

**U.S. Department of the Interior
U.S. Geological Survey**

**U.S. Department of Agriculture
Forest Service**

A Guide to Bottomland Hardwood Restoration

J.A. Allen, B.D. Keeland, J.A. Stanturf, A.F. Clewell, and H.E. Kennedy, Jr.

USGS BRD Information and Technology Report 2000-0011

USDA Forest Service
General Technical Report SRS-40

Revised May 2004

U.S. Department of the Interior
Gale A. Norton, Secretary

U.S. Geological Survey
Charles G. Groat, Director

U.S. Department of Agriculture
Ann M. Veneman, Secretary

Forest Service
Dale Bosworth, Chief

U.S. Geological Survey, Reston, Virginia: 2001
(revised May 2004)

Any use of trade, product, or firm names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Copies of this publication are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161 (1-800-553-6847 or 703-487-4650). Copies also are available to registered users from the Defense Technical Information Center, Attn.: Help Desk, 8725 Kingman Road, Suite 0944, Fort Belvoir, Virginia 22060-6218 (1-800-225-3842 or 703-767-9050) and from the Southern Research Station, Attn: Publications Distribution, P.O. Box 2680, Asheville, North Carolina 28802 (828-257-4392).

Suggested citation:

Allen, J.A., Keeland, B.D., Stanturf, J.A., Clewell, A.F., and Kennedy, H.E., Jr., 2001 (revised 2004), A guide to bottomland hardwood restoration: U.S. Geological Survey, Biological Resources Division Information and Technology Report USGS/BRD/ITR-2000-0011, U.S. Department of Agriculture, Forest Service, Southern Research Station, General Technical Report SRS-40, 132 p.

Preface

The primary focus of this guide is to provide information for land managers and landowners who want to re-establish bottomland hardwood forest vegetation, particularly the trees, on lands where they formerly occurred. Restoration and reforestation are approached with the realization that hydrology, as the driving force of wetland ecosystems, must be explicitly considered in all projects. Without the proper hydrologic regime for the site conditions and tree species selected for planting, it is unlikely that a project will be a success. It is assumed that the goal of the audience using this guide is at least the reestablishment of bottomland hardwood forest systems and hopefully the restoration of all functions and values associated with these forests (e.g., storage of floodwaters, water quality improvement, provision of wildlife habitat, etc.).

It is unlikely that a publication will ever be produced that contains all the information needed for an untrained person to plan and implement a completely successful restoration project. Certainly, this guide has no such pretensions. We have tried to make the guide as comprehensive as possible but concise, realizing there is probably much that we have missed. In addition, there are currently information needs expressed by practitioners that have not been adequately addressed by researchers.

This guide will provide the reader with a reasonably comprehensive introduction to the wide range of activities and techniques which, taken together, make up the process of bottomland hardwood restoration as it is now understood. Hopefully, this guide will also provide valuable information to experienced, professional ecosystem ecologists, especially those who have worked mainly with other types of wetland systems.

Whenever possible, the novice restorationist should seek opportunities to work with experienced professionals during every phase of their projects, from initial planning, through implementation, to monitoring and reporting. Opportunities to visit ongoing or completed restoration projects should also be sought.

First and foremost, though, understanding the ecology of bottomland hardwood systems is vitally important. Without a fundamental understanding of factors such as the seasonal patterns of flooding and groundwater dynamics, species-site relationships, seed dispersal mechanisms, plant establishment requirements, and plant-animal interactions, a restoration project is unlikely to be fully successful. In many ways, ongoing efforts to reestablish bottomland forest systems is a continuing experiment. As new information is gained, it should be cycled back into the decision-making process and subsequent forest reestablishment efforts.

