Buffers. USDS Forest Service Northeastern Area State and Private Forestry NA-TP-02-97, Newtown Square, PA. http://www.chesapeakebay.net (publications).

Pannill, P.D., A.B. Hairston-Strang, C.E. Bare, and D.E. Robbins. 2001. Riparian Forest Buffer Survival and Success in Maryland. FWHS-FS-01-01. Annapolis, MD: MD Dept. of Natural Resources. 50p. http://www.dnr.state.md.us/forests/publications.

Seagle, S. W. and S. Liang. 2001. Application of a forest gap model for prediction of browsing effects on riparian forest succession. Ecological Modelling 144 (2001): 213-229.

Sharew, H. and A. Hairston-Strang, 2005. A comparison of light transmission and seedling growth among tree shelters. Northern Journal of Applied Forestry 22(2): 102-110. http://www.dnr.state.md.us/forests/download/treeshelters.pdf

Sharew, H. and J. Kays. 2004. http://www.dnr.state.md.us/forests/download/vole_damage.pdf

Sweeney, B.W., T.L. Bott, J.K. Jackson, L.A. Kaplan, J.D. Newbold, L.J. Standley, W.C. Hession, and R.J. Horwitz. 2004. Riparian deforestation, stream narrowing, and loss of stream ecosystem services. *Proceedings of the National Academy of Sciences* Vol. 101 No. 39: 14132-14137.

Sweeney, B. W., S. J. Czapka, and T. Yerkes. 2002. Riparian forest restoration: Increasing success by reducing plant competition and herbivory. Restoration Ecology 10(2): 392-400.

Trent, A., D. Nolte, and K. Wagner. 2001. Comparison of commercial deer repellents. Tech Tip 0124-2331-MTDC. Missoula, MT: USDA Forest Service, Missoula Technology and Development Center. 6p.

Other Information Resources

Allen, J. A. et al. 2001. A Guide to Bottomland Hardwood Restoration. Info. & Tech. Report USGS/ BRD/ITR-2—1-0011 and USDA Forest Service Gen. Tech. Report SRS-40. Southern Research Station, PO Box 2680 Asheville, NC 28802. 132p.

Bargeron, C.T., D.J. Moorhead, G. K. Douce, R.C. Reardon and A.E. Miller. 2003. Invasive Plants of the Eastern United States: Identification and Control. The University of Georgia, USDA APHIS PPQ and USDA Forest Service Forest Health Technology Enterprise Team. FHTET-2003-08. Images of invasive plants, distribution map from PLANTS database, links to ID and control in other manuals, below. Most comprehensive species list. http://www.invasive.org/eastern/

Connecticut River Joint Commission www.crjc.org
1) Introduction to Riparian Buffers; 2) Backyard Buffers; 3) Forestland Buffers; 4)Urban Buffers; 5) Buffers for Agriculture; 6) Guidance for Communities; 7) Planting Riparian Buffers; 8) Riparian Buffer Field Assessment; 9) Sources of Assistance;

Delaware Riverkeeper Network. 2003. Adopt-A-Buffer Toolkit: Monitoring and Maintaining Restoration Projects. Available for free download at www.delawareriverkeeper.org or hard copies sold by Delaware Riverkeeper Network, PO Box 326, Washington Crossing, PA 18977-0326.

Heffernan, K. E. 1998. Managing Invasive Alien Plants in Natural Areas, Parks, and Small Woodlands. Natural Heritage Technical Report 98-25. Virginia Department of Conservation and Recreation, Division of Natural Heritage, Richmond, VA. 17p. www.dcr.state.va.us/dnh/mnginv.htm.

Maryland Department of Agriculture Plant Protection and Weed Management Program. http://www.mda.state.md.us/plants-pests/ . 50 Harry S. Truman Parkway, Annapolis, MD 21401 410-841-5920.

Maryland Native Plant Society. Website with invasive and native plant lists and plant suppliers. www.mdflora.org

Natural Resource Conservation Service PLANTS database- http://plants.usda.gov/ information on plant characteristics, growth habits, shade, soil, and salt tolerances, ability to sprout from cuttings, whether US native plant and much more. Advanced search features allows generation of a plant list for a set of site or plant characteristics.

Plant Conservation Alliance. Weeds Gone Wild: Alien Plant Invaders of Natural Areas. Brief information on native range, description, ecological threat, distribution and habitat in U.S.,

background, biology and spread, and detailed information on management options. http://www.nps.gov/plants/alien

Remaley, T. Southeast Exotic Pest Plant Council Invasive Plant Manual. Line drawings and images for identification, descriptions, origin and distribution, similar species, life history, habitat, and mechanical and herbicidal control. Detailed herbicide recommendations. http://www.invasive.org/eastern/eppc/index.html

Riparian Forest Buffer Fact Sheets, University of Maryland http://www.naturalresources.umd.edu/Publications.cfm

- Managing deer damage in Maryland
- Reducing vole damage to plants in landscapes, orchards, or nurseries http://www.naturalresources.umd.edu/Pages/Vole_fs.pdf
- Wildlife damage management: Resistance of woody ornamentals to deer damage http://www.agnr.umd.edu/MCE/Publications/PDFs%5CFS655.pdf
- Using commercial deer repellents to manage deer browsing in the landscape http://www.agnr.umd.edu/MCE/Publications/PDFs/FS810-A.pdf

