BOTTOMLAND HARDWOOD RESTORATION IN THE MISSISSIPPI ALLUVIAL VALLEY: LOOKING PAST THE TREES TO SEE THE FOREST

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Abstract. Planned restoration of bottomland hardwoods is important to adequately address negative consequences resulting from the severe loss and fragmentation of forested wetlands in the Mississippi Alluvial Valley. Reforestation efforts have been promoted through government initiatives of state and federal agencies (e.g.,Wetland Reserve Program) and private conservation groups. To clarify discussions of forested wetland restoration, we offer definitions of reforestation and restoration, review historic reforestation practices, identify additional needs, and propose a conceptual framework to assist in future reforestation efforts. Future reforestation efforts should include: (1) comprehensive planning among participating agencies, (2) standardized documentation of methods, and (3) short-term and long-term monitoring protocols that permit refinement of methodologies. Implementation of these concepts will promote cooperative planning among participants and facilitate research to evaluate bottomland hardwood restoration efforts.

Key words: bottomland forests, conservation planning, Mississippi Alluvial Valley, reforestation, restoration.

In the southeastern USA, bottomland hardwood forests represent a complex mosaic of plant and animal diversity that provide a myriad of ecological and societal benefits to the surrounding landscape (Wharton et al. 1982, Mitsch and Gosselink 1993, Brinson and Rheinhardt 1998). In spite of these benefits, vast areas of forested wetlands have been lost (MacDonald et al. 1979, Dahl 1990) to agricultural expansion and intricacies resulting from flood control projects (Reinecke et al. 1988, Stavins and Jaffe 1990). Case in point is the Mississippi Alluvial Valley (MAV), where only 26% (2.6 million ha) of the 10 million ha remains forested (Twedt and Loesch 1999). Large-scale disturbance and deterioration of the nation's largest floodplain has produced a fragmented landscape with diminished capability to support fish and wildlife populations. In response to this environmental concern, conservation initiatives (e.g., North American Waterfowl Management Plan and Partners in Flight) have established habitat objectives that seek to reverse the loss of forested wetlands through reforestation and hydrologic restoration in the MAV (Lower Mississippi Valley Joint Venture Management Board 1990, Mueller et al. 1999). Originally, reforestation focused on enlargement of existing forest tracts on public land, whereas, the majority of reforestation today has shifted to private land in response to the U.S. Department of Agriculture's Wetland Reserve and Conservation Reserve programs and to a lesser extent by the U.S. Fish and Wildlife Service's Partners for Wildlife Program. Reforestation also has been undertaken by other public and private conservation organizations. To date there has been limited coordination among these groups and even less forethought given to the role of each reforested site in the landscape.

Historically, reforestation has been reactive. That is, bottomland hardwood forests in the MAV have disappeared at an alarming rate, therefore, "let's plant as many acres as possible." As a result, circa 250,000 ha of marginal agricultural land have been reforested (Stanturf et al. 1998, King and Keeland 1999, Lower Mississippi Valley Joint Venture, unpublished data). Although this extensive approach may have been warranted initially, it fails to recognize important components of successful ecosystem restoration (e.g., clearly stated goals and objectives, and a recognition of an ecosystem's dynamic nature) as outlined by Clark (1998). Specifically, reforestation efforts in the MAV currently lack clearly defined site-specific objectives linked to succinct landscape objectives. Further, a "one-size fits all" planting methodology has been adopted across the region, while standards for documenting

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and monitoring reforestation have varied among delivery groups.

In this paper, we offer examples of concise goals and objectives and a conceptual framework to facilitate reforestation and establish a basis for evaluating restoration of forested wetlands. We recommend that future reforestation efforts: (1) coordinate planning among participating entities, (2) identify landscape and site-specific objectives, (3) standardize documentation of methods, (4) implement short-term and long-term monitoring procedures, and (5) use acquired data as a feedback mechanism to refine reforestation methodologies (Fig. 1).

