VIRGINIA COOPERATIVE EXTENSION

MASTER GARDENER PROGRAM

TREE STEWARD MANUAL

2021

Virginia Cooperative Extension

Virginia Tech • Virginia State University

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Tree Steward Manual is designed for Virginia Cooperative Extension Master Gardeners who are training to be certified advanced Master Gardener tree stewards. Written by a dedicated team of volunteers who themselves completed advanced Master Gardener tree steward training, the manual covers a wide range of topics, specific to each region of Virginia, including identifying trees, selecting and planting appropriate trees for local landscapes, caring for trees, and troubleshooting tree problems.

In Virginia, advanced Master Gardener tree steward training is offered by the local Extension Master Gardener (EMG) program. Once the training is completed, volunteers become certified advanced EMG tree stewards and commit to a specific number of volunteer hours working on local tree steward projects. EMG tree stewards work on projects based on the needs of their local community as determined mutually between the local agent/coordinator and active tree stewards.

While *Tree Steward Manual* was developed with EMG training in mind, it is also appropriate for general readers who want to deepen their knowledge of trees and tree care.

Tree Steward Manual is published in association with Virginia Tech Publishing. As an open educational resource (OER), it is made freely available online in multiple formats including PDF, Open Document Format (ODT), and ePub. For more information, visit the main landing page for the book at:
http://hdl.handle.net/10919/103953

About the Extension Master Gardener program. Virginia's EMG program is made possible thanks to more than 4,000 volunteers who annually contribute 400,000+ hours of volunteer service related to home horticulture in Virginia. Volunteers receive more than 30 hours of training through their local Virginia Cooperative Extension office and serve their communities through projects like school and community gardens, horticulture help desks, and educational programs. EMGs can also choose to receive additional training in one of three advanced program areas: trees, water, or land care. Tree steward training programs can be offered through a local Extension office if there is local interest.

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Tree Steward Manual

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This Manual is intended to be used for training EMG Tree Stewards across Virginia. It is designed to support initial training programs both locally and when offered at MG College. It is also meant to be a resource for the continuing development of the graduates and their mentoring Agents and Tree Stewards. The authors hope that the particular focus of this manual will be helpful to other states' EMG Tree Steward programs.

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Chapter 4: Botany of Trees	Carol King
Chapter 5: Tree Taxonomy, Identification, and Measurement	Patsy McGrady
Chapter 6: Soil Properties and Management	Gwen Harris ad Cherilyn Kern
Chapter 7: Trees and Ecology	Carol King and Laurie Fox
Chapter 8: Siting, Selecting, and Planting	Carol King and Ed Olsen
Chapter 9: Tree Health Care and Pruning	Carol Fryer
Chapter 10: Problems of Trees	Patsy McGrady
Chapter 11: Structural Defects, Tree Failure, and Risk	Cindy Ogle

Indicia Statement

HOW TO USE THIS BOOK

What is this book?

This is the training handbook for Virginia Cooperative Extension's advanced Master Gardener Tree Steward training. While this handbook is meant to help Extension Master Gardeners during their training as tree stewards, it is also a useful reference book for anyone interested in trees!

What is the Extension Master Gardener program and what is tree steward training?

Extension Master Gardeners (EMG) are trained volunteer educators who bring the resources of land-grant universities to the people of Virginia. Virginia's EMG program consists of more than 4,000 volunteers who annually contribute 400,000+ hours of volunteer service related to home horticulture in Virginia. Volunteers receive more than 30 hours of training through their local Virginia Cooperative Extension office and serve their communities through projects like school and community gardens, horticulture help desks, and educational programs.

EMGs can also choose to receive additional training in one of three advanced program areas: trees, water, or land care. This handbook guides EMG volunteers seeking certification as an Advanced EMG Tree Steward. Tree Steward training programs can be offered through a local Extension office if there is sufficient local interest.

Other items to print

In addition to printing the PDF of this handbook, we also recommend you print the following Extension publications and insert them as appropriate into the handbook:

- "Develop a Preventative Pruning Program for Young Trees" from IFAS The University of Florida Extension https://edis.ifas.ufl.edu/pdf%5CEP%5CEP31500.pdf and insert in Chapter 9 at page 215
- "Develop a Preventative Pruning Program in your community: Mature trees"from IFAS The University of Florida Extension https://edis.ifas.ufl.edu/pdf%5CEP%5CEP31600.pdf and insert in Chapter 9 at page 216
- "20 Questions on Plant Diagnosis" from Ohio State University Extension https://ohioline.osu.edu/factsheet/plpath-gen-3 and insert in Chapter 10 at page 253.

Online version

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CHAPTER 1: ABOUT ADVANCED VIRGINIA COOPERATIVE EXTENSION MASTER GARDENERS AND THE TREE STEWARD TRAINING MANUAL

"Where are we going and how do we get there?"

Chapter Contents:

Introduction

To be an Extension Master Gardener Tree Steward (EMG TS) is to see new wonders: where once you walked in a park and enjoyed a mass of greenery for the shade, now you will recognize individual friends in the trees which provide that shade. When you see a venerable giant, you will know something about how it got to be that way. Trees are the largest living things on earth, and they are vital to the web of water, air and food which makes life possible on our fragile planet. You are about to learn how to learn about them, how to take care of them, and how to help our communities value them as they deserve. You may even be able to help tackle some of our worst challenges in urban tree survival under hostile conditions, or the preservation of healthy rural forests from significant ecological threats.