Slattery, Britt E., Kathryn Reshetiloff, and Susan M. Zwicker. 2003. Native Plants for Wildlife Habitat and Conservation Landscaping: Chesapeake Bay Watershed. U.S. Fish & Wildlife Service, Chesapeake Bay Field Office, Annapolis, MD. 82 pp. http://www.nps.gov/plants/pubs/chesapeake/index.htm

Swearingen, J., K. Reshetiloff, B. Slattery, and S. Zwicker. 2002. Plant Invaders of Natural Areas. National Park Service and U.S. Fish and Wildlife Service. 82pp. Brief information on origin, background, distribution, ecological threat, description and biology, prevention and control. Also highlights native alternatives to invasive plants commonly used in landscaping. http://www.invasive.org/eastern/midatlantic/index.html

Tennessee Exotic Plant Management Manual: http://www.se-epc.org/doc.cfm?id+469

The Nature Conservancy Invasive Species Initiative. Detailed information on selected invasive species and a control methods handbook. http://tncweeds.ucdavis.edu/control.html.

USDA Forest Service. 1989. A Guide to the Care and Planting of Southern Pine Seedlings. USDA Forest Service, Southern Region, Management Bulletin R8-MB39. 44p.

USDA Forest Service Invasive Species Program Web Site: http://www.fs.fed.us/invasivespecies

Van Driesche, R., S. Lyon, B. Blossey, M. Hoddle, and R. Reardon, eds. 2002. Biological control of Invasive Plants in the Eastern U.S. USDA Forest Service Publication FHTET-2002-04. 413p. Information on pest status, nature of damage, distribution, taxonomy, biology, natural enemies, options for biological control (not using herbicides) including biology of enemies and likely effectiveness of biocontrol options. http://www.invasive.org/eastern/biocontrol/index.html

Appendix A: Planting Design Checklist

Objective (check all that apply):

☐ Water quality ☐ Recreation ☐ Wildlife ☐ Timber

Natural Regeneration Potential

☐ Seed source within 300 ft ☐ Minimal invasive weeds ☐ Mineral soil growing sites

Prior Land Use

☐ Crop ☐ Pasture/Fallow ☐ Turf/other See Tables 4-6 for recommendations by land use

Limiting Soil Conditions

☐ Wet ☐ Dry ☐ Compacted ☐ Low organic matter/infertile/ rocky

Manage wet or dry soils with species choices. Plow or rip very compacted soils. Amned infertile soils.

Noxious Weeds problematic for tree establishment (law can require control)

onsite	Latin name	Common name	DE	MD	PA	VA	WV
	Ambrosia trifida	giant ragweed	X				
	Carduus acanthoides	plumeless thistle		X			X
	Carduus crispus	curled thistle					X
	Carduus nutans	musk thistle		X	X		X
	Cirsium arvense	Canada thistle	X	X	X		
	Cirsium vulgare	Bull/spear thistle		X	X		
	Datura stramonium	jimsonweed			X		
	Galega officinalis	goatsrue			X		
	Elaeagnus umbellata	autumn olive					X
	Polygonum perfoliatum	mile-a-minute			X		
	Pueraria lobata et al.	kudzu			X		X
	Rosa multiflora	multiflora rose			X		X
	Sicyos angulatus	burcucumber	X				
	Sorghum bicolor	shattercane		X	X		
	Sorghum halepense	johnsongrass	X	X	X		X

Exotic Invasive Weeds (control is recommended prior to planting)

☐ Oriental bittersweet (*Celastrus orbiculatus*)
☐ Porcelainberry (*Ampelopsis brevipedunculata*)
☐ Japanese stiltgrass (*Microstegium vimineum*)
☐ Autumn olive (*Elaeagnus umbellata*)
☐ Japanese barberry (*Berberis thunbergii*)
☐ Japanese hops (*Humulus japonicus*)
☐ Other
☐ Tree-of-heaven (*Ailanthus altissima*)
☐ Norway maple (*Acer platanoides*)
☐ Japanese honeysuckle (*Lonicera japonica*)
☐ Bush honeysuckle (*Lonicera morrowii*)
☐ Japanese knotweed (*Polygonum cuspidatum*)
☐ Fescue

Deer Browse Pressure

☐ Low (hunting pressure high, understory present in nearby forest)
☐ High (mixed farm, forest, residential; browse line or little/no understory in nearby forest)

Other herbivores

☐ Voles (tall grass, existing tunnels in vegetation or soil, droppings animals found)
☐ Mice (surface tunnels in existing vegetation, adjacent grass/meadow habitat)
☐ Beaver (dam, lodge, or beaverpond near, beaver chew in adjacent forest)

Choose species (Not a complete list; also see NRCS PLANTS database, plants.database.gov, for searchable database)