SCOPE OF ECOSYSTEM RESTORATION

Ecosystem restoration is most readily accomplished through cooperation, where partners define succinct objectives, coordinate data collection and monitoring, and apply the principles of adaptive management (Grumbine 1997). In the MAV, ecosystem restoration is being approached by partners involved with the Migratory Bird Conservation Initiative (Loesch et al. 1995) under auspices of the Lower Mississippi Valley Joint Venture (LMVJV). Although this partnership has been instrumental in establishing habitat objectives and setting priorities for migratory birds (Mueller et al. 1999), implementation by partners is often undertaken independently with limited communication. With >250,000 ha already reforested (LMVJV unpublished data) and another 200,000 ha projected for the near future (Stanturf et al. 2001), we must broaden and strengthen partnerships to increase communication among agencies in pursuit of landscape-level restoration plans (Llewellyn et al. 1996). For example, there is currently no formal inter-agency committee charged with addressing reforestation issues in the MAV. Because the agencies/organizations involved in reforestation activities believe that bottomland hardwood forests are central to an economically and environmentally sustained ecosystem, a formal bottomland hardwood reforestation committee should be formed. The formation of such a committee would foster increased communication in planning, imple-

Table 1. Examples of goals and objectives for reforesting bottomland hardwood forests at multiple geographic scales in the Mississippi Alluvial Valley (MAV).

Regional-scale	
Goal	Reverse the long-term trend of forested wetland loss in the MAV.
Objective	Restore 4 million acres of bottomland hardwood forest by 2050.[a]
Landscape-scale	
Goal	Direct bottomland forest restoration to maximize environmental and socio-economic benefits (e.g., improved water quality, flood abatement, wildlife habitat, and timber production) in the MAV.
Objectives	(1) Enlarge area of bottomland hardwood forest tracts to promote increased productivity of forest interior species. (2) Establish corridors between forest blocks to facilitate movement of wildlife (e.g., black bears) across the landscape. (3) Increase forest area on lower elevations and along water courses to improve water quality and flood abatement capabilities within the landscape. (4) Increase the forest area managed for timber products to lessen the burden of timber production on extant bottomland hardwood forests.
Project-scale	
Goal	Reforest tracts of land in accordance with landowner objectives while concurrently maximizing on-site environmental benefits (e.g., wildlife habitat) and contributing to landscape-level objectives.
Objective	Establish forest structures that are conducive to use by wildlife, contribute to local and landscape-level objectives, and are economically viable and temporally sustainable.

[a]Based on LMVJV analysis of flood storage basins in the MAV.

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If the long-term goal of bottomland hardwood reforestation in the MAV is restoration of forested wetland ecosystems (Table 1), reforestation practitioners need to understand how habitat restoration (i.e., reforestation) impacts ecosystem restoration. However, to do so first requires an understanding of how reforestation differs from restoration. These 2 words are often used interchangeably, even though they have different meanings. By definition, restoration is returning a site to a close approximation of its former condition before alteration, with both structure (e.g., forest structure and species composition) and function (e.g., wildlife use and biogeochemical processes) restored (National Research Council 1992). Whereas, reforestation more closely resembles rehabilitation, in that, specific components (e.g., trees) are restored such that structural replication of the previous ecosystem is achieved; with an implicit assumption that over time, restoration will succeed reforestation. It is important to note that successful establishment of trees does not necessarily imply successful ecosystem restoration. Even so, the reforested ecosystem provides many of the same environmental and socio-economic benefits (both structural and functional) such as: wildlife habitat, flood storage, reduced soil erosion, improved air and water quality (Twedt and Portwood 1997, also see special issue of Restoration Ecology 5[4]: 1997).