Contents

	<i>Page</i>
Preface	iii
Abstract	1
Chapter 1. Introduction	2
Definition of Bottomland Hardwoods	2
Geographic Scope.....	2
What is Restoration?.....	2
The Need for Restoration	4
Restoration and Mitigation ..	5
Restoration, Ecosystems, and Landscape	5
The Environmental Impacts of Restoration	6
Sustainability of Restoration Projects	6
Selected References	7
Chapter 2. General Planning Considerations	9
Project Goals, Objectives, and Success Criteria	9
Project Site Design	9
Regeneration Method	10
Obtaining Planting Stock...	11
Personnel Requirements	11
Equipment.....	11
Timing of Project Operations	11
Selected References	12
Chapter 3. Evaluation of the Site	13
Abiotic Site Factors	13
Climate	13
Hydrology.....	14
Soils	15
Biotic Site Factors	16
Plant Competition and Exotic Species	16
Animals	17
Insects and Disease....	17
Human Influences	17
Selected References	17
Chapter 4. Species Selection..	19
Reference Sites	19
Selected References	34
Chapter 5. Site Preparation	35
Site Preparation on Old-Field Sites	35
Restoring Hydrology .	35
Restoring Soil	36
Control of Plant Competition	36
Site Preparation on Heavily Disturbed Sites	38
Surface Contouring....	38
Restoring Soil Characteristics	39
Establishment of Ground Cover	39
Selected References	40
Chapter 6. Seed Collection, Handling, and Storage.....	41
Seed Collection.....	41
Seed Handling	41
Seed Storage	42
Selected References	43

Chapter 7. Direct Seeding	45
Seasonal Timing	45
Depth of Sowing and Spacing	46
Hand Sowing	47
Machine Sowing	48
Aerial Seeding	52
Selected References	53
Chapter 8. Planting Seedlings	54
Choice of Seedling Type....	54
Bare-Root Seedlings..	54
Containerized Seedlings	55
Handling Seedlings.....	57
Timing of Planting.....	58
Spacing	58
Planting with Hand Tools ..	58
Planting with Machines	60
Selected References	61
Chapter 9. Other Options for Revegetation.....	62
Cuttings.....	62
Transplants.....	62
Topsoiling	63
Natural Regeneration.....	64
Selected References	65
Chapter 10. Establishing Native Undergrowth Vegetation	67
Ecological Importance of Understory Plants.....	67
Biodiversity	67
Ecological Functions .	67
Natural Regeneration of Undergrowth	68
Number of Species Necessary for Restoration	68
Establishing Undergrowth Plantings	69
Transplanting	69
Topsoiling	69
Selected References	69
Chapter 11. Postplanting Control of Undesirable Vegetation	70
Manual Vegetation Control	70
Mechanical Vegetation Control	70
Vegetation Control with Herbicides	72
Selected References	72
Chapter 12. Protection of the Restoration Site.....	75
Protection from Animals ...	75
Protection from Fire	76
Protection from Human Impacts	76
Selected References	77
Chapter 13. Monitoring.....	78
Vegetation Monitoring.....	78
Hydrologic Monitoring.....	79
Water Quality Monitoring .	82
Soils Monitoring	83
Wildlife Monitoring	83
Selected References	85
Chapter 14. Rehabilitation and Management of Existing Forests	86
Determining Present Site and Stand Conditions	86
Site Reconnaissance and Inventory	87
Assessment of Site Potential	87

Site Inventory	89
Identifying Cause of Site Degradation	89
Clarifying Objectives.....	89
Choosing the Silvicultural System	90
Management Versus Regeneration	90
Is Oak an Objective?..	90
Managing the Existing Stand	92
Regeneration.....	94
Bringing Back the Bush.....	99
Selected References.....	99
Acknowledgments.....	100
Glossary	100
Appendix A. Society of American Foresters Cover Type Descriptions	103
Appendix B. Common and Scientific Names of Plant and Tree Species	114
Appendix C. Partial List of Seed and Seedling Suppliers	118
Appendix D. Species-Site Relationships in the Midsouth.....	123
Appendix E. Species-Site Relationships in the Southern Atlantic Coastal Plain	129