Coastal Plain

Wet site	Moderate site	Dry areas
Sycamore *Platanus occidentalis*	Sycamore *Platanus occidentalis*	White oak *Quercus alba*
Swamp white oak *Quercus bicolor*	White oak *Quercus alba*	S. red oak *Quercus falcata*
Black willow *Salix nigra*	Black walnut *Juglans nigra*	Chestnut oak *Quercus prinus*
Loblolly pine *Pinus taeda*	Loblolly pine *Pinus taeda*	Loblolly pine *Pinus taeda*
River birch *Betula nigra*	River birch *Betula nigra*	Dogwood *Cornus florida*
Green ash *Fraxinus pennsylvanica*	Green ash *Fraxinus pennsylvanica*	Green ash *Fraxinus pennsylvanica*
Red maple *Acer rubrum*	White ash *Fraxinus Americana*	Persimmon *Diospyros virginiana*
Swamp chestnut oak *Q. michauxii*	N. red oak *Quercus rubra*	N. red oak *Quercus rubra*
Pin oak *Quercus palustris*	Pin oak *Quercus palustris*	Shortleaf pine *Pinus echinata*
Willow oak *Quercus phellos*	Willow oak *Quercus phellos*	Water oak *Quercus nigra*
Bald cypress *Taxodium distichum*	Serviceberry *Amelanchier canadensis*	
Serviceberry *A. canadensis*	Dogwood *Cornus florida*	Post oak *Quercus stellata*
Silky dogwood *Cornus amomum*	Silky dogwood *Cornus amomum*	Black oak *Quercus velutina*
Blackgum *Nyssa sylvatica*	Am. plum *Prunus americana*	Sassafras *Sassafras albidum*
	S. red oak *Quercus falcata*	E. red cedar *Juniperus virginiana*
	Blackgum *Nyssa sylvatica*	Fringetree *Chionanthus virginicus*
	Yellow-poplar *Liriodendron tulipifera*	
	Crabapple *Malus coronaria*	Pitch pine *Pinus rigida*
	Pawpaw *Asimina triloba*	Virginia pine *Pinus virginiana*
	Fringetree *Chionanthus virginicus*	

Piedmont

Wet site	Moderate site	Dry areas
	White oak *Quercus alba*	Dogwood *Cornus florida*
Black walnut *Juglans nigra*	White oak *Quercus alba*	
Green ash *Fraxinus pennsylvanica*	Green ash *Fraxinus pennsylvanica*	Green ash *Fraxinus pennsylvanica*
Swamp white oak *Quercus bicolor*	E. white pine *Pinus strobus*	E. white pine *Pinus strobus*
Sycamore *Platanus occidentalis*	Sycamore *Platanus occidentalis*	Chestnut oak *Quercus prinus*
Red maple *Acer rubrum*	White ash *Fraxinus americana*	N. red oak *Quercus rubra*
River birch *Betula nigra*	River birch *Betula nigra*	Post oak *Quercus stellata*
Silver Maple *Acer saccharinum*	White ash *Fraxinus Americana*	Black oak *Quercus velutina*
Cottonwood *Populus deltoides*	Cottonwood *Populus deltoids*	Sassafras *Sassafras albidum*
Pin oak *Quercus palustris*	Pin oak *Quercus palustris*	Am. plum *Prunus americana*
Willow oak *Quercus phellos*	Willow oak *Quercus phellos*	Persimmon *Diospyros virginiana*
Black willow *Salix nigra*	N. red oak *Quercus rubra*	E. red cedar *Juniperus virginiana*
Serviceberry *A. canadensis*	Serviceberry *Amelanchier canadensis*	
Blackgum *Nyssa sylvatica*	Blackgum *Nyssa sylvatica*	Fringetree *Chionanthus virginicus*
	Yellow-poplar *Liriodendron tulipifera*	
	Am. plum *Prunus Americana*	Pitch pine *Pinus rigida*
	Crabapple *Malus coronaria*	Virginia pine *Pinus virginiana*
	Dogwood *Cornus florida*	
	Fringetree *Chionanthus virginicus*	

Mountain

Wet site	Moderate site	Dry areas
Sycamore *Platanus occidentalis*	Sycamore *Platanus occidentalis*	Chestnut oak *Quercus prinus*
Swamp white oak *Quercus bicolor*	Black walnut *Juglans nigra*	White oak *Quercus alba*
Green ash *Fraxinus pennsylvanica*	Green ash *Fraxinus pennsylvanica*	Green ash *Fraxinus pennsylvanica*
River birch *Betula nigra*	River birch *Betula nigra*	Post oak *Quercus stellata*
Silver Maple *Acer saccharinum*	E. white pine *Pinus strobus*	E. white pine *Pinus strobus*
Yellow birch *Betula alleghaniensis*	N. red oak *Quercus rubra*	N. red oak *Quercus rubra*
Pin oak *Quercus palustris*	Pin oak *Quercus palustris*	Black oak *Quercus velutina*
Black willow *Salix nigra*	Downy serviceberry *Amelanchier arborea*	Pitch pine *Pinus rigida*
Blackgum *Nyssa sylvatica*	Blackgum *Nyssa sylvatica*	Sassafras *Sassafras albidum*
	Yellow-poplar *L. tulipifera*	E. red cedar *Juniperus virginiana*
	Am. plum *Prunus americana*	Am. plum *Prunus Americana*
	Crabapple *Malus coronaria*	Persimmon *Diospyros virginiana*
	Dogwood *Cornus florida*	Dogwood *Cornus florida*
	Fringetree *Chionanthus virginicus*	Fringetree *Chionanthus virginicus*