On a more mundane plane, this chapter describes Virginia Cooperative Extension Advanced Master Gardener Programs, considering especially Tree Stewards. It explains the conceptual design of the manual, with discussion and examples of practical ways for new EMG TS to support VCE objectives and improve their communities.

This manual is based upon the assumption that all EMG TS students are fully qualified EMG and are therefore familiar with the VCE Master Gardener Handbook (the basic class text). If it has been a while since training, or if you are a transfer from another state, then review may be appropriate. Each chapter in this manual will say up front which basic chapters and/or topics are relevant.

Learning Objectives

1. Understand Virginia Cooperative Extension Advanced Master Gardener program goals.
2. Understand what VCE EMG Tree Stewards do to advance VCE goals.
3. Know the intent and organization of this Training Manual.

REVIEW VCE Master Gardener Handbook 2015 (9/18 update):

- Chapter 1, Welcome to VCE Master Gardening

Advanced EMG Programs in Virginia

As of the writing of this book, there are three Advanced EMG programs: Tree Steward, Water Steward and Land Care Steward. All three require course work, training in leadership and program development, and practical application by means of a project to enhance community education, sustainability, health, or other appropriate goal. Each training program aims to help Advanced EMGs develop long range educational plans as well as short term projects. Training Courses have been offered on a rotating basis during the annual Master Gardener College and also by local VCE Agents and EMG groups around the state from time to time. This manual aims to support all such educational efforts and create more regional coordination and focus among EMG TS.

Looking farther afield, the writers of this manual reviewed all state EMG programs (and Washington, DC), looking for the status and content of their advanced EMG Programs. Information as of 2008, shows that all have EMGs and 23 programs have some form of advanced EMGs. Six of those address leadership and communication needs directly in the classroom, and all include these skills in class projects. VCE would seem to be in the forefront of using advanced EMGs to cause real, meaningful community improvement through individual and group action.

Being an Advanced EMG

Extension Master Gardeners are a special group of people: excited to learn new and useful things; passionate about their environment and the essential role plants play; and eager to make positive change at whatever level they can. This may be as simple as showing their neighbors better mulching practices or watering methods, or as significant as helping a school create a learning garden. Advanced EMGs take this a step further by specializing in one broad area so they can increase their value as a community resource. Along with this added value comes greater opportunity to educate and serve.

Who should consider becoming an advanced VCE Master Gardener? The long answer is a fully accredited EMG who is interested in furthering his/her knowledge of a Horticultural Field. In-depth training is meant to be followed by sharing that knowledge with appropriate communities, leading to new actions toward sustainable landscaping, conservation and/or environmental improvement. Some new advanced EMGs may be taking on leadership roles, while others may form supporting teams.

In this context, 'community' can be the local EMGA, neighborhood association, faith group, social, educational, governmental or other entity whose activities are consistent with the policies of VCE. Local VCE Agents should be closely involved in developing advanced EMG programs and projects, since they have the authority and responsibility for approval.

The true end goal is to engage the community to take actions that will conserve natural resources and improve the environment. Advanced EMGs should be especially helpful in finding ways to move their communities forward in these areas toward the sustainable landscapes of the future. A wide range of skills and voices will help reach members of many different communities: an essential goal for real progress.

Figure 1-1 Tree Steward Info Table. (Courtesy of Carol King)

What kind of activities should advanced EMGs expect to engage in? In the first year, new advanced course graduates are required to put in at least 20 hours of service on a project of their choice (with agent approval, of course). After that, they will work individually or (more likely) in teams to identify local needs for Conservation and Sustainable Landscape measures. They will consider possible educational and practical goals along with short and long term benefits and costs, and then work with community members to develop appropriate programs for execution and feedback. Program development can be more of a long term process, but new advanced EMGs working with VCE Agents should be able to identify short term projects which will fit into larger program goals.

Prospective advanced EMGs who are in small local numbers, or even pioneers in their local units, may face special challenges. In such a case, the advanced EMG can include regular EMGs in small scale projects such as homeowner education/assistance and community conservation efforts. At the same time, it will be important to identify community members with some degree of authority who are open to Sustainable Landscaping and/or Conservation programs or measures. While it may take time to build up a program from scratch, the development is rewarding even in the early stages. Keeping one's eyes on the long term benefits and holding those out for residents and local authorities to see will lead to success over time.

Tree Steward Possibilities

In some localities, with the approval of the local VCE Agent, tree stewards (TS) may go out on site visits to examine tree problems, educate homeowners and others on best plant care practices, and serve as a link between the public and VCE/professional experts. Such visits are usually an extension of VCE Help Desk. In addition to dealing with the specific reason for the visit, the TS will often be presented with additional opportunities for public enlightenment ("As long as you're here…") which can sometimes be a more significant educational opportunity than the original question. As with any Help Desk query, follow-up research and/or samples to send to VT labs may be needed, so a TS should not be afraid to say "I don't know, but I will find out."

Figure 1-2 EMG TS visiting a Crape Myrtle. (Courtesy of Carol King)

Another need seen by new TS is for Tree Inventories and Tree Walks. The former can be of great use in educating governmental bodies and improving tree management, especially if appropriate land/tree management authorities are closely involved. Tree Walks are clearly educational but can also serve purposes of horticultural therapy or other need. They may be guided or unguided/mapped, with or without signage. New TS may also find local Streets or Parks Departments open to help in recommending tree plantings which will lead to sustainable urban/suburban forestry, erosion control, and storm water management.