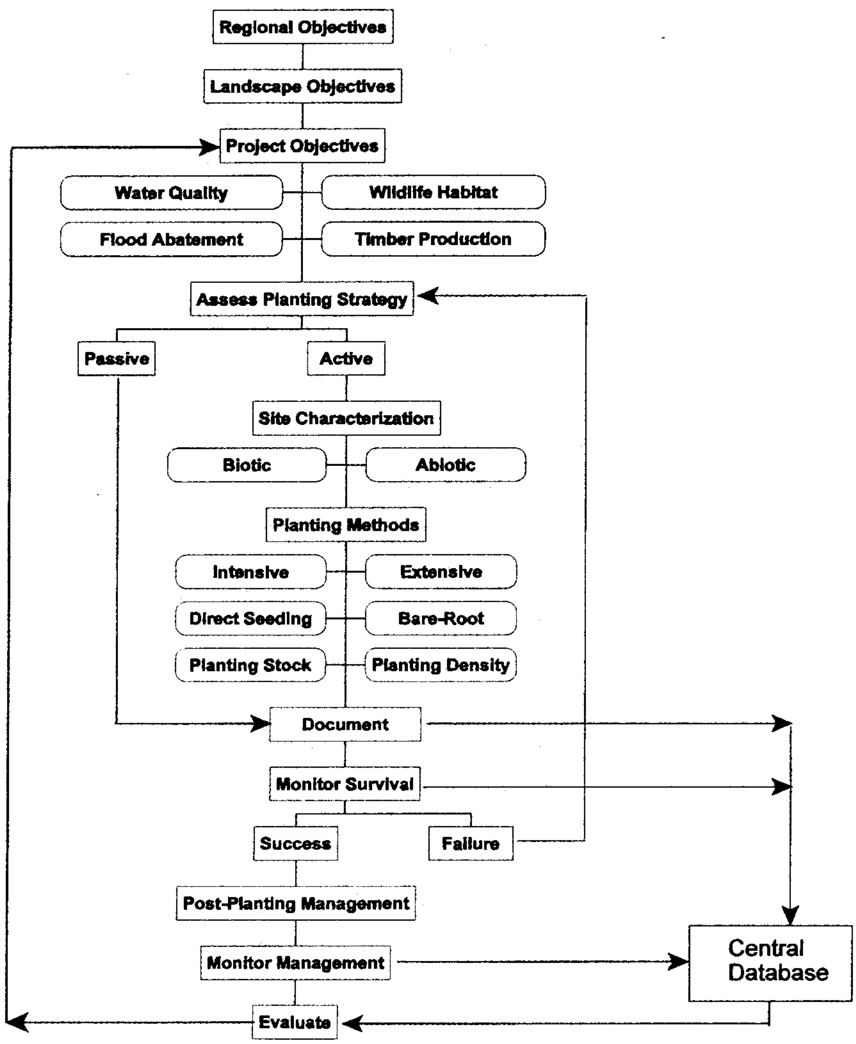
IMPLEMENTATION OF LANDSCAPE-LEVEL MANAGEMENT

Management practices at a local scale must be viewed in a broader landscape context (Petit et al. 1995), especially for development of "source" habitats for wildlife species (Pulliam 1988). Before any landscape-level restoration is contemplated, we must develop clearly defined objectives at multiple geographic scales. Strader et al. (1994) listed objectives of reforestation as: (1) creation of wildlife habitat, (2) promotion of biodiversity, and (3) production of sustainable timber harvest. Although these objectives are satisfactory for general guidance, they are too vague to develop landscape-level restoration plans. Instead, objectives should facilitate achievement of environmental and socio-economic benefits (Table 1) by focusing on pertinent conservation issues (e.g., corridors for black bears [*Ursus americanus*], increasing forest block size for forest birds, and restoration of wetland functions [e.g., flood storage, erosion control]). Once objectives have been clearly defined, priorities can be developed that identify the best planting strategy (Fig. 1.) and location suitable to achieve stated objectives. For example, Twedt and Uihlein (2005) developed a GIS model that assists in prioritizing landscape-level reforestation based on habitat objectives for forest interior songbirds. Similar models that depict other priorities (e.g., black bear habitat needs, water quality issues) are currently under development by the LMVJV Geomatics Network.