Species not preferred by deer: sycamore, serviceberry, river birch, blackgum, black cherry, flowering dogwood, black walnut to some extent

Deer candy: apple, crabapple, plum, pear, white pine, redbud, fringetree, yellow-poplar, red maple

Species not preferred by voles: black locust, black walnut, black cherry

Vole candy: fruit trees, green ash

Salt spray tolerance: persimmon, black locust, red maple, sweetgum, hackberry, catalpa, E. redcedar, fringetree, green ash, white ash. Some salt tolerance: N. red oak, willow oak, serviceberry

Species tolerant of Oust overspray for grass control: pine, oak, ash (walnut, redbud, locust, indigobush)

Species intolerant of Transline for thistle control: redbud, black or honey locust, persimmon (any legume)

Calculate number of trees

1. Measure area (estimate carefully from scaled map or measure with 100-ft tape or pacing)
_____ ft of stream length x _____ ft of average buffer width / 43,560 ft^2/acre= acres in planting.
2. Choose spacings (some examples below) or pattern

- 544/acre pine (8'x10') Rows
- 435/acre hardwood (10'x10') Random
- 302/acre hardwood (12'x12') Clustered
- 108/acre hardwood (20'x20') Mother-tree

Plant denser (>400 trees/acre) to reach forest conditions (crown closure) faster and train trees for good form for crop trees. Plant less densely to reduce planting costs, accepting tradeoff for limbier trees and longer to forest conditions.

3. Acres x trees/acre = trees needed

Area (acres)	Species	Number of Trees
	Total	

Appendix B: Planting Installation Checklist

Site preparation

Noxious and invasive weed control prior to planting (use all that apply)

☐ none present/no action ☐ Selective herbicide in May/June ☐ Mow in July/Aug.

☐ band spray 4 wks after mow

☐ Cover crop: Species _____ Seed rates _____

Herbicide:

Target species _____

Product and rate _____

Timing _____

Planting Timing

Seedlings: March/April preferred

Containerized: March-May or September-November

Plant materials Handling

Received in acceptable condition: ☐ Yes ☐ No

(No dry roots, swelled or opened buds, mold, broken stems, stripped roots- return if damaged)

Stored short-term (less than 1 week): ☐ Yes ☐ No

Use cool, dark, damp place with root systems moist.

Stored long-term (more than 1 week): ☐ Yes ☐ No

Keep them in cold storage (35-40°F). Avoid heeling in that can damage fine roots or storing long-term in water.

Planting

Plant materials are kept cool and covered until used: ☐ Yes ☐ No

Properly planted: ☐ Yes ☐ No

- Bare-root seedlings planted 1-2 inches deeper than they grew in the nursery
- Planting hole or slit is large enough for tree
- Avoid J-roots (bending bottom of root like a U or J)
- Planting site tamped down to assure good contact with roots

Protection

Protection from deer/herbivore browse (choose one if needed)

Tree shelters ☐ All trees ☐ ½ trees ☐ 1/3 trees ☐ other (#/acre) _____

Species to receive shelters: _____

Fencing ☐ none needed (no grazing animals on site) ☐ yes

Repellent: ☐ systemic ☐ topical

Hunting options: hunting lease, crop damage permit for out of season

Protection from voles

☐ Fall mow ☐ Herbicide around tubes

☐ Bait traps ☐ Rodent repellents in tree collars or mulch mats

After www.extension.iastate.edu/pubs Wray, P. H. 1997. Tree Planting: Establishment and Care. Iowa State University Extension Service, Ames, Iowa. 4p.

Appendix C: Invasive Exotic Plant Control

Listed below are some of the invasive exotic plants found in planted riparian forest buffers in Maryland. Information on the identification and biology of these plants, as well as the problems associated with invasive exotic plants in general, is readily available. Some information sources are listed at the end of this section.

Biennial Thistles (*Carduus nutans, Cirsium vulgare, Carduus acanthoides*)

Problem – Legally required to control in MD. Seed can spread great distances.

Mechanical - Mow in May and June to prevent production of viable seed. May need to be repeated.

Post-Emergent Herbicide - Best applied during rosette stage, April-May, but more commonly applied May-June.

Best – metsulfuron, triclopyr, clopyralid.

Okay – glyphosate, sulfometuron (these work well, but kill all groundcover and promotes re-growth of thistle from seed).

Pre-Emergent Herbicide - Best applied in March-April or combined with post-emergent.

Best – simazine.

Okay – pedimethalin or sulfometuron (shorter term of control for thistle).

Canada Thistle (*Cirsium arvense*), Perennial Forb

Problem – Legally required to control in MD. Very competitive with tree roots.

Mechanical – Mow regularly May-July to prevent seed production. Will not be controlled without herbicide.

Post-Emergent Herbicide - Best applied April-May or Sept.-Oct., but can also be used June-August.

Best – clopyralid.

Okay - metsulfuron, triclopyr, glyphosate (these will kill plant above-ground, but will re-grow from roots later in season or next season).