Figures

<i>Number</i>	<i>Page</i>
1.1 Distribution of bottomland hardwood forests in the lower Midwest and southeastern United States.....	3
2.1 Engineering drawings depicting surface contours, structural specifications, and locations of various forest types to be planted can be helpful	10
3.1 Hydrographs of typical bottomland hardwood sites.....	14
3.2 Topographic positions and associated forest cover types within a river floodplain	15
3.3 Soil penetrometer being used to assess soil compaction	16
5.1 Old field being disked to alleviate soil compaction before planting	37
5.2 Subsoiling for severe cases of soil compaction.....	37
5.3 Phosphate mine site showing the degree of habitat alteration.....	38
6.1 Fresh acorns being collected in an appropriate container in the field	42
6.2 Processing acorns using the float test to determine viability.....	42
6.3 Sacks of acorns in a large cold storage unit	43
7.1 Restoration site where oaks have been successfully established by direct seeding	47
7.2 This hand tool, developed by the U.S. Forest Service, can make hand sowing of acorns much easier	48
7.3 Two types of modified agricultural planters used for direct seeding.....	49
7.4 The Truax large seed planter	50
7.5 Machine developed by U.S. Forest Service for sowing acorns in nursery seedbeds.....	51
7.6 Crop duster used for sowing acorns	52
8.1 Selection of larger sized containers for growing seedlings	54
8.2 Good quality bare-root oak seedlings.....	55
8.3 Root-bound seedling grown in a 1-gallon container	55
8.4 Carolina ash seedlings grown in plastic sacks.....	56
8.5 Dahoon tubelings removed from their pots and ready for planting.....	56
8.6 A bulb planter is a commonly used hand tool for planting seedlings	57
8.7 A good field method to protect the roots of seedlings is to carry them in a planting bag	57
8.8 Bare-root seedlings can be planted using a sharpshooter shovel, dibble bar, or bulb planter	58
8.9 Planting technique for use with hand tools	59
8.10 It is critical that tree seedlings be planted properly.....	59

8.11	Mechanical seedling planter.....	60
9.1	Bundle of cottonwood cuttings.....	62
9.2	One-year-old green ash seedling grown from a horizontally planted cutting	62
9.3	Tree spade used for planting large saplings or small trees	63
9.4	Scrapers are useful for short-distance transport of topsoil.....	64
9.5	Bulldozer spreading topsoil at Hall’s Branch restoration site	65
11.1	Manual vine control can be accomplished using brushhooks or machetes.....	70
11.2	Mechanical cultivation of a restoration site.....	71
11.3	Guidance on the timing of herbicide applications in commercial forestry	73
11.4	Herbicide application with a backpack sprayer.....	73
12.1	Herbivory protection by (a) wire predator guard and (b) plastic tree shelter	75
12.2	An informative sign such as this can provide useful information to individuals using or visiting the site.....	76
13.1	Diagonal layout of sample transects across a direct-seeded field	80
13.2	Location of forest reclamation strip quadrats at the Agrico Swamp West restoration site	80
13.3	Tree survival trends at Morrow Swamp (Agrico Swamp West) restoration site	81
13.4	Staff gages, piezometers, and monitoring wells can be used to determine the pattern of flooding (hydrologic regime) of a restoration site.....	81
13.5	Placement of piezometers and staff gages on a reclaimed phosphate site in Florida.....	82
13.6	Example of an automated, single purpose water level recorder, the WL-80.....	83
14.1	Bottomland hardwood stand degraded by years of mismanagement	86
14.2	A generalized guide for regenerating southern hardwoods.....	92
14.3	Example of damage caused by poor logging practices	93
14.4	Mature cane brakes provide habitat for numerous wildlife species	94
14.5	Snags left in a clearcut on Scott Paper land near Mobile, Alabama.....	95
14.6	Natural forest site that has been clearcut, sheared, root-raked, and disked.....	96
14.7	Five to 10-year-old regenerating clearcut.....	97
14.8	Shelterwood cut.....	98
14.9	Aerial photo of several group selection cuts	99

Tables

1.1	Bottomland hardwood forest cover types.....	2
2.1	General definitions of mitigation success used in MiST.....	10
2.2	Seven “grievous errors” that have been made on restoration projects in the absence of adequate training and supervision.....	11
2.3	Partial list of equipment occasionally used in restoration projects and examples of how they are used	12
3.1	Abiotic site data that should be obtained if possible	13
4.1	Characteristics of selected tree and shrub species suitable for reforestation of bottomland hardwood forests in the southeastern United States.....	20
7.1	Pros and cons of direct seeding and planting seedlings	46
7.2	Number of seeds or seedlings required per hectare at various spacings	47
11.1	Commonly used herbicides	72
11.2	Weed species susceptible to Oust.....	72
13.1	Measures of vegetation abundance and plant performance that can be used for monitoring.....	79
13.2	Wildlife species that use early successional stages of bottomland hardwood forested wetlands.....	84
14.1	Species groups and expected regeneration under different silvicultural systems for important southern bottomland hardwood associations	88
14.2	Selected species of bottomland hardwood trees and their associated values as wildlife food	91
14.3	Decision key for choosing a regeneration procedure for bottomland oaks	92