We acknowledge that reforested sites most likely will have different local-scale objectives, but based on their relative position in the landscape, they should attempt to collectively meet landscape-level objectives. Therefore, a single management strategy may not be suitable for all reforested sites. Instead, implementation options need to be influenced by pre-defined, multi-scale objectives. For example, if the objective is to reduce erosion along watercourses, then, passive restoration (i.e., recovery via natural succession) may be a suitable approach (Hupp 1992). Conversely, providing habitat for specific forest wildlife or profitable timber production may require active reforestation. If active reforestation is selected, practitioners must then decide if an extensive or intensive approach is required. Regardless of which approach is selected, some degree of post-planting management (e.g., thinning, enrichment planting) must be incorporated into the planning process to improve stand structure (Twedt and Wilson 2002, Stanturf et al 2001).

Clearly stated objectives also can influence the stocking rate (i.e., planting density). For example, Twedt and Wilson (2002) suggested that the current stocking rate of 755/ha (302/ac) is more than sufficient to establish wildlife habitat. They also suggested diversifying the planting stock to include fast-growing, early successional species (e.g, cottonwood [*Populus deltoides*] or sweetgum [*Liquidambar styraciflua*]) and not planting several small areas within the stand to promote both vertical and horizontal structure (Twedt et al. in press). Conversely, Stanturf et al. (2001) suggested that for good timber production, the stocking rate should be doubled to promote self-pruning and to ensure adequate stocking to support a commercial pulpwood thinning for shaping stand structure. While we may never know the most appropriate stocking rate, we do know that the adequacy of stocking and the

Figure 1. Conceptual decision support framework for planning, implementing, monitoring, and evaluating reforestation in the Mississippi Alluvial Valley.



planting density necessary to achieve it depend on stated objectives.

Regardless of planting density, selection of tree species should be based on abiotic factors (e.g., soil type and hydrology), biotic factors (e.g., competition and herbivory), and species suitable for meeting local and landscape-level objectives (Gardiner et al. in press, Stanturf et al. 2001, Twedt et al. in press). Even so, the *"status quo"* planting strategy in the MAV continues to focus on establishment of heavy-seeded species (e.g., *Quercus* spp. at a rate of 755/ha [302/acre]) due to their: (1) limited natural dispersal capabilities; (2) value to wildlife (i.e., mast crops); and (3) future timber value (Strader et al. 1994) with little regard given to on-site soil conditions, hydrology, or objectives. In fact, a recent survey by King and Keeland (1999) found that *Quercus* species represented 78% of species composition on reforested tracts. Although market availability is presumed to be the driving force behind this limited species selection (e.g., <25 of the 70-plus native bottomland hardwood species are currently available through commercial nurseries), most nurseries will produce seedlings of other species if requested to do so (Gardiner et al.2002).

With restoration of bottomland hardwood forests as our primary objective, practitioners need a better understanding of site variation and how local scale abiotic factors impact the species being planted. For example, Stanturf et al. (1998) suggested that many reforestation efforts have failed because these factors were ignored. Although many reforested sites in the MAV are relatively flat, elevational changes of only a few inches can have a dramatic impact on species occurrence and development (Hodges and Switzer 1979). As such, increased attention needs to be given to local scale hydrologic conditions (drainage and soil moisture), soil type, texture, structure, and pH when selecting species to plant, as well as, when evaluating the success of tree establishment (Stanturf et al. 1998, Stanturf et al. 2001, Gardiner et al. 2002).