Pre-Emergent Herbicide - Best applied March-April or combined with post-emergent. Will not prevent re-growth from extensive root system.

Best – simazine.

Okay – pedimethalin or sulfometuron (shorter term of control for thistle).

Japanese Stiltgrass (*Microstegium vimineum*), Annual Grass

Problem – Spreads easily and persists even after crown closure.

Manual/Mechanical – Mow or hand pull in July prior to production of viable seed. May need to be repeated.

Post-Emergent Herbicide - Best applied May-July, but can also be applied in August, though some viable seed may be produced.

Best – glyphosate, clethodim, fluazifop, sulfometuron.

Pre-Emergent Herbicide - Best applied in March-April or combined with post-emergent. Will not prevent re-growth from rhizomes.

Best – pedimethalin or sulfometuron.

Okay – simazine.

Tall Fescue (***Festuca arundinacea***)**,** Perennial Grass

Problem – Very competitive and allelopathic with tree roots. Provides excellent habitat for destructive voles.

Mechanical – Mowing favors and promotes fescue, though regular mowing reduces vole habitat. Tillage or herbicide is required for control.

Post-Emergent Herbicide - Best applied Sept.-Oct. (glyphosate) or March-June for others, but can be applied anytime actively growing.

Best – glyphosate, sulfometuron.

Okay – clethodim, fluazifop (these work well on new grass seedlings, not as well on established grass).

Pre-Emergent - Best applied in March-April or combined with post-emergent.

Best – pedimethalin or sulfometuron.

Okay – simazine.

Johnsongrass (***Sorghum halepense***)**,** Perennial Grass

Problem – Legally required to control in MD. Very competitive with young trees through root competition and shading.

Mechanical – Mow regularly June-August to prevent seed production. Will not be controlled without herbicide.

Post-Emergent Herbicide - Best applied May-June, but can also be applied July–Sept., re-treatment usually needed to deplete rhizomes.

Best – clethodim, fluazifop (these work well on new grass seedlings, not well on re-growth from rhizomes, require >1 treatment/year).

Satisfactory – glyphosate (requires >1 treatment/year), sulfometuron

Pre-Emergent Herbicide - Best applied in March-April or combined with post-emergent. Will not prevent re-growth from rhizomes.

Best – pedimethalin or sulfometuron.

Okay – simazine.

Japanese Hops (*Humulus japonicus*), Annual Vine

Problem – Grows and spreads rapidly, climbing and covering young trees.

Mechanical – Mow at frequent and regular intervals to keep low and prevent production of viable seed. Herbicide treatment is usually needed.

Post-Emergent Herbicide - Best applied May-July, but can be applied August-Sept. although viable seed may be produced.

Best –glyphosate, metsulfuron, triclopyr, imazapyr, sulfometuron.

Pre-emergent Herbicide - Best applied March-April, or combined with post-emergent.

Best - simazine, sulfometuron.

Okay – pendimethalin.

Mile-a-Minute (*Polygonum perfoliatum*), Annual Vine

Problem –Thorny vines spread easily and climb young trees.

Manual/Mechanical – Mow or hand pull in May or June as soon as it appears. Will need to be repeated at regular intervals to prevent production of viable seed. Herbicide treatment is usually needed. Start control before vines get large and climb into trees.

Post-Emergent Herbicide - Best applied May-July, but can be applied August-Sept. although viable seed may be produced, always use generous amount of surfactant ~1% of solution.

Best – glyphosate, metsulfuron, triclopyr, imazapyr, sulfometuron.

Okay – clopyralid .

Pre-Emergent Herbicide - Best applied March-April, or combined with post-emergent.

Best - simazine, sulfometuron.

Okay – pendimethalin

Japanese Honeysuckle (*Lonicera japonica*), Perennial Vine

Problem – Climbs and strangles young trees. Persists after crown closure.

Mechanical – Regular mowing can keep honeysuckle low, but it will continue to creep and climb.

Post-Emergent Herbicide - Best applied May-July, but can be applied August-Sept.

Best – glyphosate, triclopyr.

Okay – metsulfuron, imazapyr.

Pre-Emergent Herbicide – no product recommended.

Oriental Bittersweet (*Celastrus orbiculatus*), Perennial Vine

Problem – Climbs, covers and strangles trees of all sizes.

Mechanical – Regular mowing can keep bittersweet low, but it will continue to creep and climb.

Post-Emergent Herbicide - Best applied May-July, but can be applied August-Sept.

Best – glyphosate, triclopyr, imazapyr.

Okay – metsulfuron.

Pre-Emergent Herbicide – no product recommended.

Bush Honeysuckle (*Lonicera tartarica, L. maackii, L. morrowi*), Shrub

Problem – Can dominate the understory and persist after crown closure.

Mechanical – Regular mowing can keep honeysuckle low, but will re-grow as soon as mowing stops.

Post-Emergent Herbicide - Best applied May-July, but can be applied August-Sept.).

Best – glyphosate, metsulfuron, imazapyr.

Okay – triclopyr.

Pre-Emergent Herbicide – no product recommended.