Figure 1-3 Tree Inventory in a Local Park. (Courtesy of Carol King)

More complex projects will generally mean developing plans with community leaders to identify and address significant ecological challenges. Topics for such plans might include organizing reforestation in and around public areas, promotinge the use of site-appropriate trees through education, or incorporating tree management goals in city and county planning documents. Considering the dire situation faced by trees in urban settings and the challenges to our remaining rural forests, there is real need for public education and motivation based on scientific information. In our cities and paved-over suburbs, inhospitable soils and hostile growing conditions mean that existing trees die from construction and newly planted trees may survive as long as 25 years, suffering stress-related pests for most of their short lives. In more rural settings, invasive plants and insects increasingly threaten the healthy balance that is essential to forest survival; if indeed that forest is not cut down for development. So there are many avenues to follow to make a difference, starting with our own education and networking to join or create productive teams. There are many possible partners and resources, depending on the locality. It may be worthwhile to look for city or county boards that manage or advise on trees and tree planning. These boards may be found in Parks and Recreation, Public Works, and/or Planning Commissions.

Chapter Seven (Trees and Ecology) includes a much more detailed discussion of ways EMG TS and others can make a difference in their local environments.

The Virginia Urban Forest Council, also known as Trees Virginia, is a non-profit organization associated with the Virginia Department of Forestry. It represents a wide range of people and organizations joined to stimulate public awareness of the role trees and forests play in the urban environment. Trees Virginia programs in many parts of the state are useful partners with VCE TS, though the specific focuses of each may differ. There are two consortium groups that bring together a wide variety of tree actors, with the support of VDOF: the Urban Forest Roundtables of Northern Virginia (NOVA) and Southeastern Virginia (SEVA). If you live in either area, their periodic meetings are a valuable resource of current trend information and networking.

Other organizations which are worth looking into include the National Arbor Day Foundation, which runs the Tree City USA, Tree Campus USA and Tree Line USA programs. US Department of Agriculture, US Forest Service, National Park Service, VA Department of Game and Inland Fisheries, expert tree companies and/or landscapers may all be of help with public-benefit outreach efforts.

The American National Standards Institute (ANSI) is a not-for-profit organization founded in 1918 which oversees and communicates norms and guidelines in many industries. It is also an information bridge between these industry standard developers and appropriate government and international agencies. From the perspective of Tree Stewards, their most significant publications are ANSI Z60.1, "Nursery Stock Quality," and the wide-ranging ANSI A300, "Tree, Shrub, and Other Woody Plant Management Standard Practices." Topics covered by this second document include Soil Management, Root Management, Transplanting, Support and Lightning Protection Systems, and Tree Risk Assessment. The Tree Care Industry Association (TCIA) is the A300 directorate.

The International Society of Arboriculture (ISA) is a leader in developing and enforcing professional arborist certification programs. ISA also has a strong public education program for tree owners and interested parties on their website and in their publications. Chapters from the A300 standard are available through ISA, as well as Best Management Practices (BMP) which provide more detailed explanations in the various A300 topic areas. Tree Stewards who are interested in working with tree care professionals will find the BMPs helpful as a common point of reference.

Tree Steward Manual Objectives and Concept

The primary purpose of the manual is to support advanced EMG Tree Steward Training Programs across Virginia. The text is intended to be flexible enough to cover the wide range of climatic and horticultural conditions in the state, leaving room for additional resources to address local and specialist concerns. TS students in specific training courses should be provided with or directed to websites and publications which are significant to their work: field guides, plant data bases, expert pruning manuals, pathology resources, and the like.

One of the major concerns of the authors is to encourage local or regional VCE Agents and EMG Associations to hold TS Courses which optimize knowledge of local trees and conditions. Local Agents and Associations also need help in developing the talents of TS who have been trained at Master Gardener College. This manual hopes to encourage regional and other cooperation to enhance the overall effectiveness of the EMG TS statewide.

The manual is organized in three groups of topics. The first three chapters set the stage, from an introduction to EMG Tree Stewards through initial educational programming and a large motivational step to consider the fundamental questions 'Why Trees?' (Chapter 3). The theory is that EMGs attracted to the TS Program already have an intuitive appreciation of the importance of trees but probably do not yet understand the environmental and scientific significance of the largest and most productive plant partners in the cycle of life on earth. Addressing students' key motivations first builds upon their initial enthusiasm and prepares them for learning about the necessary scientific and empirical detail. The next four chapters are devoted to scientific building blocks, culminating in ecology discussions on the state and regional level. The last four state-level chapters discuss key techniques and practices essential to making use of the scientific and practical knowledge. The final chapter is for forms and locally developed materials such as city/county tree ordinances or planning documents, recent news articles, and anything else which will help the Tree Steward Interns put their training to good, local use.

Chapter Specifics: Big Picture, Building Blocks and Practices

> "But for tree planting to be sustainable, we must not simply plant a tree. Rather we must carefully choose, situate, and cultivate a tree so that it is healthy, robust, long-lived and functional. We call this "right tree, right place." When we put the wrong tree in the wrong place, then that tree is unsustainable. It might become invasive, create infrastructure conflicts, develop defects, or fail to thrive. In all of these instances, the tree's costs outweigh its benefits, and it therefore has practically no value to society or the environment." Dr. P. Eric Wiseman, "Sustainability Practices in Arboriculture," *Tree Care Industry Magazine* XXIV (7): 7-11.

Big Picture: Chapters One through Three.