Regardless of tree species planted, several biotic factors also may impact establishment of trees (Twedt et al. in press). Without chemical or mechanical treatments, herbaceous plants (annual and perennial grasses and forbs) and woody vines will dominate the site for several years leading to increased competition for nutrients and sunlight (Myster and Pickett 1992, Gardiner et al. 2002. Further, many of these species are allelopathic and directly inhibit colonization of reforested sites by natural seed sources (Rice 1972). For example, Asters and goldenrods, 2 of the most common perennial forbs on reforested bottomland sites (Allen 1990, Morgan 1993) have allelopathic properties that inhibit germination of woody species. Dense stands of herbaceous cover also can support high densities of rodent populations (P. Hamel, U.S. Forest Service, unpublished data) which depredate planted acorns (Savage et al. 1996), as well as naturally deposited seeds (Meiners and Stiles 1997, Reader 1997). Thus, establishment of both planted trees and natural invaders can be influenced by competition, allelopathy, depredation, and/or herbivory.

Even so, current methods of tree establishment appear adequate for establishing heavy-seeded species (Allen 1990, Twedt and Wilson 2002, Wilson and Twedt 2005), although the amount of natural invasion by light-seeded species is limited by distance and direction from existing seed source (Allen et al. 1998), with most regeneration occurring <100 m from a forested edge (Allen 1997, Wilson and Twedt 2005). Therefore, the supposition that light-seeded species will establish naturally and result in a diverse forest may not be realistic. To ensure floristic diversity in these restored bottomland hardwood forests, restoration sites' position in the landscape should be considered. That is, when sites are distant from natural seed sources, additional species should be planted. We also encourage reforestation practitioners to work with commercial nurseries to expand the number of native species available for planting and to consider project-scale abiotic and biotic factors, as well as local and landscape-level objectives when selecting species to plant.

MONITORING MANAGEMENT ACTIVITIES

Mitsch and Cronk (1992) suggested that the knowledge of building and restoring wetlands is learned and relearned every time a new wetland is built. Although they were referring to physical construction of wetlands through mitigation projects, the same can be said for restoration of forested wetlands via reforestation. Structure and composition of vegetation not only influence colonization of reforested sites by different taxa, but also influence ecosystem functions. Thus, there is no substitute for reliable monitoring to help determine success and failure of management actions (Noss and Cooperrider 1994). Documenting methods and monitoring results of reforestation is, therefore, a necessary and vital component of ecosystem restoration.

Documentation

Although each delivery program and agency has its own protocols and procedures for documenting reforestation activities, there has been little effort to consolidate this information into a central database. These protocols generally document programmatic accomplishments (i.e., acres planted) with little regard to biological parameters (e.g., site preparation, planting stock, stocking rate) or the spatial location of reforestation activities within the landscape. Further, standardization of documentation among partners has not been achieved.

To facilitate standardized documentation, the Lower Mississippi Valley Joint Venture has developed a database to track reforestation. This database includes both tabular data (e.g., species planted, stocking rate, year planted, propagule type) and spatial data (location in the landscape; Appendix 1). Spatial data are recorded in an ArcView file that is linked with the tabular database to allow the user to quickly view planting records for a particular tract of land. This database is designed to: (1) standardize and consolidate documentation among agencies, (2) promote planning for acquisitions, (3) coordinate cooperative efforts among partners, (4) facilitate development and refinement of landscape-level management plans, (5) provide background data needed to monitor and evaluate reforestation methodologies, and (6) allow monitoring of landscape context. If reforestation practitioners embrace this database and submit their planting records, the data will provide a comprehensive portfolio of reforestation efforts in the MAV. A web-enabled version is anticipated to be released in the summer of 2002. More information about this tracking system can be obtain by contacting Blaine Elliott (LMVJV; 601-629-6625; blaine_elliott@fws.gov).