Multiflora Rose (*Rosa multiflora*), Shrub

Problem **– Thorny branches discourage management activity. Can persist after crown closure.**

Mechanical – Mowing can reduce impenetrable stands for later herbicide application, and regular mowing can keep rose low, but will re-grow as soon as mowing stops. Some bushes are dying from Rose rosette disease after 2-5 years, but many do not (more likely for wetter, browsed, stressed bushes- disease is selective)

Post-Emergent Foliar Herbicide - Best applied May–July, but can be applied August-Sept.

Best – metsulfuron, imazapyr, glyphosate.

Okay – triclopyr.

Post-Emergent Basal Bark Herbicide - Best applied May–October.

Best - triclopyr in oil (Garlon 4 or Pathfinder II.)

Pre-Emergent Herbicide – no product recommended.

Tree-of-Heaven (*Ailanthus altissima*), **Tree**

Problem – Re-sprouts and root suckers. Becomes part of the forest canopy.

Mechanical – Regular, frequent mowing can keep tree-of-heaven low, but it will re-grow and multiply from root suckers as soon as mowing stops. Herbicide treatment is almost always needed.

Post-Emergent Foliar Herbicide - Best applied June – Sept.

Best – metsulfuron, triclopyr, imazapyr.

Okay – glyphosate.

Post-Emergent Basal Bark Herbicide - Best applied June – Sept.

Best – triclopyr ester in oil (Garlon® 4, Tahoe™ 4E, or Pathfinder® II).

Post-Emergent Cut Surface Herbicide - Best applied June – Sept.

Best – triclopyr amine (Garlon® 3A, Tahoe™ 3A)

Pre-Emergent Herbicide - no product recommended.

Appendix D: Herbicides for Control of Invasive Exotic Plants in Riparian Forest Buffers

Herbicide trade names and a brief description of their uses and limitations are included below. It is essential that the label for a particular product be checked prior to purchase or use, and that the information on uses, target species, application rates, and precautions be followed. Reference to a specific product does not constitute a warrantee or endorsement by the authors, nor does it imply their suitability to the exclusion of other products that may also be suitable. All of the products listed below are labeled for use in tree plantings (although the specific sites vary), and none are restricted use pesticides.

Non-Selective Post-Emergent Herbicides

Chemical name: **glyphosate**
Brand Name(s): Roundup®, Accord®, GlyPro®, GlyStar™, Rodeo®, Razor®, many others
Typical Form of Product: Liquid
Uses: Post-emergent non-selective control of grasses, and most broadleaf weeds and woody plants. Do not apply over-top, or allow contact with bark or foliage, of desirable trees or shrubs. Usually used for site preparation and for directed spray after planting. Best product for established grasses, especially perennial grasses. No uptake through roots or pre-emergent effect.

Selective Post-Emergent Grass Herbicides

Chemical name: **clethodim**
Brand Name(s): Envoy®
Typical Form of Product: Liquid
Uses: Post-emergent selective control of many grasses. Does not kill broadleaf weeds or sedges. Works best on young, short grasses, especially annual grasses. May be applied over-top desirable trees or shrubs with non-ionic surfactant rather than crop oil. Usually used after planting over young trees to release from new grass competition. No uptake through roots or pre-emergent effect.

Chemical name: **fluazifop**
Brand Name(s): Fusilade®, Ornamec®
Typical Form of Product: Liquid
Uses: Similar to clethodim.

Selective Post-Emergent Broadleaf and/or Woody Plant Herbicides

Chemical name: **metsulfuron**
Brand Name(s): Escort XP®, Patriot®
Typical Form of Product: Dry flowable granules that mix with water.
Uses: Post-emergent control of many woody plants and broadleaf weeds. Does not kill grasses. Do not apply over-top, or allow contact with bark or foliage, of desirable trees or shrubs. Usually used for site preparation, or for directed spray outside root zone of planted trees. Best product for multiflora rose

control and foliar spray of tree-of-heaven. Has some potential for uptake through roots and slight pre-emergent effect.

Chemical name: **triclopyr**
Brand Name(s): Garlon® 3A, Garlon® 4, Brush-B-Gon®, Crossbow® (with 2,4-D), Power Force Brushkiller Plus, Tahoe™ 3A, Tahoe™ 4E, Pathfinder® II (pre-mixed for basal bark only)
Typical Form of Product: Liquid.
Uses: Post-emergent control of woody plants and broadleaf weeds. Does not kill grasses. Do not apply over-top, or allow contact with bark or foliage, of desirable trees or shrubs. Usually used for site preparation, or for directed spray outside root zone of planted trees. Good product for multiflora rose control and foliar spray of tree-of-heaven. Garlon® 4 or Tahoe™ 4E may be mixed with an oil carrier and used for basal bark application, and Pathfinder is a pre-mixed form for this use. Has slight potential for uptake through roots and slight pre-emergent effect.

Chemical name: **clopyralid**
Brand Name(s): Transline®, Stinger®
Typical Form of Product: Liquid.
Uses: Post-emergent control of broadleaf weeds. Does not kill grasses, but can kill or damage some trees and shrubs through contact or root uptake. May be used over-top some hardwoods and shrubs while not actively growing or if used without surfactant. Do not apply over-top, or within root zone, of desirable legume trees or shrubs (e.g., locust, redbud). May be used for site preparation, or for over-top or directed spray outside root zone of planted trees. Best product for Canada thistle control. Has some uptake through roots, and slight pre-emergent effect.