The first chapter is the introduction, which you are reading now. The second chapter explains how to find ways to improve local conditions for and with trees. This has been called the Logic Model or just Programming, both terms of significant aridity. In real terms, it is nothing more than a way to organize information and intentions. In a sea of miscellany, it is a skill to be able to find the important stuff and make it useful. The third chapter provides detail on Why Trees Matter. This is a very large topic, with impact on human society and the environment, urban and rural and in between. There are wonderful studies showing the positive effects of trees on people: better health outcomes, lower crime, more prosperous businesses. These are effects we can all appreciate unscientifically simply by standing under a large oak on a hot summer day. But just any tree in any place will not add benefit without due consideration of local conditions and tree specifics. Hence, there is a need for education about trees and tree management at any and all levels. This is the heart of everything EMG TS are meant to do for our communities.

Building Blocks of Knowledge: Chapters Four through Seven.

The fourth chapter is Botany of Trees, looking specifically at trees as compared to other plants. The intent is not to repeat basic MG material but rather to understand how trees become the giants of our plant world and how they interact with their environments. The goal of this chapter is help the students learn to "think like trees."

The fifth chapter is devoted to actual trees, with the title Tree Taxonomy, Identification and Measurement. Bringing this level of detail in so early is because many past students complained that they joined the course to learn to learn about trees specifically, not just as a general topic. As an advanced EMG Training Program, we need to recognize that our students come with significant EMG backgrounds already and are more focused in their goals than basic MG students. That said, the chapter starts with an understanding of Taxonomy and Dichotomous Keys in order to make sense of tree nomenclature and organization. Then the chapter covers a number of Tree Families and exemplars, selected for their relevance to Virginia's environment, economy, history and horticultural experience.

The sixth chapter is Soil Properties and Management. The idea is for TS to look at their soils as the first partner in growing and sustaining trees. The soil descriptions are both local and regional, some naturally occurring, and a distressing portion impacted by human activity. It may be argued that Soils should come first, as the foundation of all plant growth, but the manual figures that the prior topics will highlight the importance of Soils and lead to a broader understanding of the situations faced by many of our agricultural, forested, industrial, suburban and urban soils. The coverage of Nutrients and Fertilizers aims to equip new TS with the tools to make wise decisions as they work with the trees of their futures.

The seventh chapter, Trees and Ecology, considers the larger context within which our trees live and explores the nature of arboriculture and sustainable forestry. The first part of it looks at definitions and general relationships among environmental factors. Then it considers distribution patterns of those factors across the state. Finally, the state is divided into regions (one among many possible) and each region has a local descriptive section. The intent is for local Tree Steward Training Programs to give their students a general state picture and, more importantly, an understanding of the local ecological challenges.

Practices: Chapters Eight through Eleven.

The last four chapters deal with techniques: Siting and Planting; Tree Health Care and Pruning; Biotic and Abiotic Problems of Trees; and Structural Defects, Tree Failure, and Risk. These topics will not repeat Basic MG Training but rather expand upon it with more advanced advice. The goal is to for the new advanced EMGs to be able to develop their expertise as they experience local tree problems and challenges. These final chapters are not intended for the students to master during their initial courses, but rather as an introduction to further knowledge and a particular resource for EMG Tree Stewards and their VCE Agents.

Is My Tree a Hazard?

Tree Stewards may be tempted to engage in tree risk assessment, but should instead become very familiar with the criteria professional arborists use to make such judgements so they can advise homeowners when a professional should be called in. TS can also perform a significant service by advising tree owners on how to avoid having to call for a risk assessment in the first place: better maintenance and routine care, also (best!) right-tree/right-place to begin with.

Finally, a twelfth chapter is included for forms and local matters of any sort. It includes an example worksheet and proposal form which has been useful in past courses of the Peninsula EMG Tree Stewards. Units are welcome to modify this form or develop their own to address local situations. The rest of this chapter may include local maps, environmental surveys, county or city documents, links to USFS, VDOF etc. It is also possible for a local unit to document past projects and future prospects in this chapter.

A Note about Fruit Trees

No VCE MG Tree Steward training can be complete without addressing Fruit Trees, particularly in the Home Garden. However, the subject is a large one, with many regional variations in both best selection and potential Help Desk problems. Also, a basic 30 to 36 hour EMG TS training course is already pretty full with the other materials in this manual. Thus, it is recommended that regional EMG TS programs set up advanced Training Sessions on the appropriate fruit trees for their regions.

Review Questions

1. What are advanced EMGs?
2. Why Tree Stewards?
3. Why do you want to be a Tree Steward?
4. Is there something in your community which can be helped with the right trees?
5. How can you help make this happen?

CHAPTER 2: THE LEARNING EXPERIENCE

"It is impossible to map out a route to your destination if you don't know where you're starting from."- Suze Orman

Chapter Contents:

Introduction

In EMG we use program planning to develop educational opportunities for the public. Why do we do program planning? We use program planning as a tool to create a learning experience for the public, which are based on identified needs. Virginia Cooperative Extension is based on public needs identification and iterative educational programing to focus on answering those needs. The entire Master Gardener Tree Steward Certification process is part of a larger program which focuses on the value of the forest ecosystem. This ecosystem enhances our air, water, and soil quality inside the dome of our atmosphere through multiple scientific processes. In this chapter we will focus on the process of program planning for new Tree Stewards to use as they develop projects that meet the needs of the community and their own education as Tree Stewards.