Monitoring

To accurately assess progress toward meeting stated objectives, reforestation efforts need to be monitored at different temporal and spatial scales (White and Walker 1997). If appropriately designed, these data will serve as a feedback mechanism for refining reforestation methodologies. However, for feedback to be meaningful, we need standardized protocols for monitoring ecological responses. For example, contemporary protocols for short-term ($\leq$3 yr) evaluation of tree establishment vary greatly among agencies, ranging from 312 trees/ha (125/ac) to 563 trees/ha (225/ac) including non-planted trees (i.e., natural invaders). While a diverse forest may be the "ultimate" objective, inclusion of non-planted trees confounds any attempt to evaluate effectiveness of planting methods and can lead to erroneous assumptions regarding planting success. Although standard short-term monitoring procedures can likely be agreed upon by partners (defined through an inter-agency reforestation committee), practitioners of reforestation generally do not have the time nor funding to support long-term monitoring. Additionally, multiple monitoring protocols are needed for other functional aspects as well (e.g., wildlife use, biogeochemical processes). Thus, new partners need to be identified (e.g., academia) and encouraged to assist practitioners in monitoring and evaluating progress toward meeting stated objectives.

THE FUTURE

In conclusion, we agree with Mitsch and Wilson (1996) that, "....restoration of viable wetland ecosystems requires: (1) an understanding of wetland functions, (2) adequate time for recovery, and (3) the self-designing capacity of nature." The restoration of forested wetlands from agricultural lands will not only require the knowledge of foresters, but the expertise of ecologists, hydrologists, engineers, and a host of other experts. Further, we often tend to be near-sighted and fail to see the forest for the trees. That is, historically, reforestation has focused primarily on establishment of heavy-seeded *Quercus* species without regard to ecological processes (e.g., secondary succession, faunal colonization rates). This poses several important questions. Is this method appropriate for mitigating loss of structurally diverse and species rich forested wetlands? Will all functions and values be mitigated for? How long will restoration take (sensu Ribbeck and Hunter 1994)? Because it is doubtful any reforested site will be restored to historic conditions without the return of meandering rivers and natural flood pulses (Junk et al. 1989, Newling 1990, Bayley 1995), success will likely be judged on how well realized consequences of management strategies reflect expected results.

As reforestation of agricultural land in the MAV represents 1 of the largest restoration efforts ever undertaken globally, we should strive to set a high standard. To be successful, we need: (1) increased coordination and planning among partners, (2) explicit objectives expressed at multiple spatial and temporal scales, and (3) standardized protocols for documenting methods and monitoring results of reforestation efforts. Finally, we need to establish an "institutional memory" so that data from monitoring activities can be used to improve restoration of bottomland hardwood forests in the MAV.

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Appendix 1.

Instructions, data collection forms, and definitions for the Lower Mississippi Valley Joint Venture's

(LMVJV)reforestation tracking system.

BACKGROUND

Those private, state, and federal partners that make up the Lower Mississippi Valley Joint Venture Management Board are seeking your help in completing the LMVJV Reforestation database. This database is intended to help each of us in our collective efforts to plan, monitor, and evaluate the considerable reforestation efforts and opportunities that we are blessed with in the Mississippi Alluvial Valley.

INSTRUCTIONS

1. Review definitions (see below).
2. Using the provided map, delineate the boundary (using a permanent marking pen) for the area of actual tree planting on a specific site. If multiple sites were planted on a single tract of land, then count these as separate planting events.
3. Assign the reforestation unit a unique and sequential number (beginning with JV-001) on both the map and Form 1 (Site-specific information).
4. Complete Form 1 and Form 2 (Planting Stock Information).
5. Repeat steps 2-4 for each unique planting event (i.e., Form 1 and Form 2 should be completed for each unique planting event).

FORM 1. Site-specific planting information.

LMVJV Reforestation Tracking System

Site-specific Planting Information

Managing Agency (e.g., USFWS, NRCS, etc.)____

Ownership (Public Private)

Program Type (e.g., WMA, WRP, Utilitree, NWR, etc.) Other (specify)__________________

Contract Duration (Perpetual 10 yrs 15 yrs 30 yrs 50 yrs) Other (specify)_______________

Overseeing Management Party (e.g., Yazoo NWR) ____________________________________

General vicinity (e.g., Cross Bayou Unit, NE part of WMA, etc.)_________________________

Specific location (Lat.-Long. or township/range/section) _______________________________