Chemical name: **imazapyr**
Brand Name(s): Arsenal®, Arsenal® AC
Typical Form of Product: Liquid
Uses: Post-emergent control of many woody plants, broadleaf weeds and grasses. Usually used for site preparation or for overtop or directed spray for pines only, primarily loblolly pine. Do not use near desirable hardwoods or shrubs. Has potential for uptake through roots and some pre-emergent effect.

Pre-emergent Herbicides

Chemical name: **pendimethalin**
Brand Name(s): Pendulum® 3.3 EC, Pendulum® WDG, Pendulum® Aquacap™
Typical Form of Product: Liquid, or powder that disperses in water.
Uses: Pre-emergent control of many grasses and some broadleaf weeds. Does not kill existing grasses or broadleaf plants and will not usually damage trees or shrubs through contact or root uptake. May be used over-top most trees and shrubs. Usually used after planting, in spring, to keep new weeds from developing. May be mixed with other herbicides, such as glyphosate. Will stain equipment yellow, except for newer Aquacap form. A fairly mild, short-term pre-emergent product that is better at controlling grasses than broadleaf weeds.

Chemical name: **simazine**
Brand Name(s): Princep® 4L, Princep® 90DF, Simazine 4L, Simazine 90 DF, Caliber® 90.
Typical Form of Product: Liquid, or powder that disperses in water.
Uses: Pre-emergent control of many broadleaf weeds and some grasses. Does not kill existing grasses or broadleaf plants and will not usually damage trees or shrubs through contact or root uptake. May be used over-top most trees and shrubs. Usually used after planting (after first year), in spring, to keep new weeds from developing. May be mixed with other herbicides, such as glyphosate. It is better at controlling broadleaf weeds than grasses, and works well in combination with pendimethalin.

Herbicides with Post-Emergent and Pre-Emergent Effect

Chemical name: **sulfometuron**
Brand Name(s): Oust® XP, Spyder™
Typical Form of Product: Dry flowable granules that mix with water.
Uses: Post-emergent and pre-emergent control of grasses and many broadleaf weeds. May be used over-top many trees and shrubs while dormant, but not during active growth. Conifers are more tolerant than hardwoods, for which low rates (1 oz) and precise control of rate are required. Usually used for site prep or immediately after planting. May also be used in early spring in following years. May be mixed with other herbicides, such as glyphosate. It is better at providing long-term control of grasses than broadleaf weeds, and thistles are common in treated areas the following year unless treatment repeated.

Further Information

Huebner, Cynthia D., Cassandra Olson, Heather C. Smith, 2004. Invasive Plants Field and Reference Guide: An Ecological Perspective of Plant Invaders of Forests and Woodlands. NA-TP-05-04. USDA Forest Service, Morgantown WV. 88 pages.

Citizen's Guide to the Control of Invasive Plants in Wetland and Riparian Areas, 2003. Alliance for the Chesapeake Bay, Baltimore MD. 65 pages.

Plant Invaders of Mid-Atlantic Natural Areas, 2003. National Park Service & U.S. Fish and Wildlife Service, Washington DC. 82 pages.

Appendix E: Cost comparison of techniques for tree establishment

Cost information is based on 2003-2005 costs of different techniques. Costs can vary dramatically from region to region along with the terrain and price of labor, so most are expressed as general ranges. Costs will change over time, sometimes quickly, although relative costs tend to be more stable.

Practice	Cost/acre range
Plant Materials	
Pine seedlings	$25/acre for 435 trees ($11-40/ac range)
Hardwood seedlings	$120-275/acre for 435 trees
Containerized trees	$3,000-$7,500/acre for 300 trees ($10-25/tree)
Planting	
Shovel planting (planting hole)	$150/acre for 400 trees (species with large roots like oak and sycamore can benefit)
Dibble bar planting (slit)	$25-125/acre for 400 trees (usually flat land)
Hoedad planting (slit)	$25-200/acre for 400 trees (usually sloping land)
Machine planting (trench)	$75-200/acre
Site Preparation/Maintenance	
Prescribed burning (site prep)	$80-120/acre
Aerial spraying	$85-100/acre for hardwood control (Arsenal/imazapyr)
Ground spraying- strip spray	$30-60/acre at time of planting
Ground spraying-spot spray	$100-1,500/acre- depends on terrain and amt needed
Mowing	$35-150/acre
Tree protection/growing aid	
Tube	$800-1,000/acre installed, 200 trees ($4-5/tube, installed, 4 ft. tube)
Vole/rodent repellent	$12-15/acre as pellets
Tree collar (e.g., Tassu)	$400/acre for 435 trees, materials only
Mat	$545-610/acre (435 trees, $1.25-1.40/tree)
Fertilizer	$87-348/acre (435 trees, $0.20-.80/tree)

Appendix F: Installing Tree Shelters

Choose tree shelter: Generally lighter color tubes transmit more light. Vented tubes reduce problems with elevated temperatures during drought, premature spring green-up and delayed winter dormancy. Preformed tubes install more rapidly. Double wall construction is stronger. Use 2-ft tubes where flooding is likely next to stream, 4-ft tube elsewhere. 5-ft tubes have more problems with weak, wispy stems, especially in oak (slower grower, in tubes longer).