Learning Objectives

1. Understand Virginia Cooperative Extension Learning Experience
2. Identify the steps in Program Planning
3. Understand a Logic Model

4. Understand the differences between lectures, demonstrations, workshops and projects

REVIEW:

- VCE Master Gardener Handbook (2015 Ed): Chapter 1, Welcome to VCE Master Gardening

Educating the Public through a Learning Experience

A learning experience emerges from a journey through the combined acts of perception, action, emotion, understanding, and motivation. This encased in one's sense of the world, brings about a new paradigm or lens for processing experiences. How do you create perceived value and inspiration in a package to motivate the public to; study, protect, enhance and extend our local forest systems? That is the guiding question we are striving to answer as tree stewards and should also be the basis for our projects as we do program planning.

What is the purpose of a project? A project is one step in program planning that allows volunteers to experience the knowledge and new processing lens that they have gained from their course work in a real world application. The most important step in creating a lasting impact is giving the knowledge user the ability to engage their skill within their local atmosphere so to speak. If the skill is not repeatable, adjustable or relevant enough the information is put on a shelf so to speak in our sub-consensus and enthusiasm for the knowledge wanes. Giving validity to the experience through a project is just one part of program planning that makes up the learning experience.

Program Planning Steps

1. Assess the needs of the community and set priorities
2. Program development (map of inputs, outputs, outcomes)
3. Developing the learning experience (presentation, project, activities)
4. Develop promotion (marketing materials) of the program
5. Delivery of the presentation or implementation of the project
6. Evaluation (How did it go?)
7. Communicating results (tell the program's story)

There are **7 major steps in program planning** for a learning experience. **The first step is** to assess the needs of the community and set priorities. In this instance community means more than just the local citizens, it means all people that interact in an area. This includes groups like churches, Boy and Girl Scouts, schools, societies, clubs, places of work, local stores, local government as well as the actual inhabitants. How do we connect to community needs? How do we connect the value of the forest ecosystem to citizen's daily lives? What needs are out there that we might help address with education? To answer these questions we need to listen, observe, and examine what is going on around us locally. Examples of issues could be recurring flooding, poor air quality, lack of healthy foods to eat, obesity, lack of connection to nature or agriculture, or lack of value for the ecosystems in general. Every need won't be addressable, some needs will be greater than others, and some needs will fit better as educational opportunities that we can focus on. Some criteria that can help us prioritize these identified needs are; the importance of the issue, the number of people affected, how it fits the VCE mission, how important is it to local officials, what Extension's ability to respond is, and who else is working on it.

Gloucester County VA: the Woodville Park Project

This is a fairly rural county just north of the Hampton Roads urban concentration. It has a lot of forest land, including along the Chesapeake Bay and York River, but not very much public park land. A few years ago, local benefactors gave the county 100 acres for a park in the middle of the county. So, here was both a need and an opportunity. The local EMG TS saw an opening for incorporating trees and tree education in the planning process from the beginning.

Step 1: Assess Need. Partly done already, just because they lived there and were already involved with county issues. EMG TS then got themselves included with community actors and county government officials in the ad hoc committee which assembled to decide what needs the park should address: for example, a soccer field. Some of the land was open with poor drainage, while the rest was forest and forested swamp. It was clear that any plan had to take into account what was already there.

Once the assessment is done, and the major educational priority themes are fleshed out, **the second step is to create a map (program development)**. The first task in the planning step is to document objectives, necessary inputs, expected outputs, assumptions, external factors, short & medium term outcomes and long term impacts. Several tools have been developed to help in this process. For objective setting, part of the map, there are two major tools commonly used, the S.M.A.R.T. and A.B.C.D. Models. The first acronym stands for learning objectives that meet the following criteria; Specific, Measurable, Attainable, Results-Focused, and Time-Focused. A third tool that will help you with the bigger picture is the logic model which basically helps you create a visual road map for your programing. All of these tools can be easily researched on-line, but we will go into more detail about logic models, as it is a foundation to Extension Programming across the Country.

Woodville, Step 2: Create a plan. The ad hoc committee hired a designer to work with county staff on a plan. However, the EMG TS noted that the existing trees should first be documented at least in the areas tentatively designated for clearance or high traffic use. Drainage in this low-lying, Bay-bordering county is an important consideration in any land-use decision. What came next was a bit of engineering comedy: the EMG TS mapping tools and the county maps were using different systems, which took a while to sort out. After that, the planners and EMG TS were able to rearrange the parking areas around the sports field to promote appropriate screening and shade while leaving the lowest draining areas (with existing trees) for the educational area. So far so good!

Logic models help us develop logical connections between what we need, who we need, what we do, what we accomplish and how it can be tweaked to improve impacts based on what we have observed. This is set up in the form of; situation statement, inputs, outputs, outcomes, impacts, assumptions, and external factors. It answers the question "How do you know if you have arrived, if you don't know where you are going?" A logic model helps link activities to results, serves as a basis for communication with others, guides program planning and evaluation, makes gaps in logic visible, makes explicit theories of change, and improves decision-making. The situation is defined as the current condition, issue or opportunity calling for programming. An input stands for resources we invest to bring about change. Outputs are what we generate such as activities and products. Outcomes are short and medium term and speak to what is different as a result of our efforts. Impacts are the long term version of outputs that affects conditions such as social norms, economics or the environment. Assumptions are beliefs and expectations that inform our programming choices. External Factors are influences that are outside of our control.