Specific Site name (e.g., Chapman Field) ____________________ Planting Date ____/____/____

Locally assigned code # (for your use) ___________________________

Planting unit assigned code # (for map use) JV - ___________

Estimated acreage this unit _______________

Planting event # ____ of ____ total events (all years) at this unique location

Supplemental planting Yes or No

Type of site preparation for this unit (Disking Mowing Burning None) Other__________

Habitat prior to planting
(Farmland 1-yr Fallow 2-yr Fallow Previous planting Cleared Forest)

Specific habitat description____

Your Name ___________________________________ Today's Date_____________________

Comments____

FORM 2. Planting Stock Information.

LMVJV Reforestation Tracking System

Planting Stock Information

	Rate/acre				
Stock species (Alpha Code)	Seeds (lbs)	Seedlings (stems)	Containers (stems)	Age of seedlings	Mechanics used (hand, aerial, tractor)

LMVJV Reforestation Tracking System

Definitions

Tract name - local name of site or field where reforestation occurred.

Program type - type of conservation/restoration program under which land holding is administered.

Contract term - longevity of contract agreement, easement, etc.

Planting unit - a discrete location within a tract that represents a single reforestation site that was installed within **1 planting year**. A boundary should be drawn to represent the area extent of each reforestation effort and each area must be associated with a unique number, labeled on both the data sheet and the map provided. The first site should be assigned #1 and numbers should proceed sequentially around map until all sites have been reported.

Planting - separate reforestation efforts **including failures** that are conducted within a particular planting unit. One planting equals all reforestation applied to a single planting unit of a tract in any planting year. Information for **all** plantings over **all years** should be recorded when possible.

Planting year - from September through August of the following year.

Planting date **-** point within planting year in which active reforestation began OR time when site was initially allowed to passively reforest.

Stock species - 4-letter code based on the first 2 letters of both the genus and species names (Ex: QUNU = *Quercus nuttallii* = Nuttall oak). See attached list of species codes.

Mechanics - the mechanical method primarily utilized in planting a particular species (e.g., aerial, tractor, hand, etc.).

LMVJV Reforestation Tracking System

Tree Species Codes, Scientific and Common Names

QUNU	Quercus nuttalli	Nuttall oak
QUNI	Q. nigra	Water oak
QUPH	*Q. phellos*	Willow oak
QUFA	*Q. falcata*	Southern red oak
QULY	*Q. lyrata*	Overcup oak
QUMI	*Q. michauxii*	Swamp chestnut oak
QUPA	*Q. palustris*	Pin oak
QUSH	*Q. shumardii*	Shumard oak
QUAL	*Q. alba*	White oak
QUST	*Q. stellata*	Post oak
QUAC	*Q. acutissima*	Sawtooth oak
QUVI	*Q. virginiana*	Live oak
QUSP	*Q.* sp.	Oak species
CELA	*Celtis laevigata*	Southern hackberry
DIVI	*Diospyros virginiana*	Persimmon
TADI	*Taxodium distichum*	Bald cypress
CAIL	*Carya illinoensis*	Sweet pecan
CAAQ	*C. aquatica*	Bitter pecan
FRPE	*Fraxinus pennsylvanica*	Green ash
LIST	*Liquidambar styraciflua*	Sweetgum
PLOC	*Platanus occidentalis*	American sycamore
NYSY	*Nyssa sylvatica*	Black gum
NYAQ	*Nyssa aquatica*	Water tupelo
MORU	*Morus rubra*	Red mulberry
PODE	*Populus deltoides*	Cottonwood
PRSE	*Prunus serotina*	Black cherry
ULAM	*Ulmus americana*	American elm
ULCR	*Ulmus crassifolia*	Cedar elm
JUNI	*Juglans nigra*	Black walnut
CECA	*Cercis canadensis*	Eastern redbud
CROP	*Crataegus opaca*	Mayhaw
UNKN	Unknown species	Unknown