Choose stakes: Stakes should wooden, strong, straight, and somewhat decay-resistant, nominally 1"x1", up to 1.5" x 1.5" and about a foot longer than the shelter being staked. For 4' tree shelters, the stake should be at least 54" long. Stakes need to be inserted firmly into the ground, particularly on a wetter site (lower soil strength). Generally, oak is used, but black locust, black walnut, or red cedar also may be used and be even more durable. Untreated pine or soft hardwoods (maple, yellow-poplar) are weaker and rot-prone and should not be used unless treated (preferably with pointed end cut). Metal pipe, rebar, or fence poles are not recommended since they can fall over and pose a long-term hazard to equipment such as mowers.

Assemble shelters if needed. Establish spacing control with marked rows, can use string/tape to measure distance from planting site to planting site. Identify species to preferentially shelter (usually oak species) and not to shelter (e.g. sycamore) and rate of shelter installation (1 per every 3 or 4 trees). Scalp planting site (remove turf to expose bare ground) for easier embedding of shelter (not always recommended in pasture).

Insert wooden stake about 12" into ground, about 2" from tree (needs to be just a little more than the radius of the tree shelters). For 4' shelter, use 4' (48" stake). Stake should be at least 2" above highest tie, but not taller than the shelter to avoid damaging trees after they grow above the top.

Slip shelter over tree carefully, sliding ties over the stake along the way (or inserted between layers for Blue-X®). If the tree has branches, gather them with tips up before lowering the shelter.

If shelter is rigid plastic, insert 1" or more into ground (can pound with wooden or rubber mallet or block if double wall construction) to discourage mouse and vole access. (Some manufacturers recommend close contact with the ground to avoid drying chimney effects, but not in-ground insertion to avoid rodent nesting). Optional: Can drop in deer repellent tablet or fertilizer pack in tube.

Cover shelter top with bird net.

Maintenance

After flooding or high winds, straighten tree shelters, tighten ties, replace broken or rotted stakes or broken ties (usually less than 1% of shelters). Remove bird nets when leaves reach top of tube (will damage leaves and branches and restrict growth if left). Remove wasp nests if blocking air and light from top of tube.

Optional: In early fall, the tube can be raised slightly at the bottom (e.g., blocked up with chunk of wood) to reduce temperatures and encourage hardening off. This discourages continued growth in the fall and increases frost resistance. In the spring, if the tree is already growing out of the tube, the tube can be left raised. If the tree is still leafing out in the tube, the tube should be pushed back down into the ground to avoid drying chimney or venturi effects.

Direct herbicide spray around trees with tubes to avoid impacting trees; useful when need to control noxious weeds like the very common thistle. Mowing, weed mats, or herbicide will reduce competition and improve growth, particularly on good quality sites, and increase UV exposure needed to allow tube breakdown. Some tubes have perforations, like the Tubex® laser line, to allow splitting as the tree grows. However, many tubes have not sufficiently broken down to split easily by the time the trees have grown large enough, particularly if weeds have shaded most of the tube from UV light, and top bottom rings may not split. If shelters are left on, mechanical girdling or rot from trapped moisture and leaves can damage or kill the trees. Cherry has been reported to be especially vulnerable.

Removal

Between years 3-8, remove trees tubes if not sufficiently degraded along entire length of tube. Current experience says to remove tree shelters to avoid problems with rot infecting the bark. Trees should have grown well out of the tube and above the reach of deer browse. Although some species can grow out of the tubes quickly, it is usually between 3 and 8 years when removal is needed. Average is about 5 years, but tree growth rates vary tremendously among sites and species. Fast-growing trees like green ash or river birch tend to be ready for shelter removal years before some oaks. Signs for tree shelter removal include:

- Tree canopy grown well out of the tube, subject to wind action on branches for more than 1 year (about 8 ft tall, at least 1-in caliper at top of tube);
- Tree diameter close to tube – do not allow tree to grow to fill shelter and develop rubbing damage, rot, or canker on the bark;
- Tree shelter still intact (hasn't undergone significant deterioration of materials).

When trees are an inch or larger at the top, they will be larger at the bottom of the shelter and could start having constriction or rot problems if left longer. The trees should have grown out of the shelter more than a year because they need to have wind action to develop sufficient strength in the trunks.

Time removal to avoid active season for wasps (and snakes) or carry wasp spray and wear leather gloves. Use hook knife to cut open tube. If using a straight utility knife, take care not to damage the trunk. Tube can be split and left on tree to protect from buck rub and mower damage, or removed from around tree. Stakes and tubes will eventually degrade, but can be unsightly. Used tubes are bulky to transport, and can be compacted or chipped to allow more efficient transport or use as mulch.

For a multi-species planting, some trees will be more than ready (e.g., ash, river birch) to remove shelters while others, like oaks are not. If it is operationally impractical to remove tubes at different times, retain the stake by the smaller trees (those not grown out of the tubes long enough to develop strong stems) and use biodegradable ties to secure the tree to the stake after the shelter is removed.