Logic models were created based on Bennett's Hierarchy (a well-known model for evaluating program outcomes). It is measured in 4 stages known as K.A.S.A., with the purpose of initiating change. K.A.S.A. stands for Knowledge, Attitudes, Skills, and Aspirations. The theory is that through gained knowledge, people's belief in a practice can be developed and attached to a skill that will ultimately help them create improvement. The logic model helps us ultimately take a situation statement and outline your objectives (outputs), programs/projects (inputs) and create measurable knowledge, attitude, skills (outcomes) and aspirations (impacts). Logic models also bring planning aspects together in a map that helps us identify areas for evaluation and iteration. Here is an example of what a MG Tree Steward Program Logic model might look like.

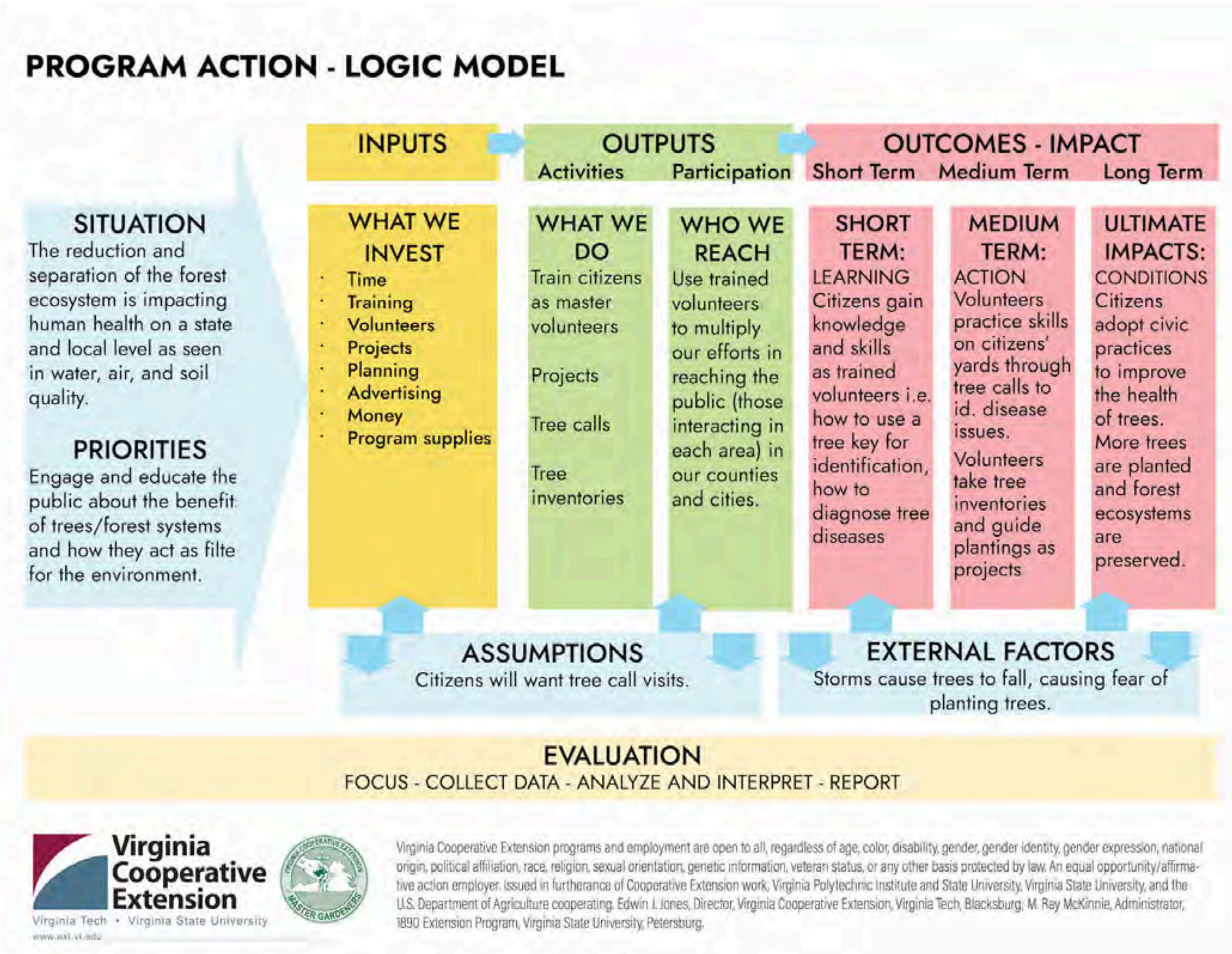

Figure 2-1 Program Action Logic Model. For a blank template logic model, click here.

Woodville, Step 3: Develop the project. At this point, the EMG TS were all set to plant new trees and make learning areas within the new park. And the public seemed to be on board in this so-far straightforward process. However, the entire project took a major new turn when a freak tornado went right across one of the nine county schools, wiping it to its foundations and destroying the majority of the county's school sports fields. For the committee, it was back to the drawing board. At a minimum, the new plan had to include football fields, which were first thought of where there were significant forest and forest swamps. The EMG TS helped steer the committee to an alternative solution but this needed public education and support.

Now that we have touched on the first two steps of project design, let's move to the **third step, developing the learning experience**. What is a learning experience again? A learning experience is a systematic set of learning activities taking information, curiosity and challenges or "games", to create an "Aha!" moment based on the learning objectives. It uses the power of discovery to engage the learner so that they understand the basis of the lesson and how it can fit into their perception of the world. By creating a self-actualized moment the person becomes more self-directed and resourceful with the new idea or understanding in applying it to their life. As part of the learning experience you will need to decide how to develop the format, create a schedule, who will deliver the lesson, the location and develop the teaching materials.

The fourth step is to develop the promotion of the program. Marketing is key to programs so that you can try to reach your intended audience with the information. You will need to decide what the expenses will be, how to obtain resources or how to solicit sponsors to provide the resources and then create the marketing tools and schedule. This is a crucial action and should be thoughtfully approached because without participants your planning efforts will not be utilized and your time will be wasted.

Woodville, Step 4: Promotion. At this point, the EMG TS recruited the Boy Scouts and others to survey paths through the woods which were targeted for football fields or adjacent parking. These new trails turned up some wonderful old growth trees and grew into popular public tour sites. Along with other educational outreach, this resulted in two good things: redesign of the football fields and a growing interest in the Woodville site for ecological preservation.

The fifth step is delivery of the presentation. As part of the delivery of the presentation, it is beneficial to look at delivery techniques such as lectures, discussion (audience speaks more than presenter), case studies or problem oriented approaches. In the problem oriented approach the learner is given a mental picture of a situation and then a problem is introduced that they must gather information to form a solution. This challenge engages learners to keep them interested through creating a need in their local situation so they can connect and visualize the experience. Practice of the solutions as part of the lesson leads to better application in a learner's daily life and helps them transfer their new skills to their situation. It is helpful to remember that the quality of a few experiences outweighs the quantity of information gathered. Practicing your presentation on a person outside of your field helps point out pitfalls that may cause confusion or lack of transfer with the information.

Woodville, Step 5: Project Delivery. At this point in the park development, a large new pond had been laid out to manage the drainage, with a second one planned. The EMG TS organized volunteer plantings of trees around the ponds, as well as riparian buffers with grasses and shrubs to handle the runoff from the sports fields and parking lots. The EMGs and other local groups set up Demonstration Gardens, extending the educational impact.

Here are some tips for engaging adult learners: start by explaining the purpose and objectives, stay task oriented in your instruction, relate the content to the learners lives, focus on the quality of several experiences rather than quantity of information, and keep the lesson in progression from concrete (learners physical experience targeting the senses to create a memorable example) to the abstract (how does this apply to the world and how can it be used?). The model below is an additional way to describe this.

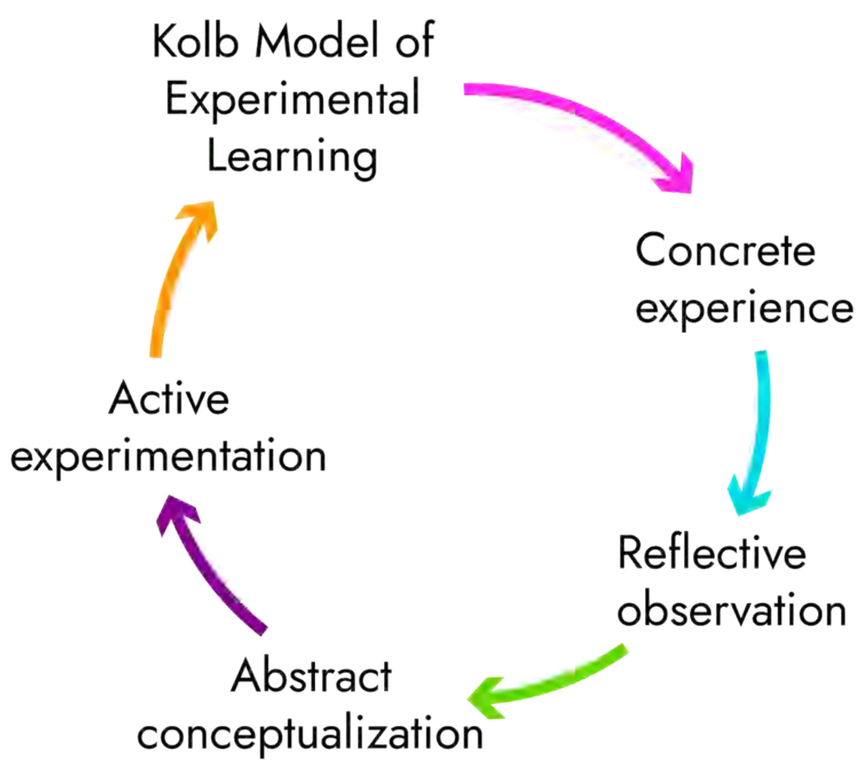

Figure 2-2 Learning model. (Courtesy of Megan Tierney)

What are the differences between lectures, demonstrations, workshops and projects? Lectures include short-term intensive learning, demonstrations include active involvement and projects include active experimentation. Workshops incorporate more concepts to include intensive learning, small group interaction, active involvement and application of the new learning encompassing the learner objectives. Workshops allow the learners to have time to interact with other participants to share their situations and help each other form strategies for dealing with the presented challenge. This time increases the impact of the learning experience through active involvement. A final thought for delivery of the program comes from correlation between presenter behavior and learner achievement. Achievement is measurably higher when the presenter has clarity, variability in strategies, discussion, and assessment, enthusiasm, task/achievement oriented behaviors and when the learners are given a clear correlation between the learned information and achievement (no wasted time).

The sixth step in program planning is evaluation and is a very important part of the iterative process. Without feedback a program would grow from only one view rather than the sum of all views. We evaluate programs to help us make better decisions about the future of the program itself. Should we keep it, improve it, or remove it? We should always be asking those questions in extension, to make sure we are up-to-date in assessing our community needs, efficiency, and effectiveness. Ultimately, extension evaluation results are reformed into outcomes and impacts showing public accountability to stake holders including funders, sponsors, and government.

Woodville Step 6: Evaluation. The EMG TS have an ongoing loop with educational classes and county staff feedback. In addition, they are monitoring the water quality of the two ponds for possible changes in riparian vegetation, compared to past records.

A key aspect of evaluation is identifying an indicator (a marker) that can be observed to show change. Good indicators relate to the objectives of the program, are understandable, are measurable, relevant, provide a representative picture, and can be updated. Bennett's Hierarchy of Evidence (model below) provides a way of understanding the relationships between program objectives and outcomes at different levels of the program and suggests the information that is appropriate to measure to satisfy achievement of the objectives.

Evaluation can be done in multiple stages of planning. Assessing community needs for program design is one form of evaluation. For an initial program you may want to start with a baseline study to capture what the current level of knowledge, attitudes, skills, and aspirations of the audience are. It is also a good time to capture what priority areas exist for intervention and what resources are available for problem solving. For an ongoing program it is best to use a formative evaluation in which questions are asked to help improve, modify and manage the program. What did you learn? Will you be able to use the skill you learned? At the end of a program a summative evaluation is appropriate to ask what were the outcomes, who participated and how and what were the cost associated with the program? Once the program is over questions are asked as a follow-up study like; what were the impacts, what was most useful to participants, and what were the long-term effects? The culmination of this information helps determine the value of the program and can be balanced against the costs to make judgement decision for its existence.

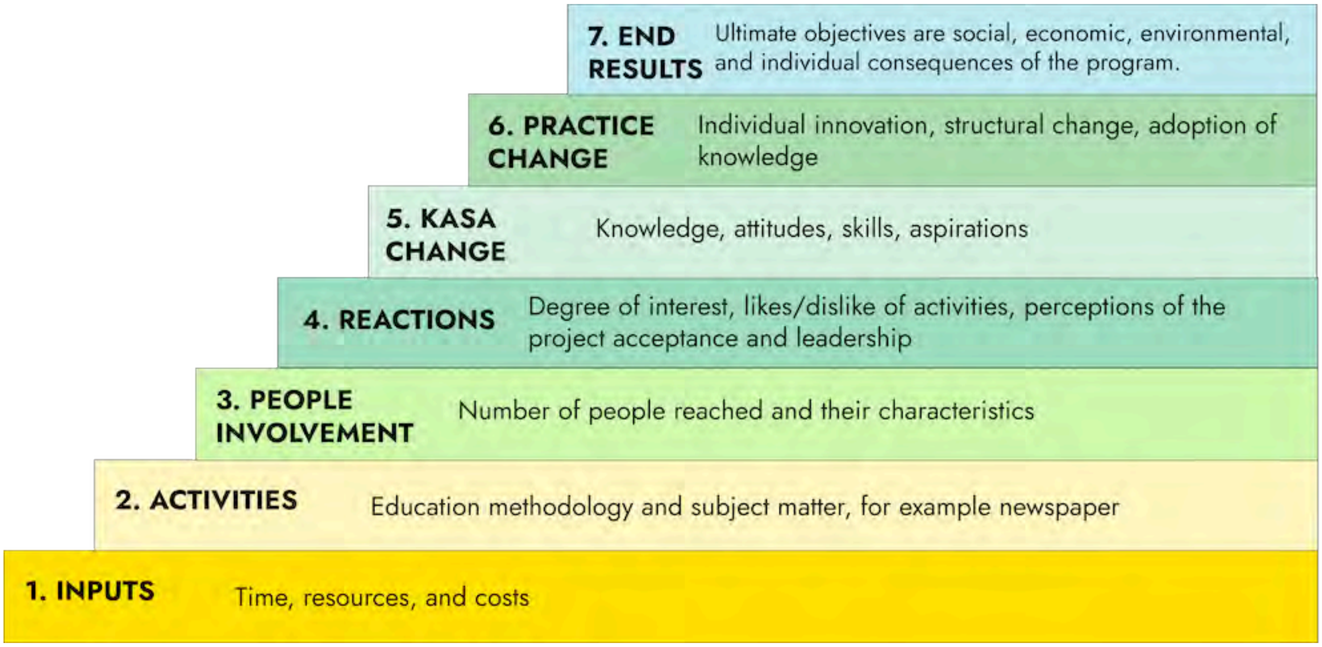

Figure 2-3 Bennett's Hierarchy of Evidence Model. (Courtesy of Megan Tierney)

The seventh and last step in planning is to communicate results. An effective way to do this is to paint a short story as to how the Extension program makes a difference in the lives of the people it serves. Tell why (rationale) and how the program was implemented (objectives and methodology), the measurable results or how program success was achieved (outcomes and impact), and define the public value of the program (future potential). In summary it is very important to have a road map for a program to insure its success and it is key to look, plan and evaluate as part of this road map.

Woodville, Step 7: Communication. This is an ongoing story, communicated through the Parks and Recreation Calendar and local newspaper; also through public interaction with the woodland trails, educational groves, and further riparian buffer remediation efforts. Through the e-naturalist system, they are in contact with VA Department of Conservation and Recreation (DCR) and Department of Game and Inland Fisheries (DGIF), looking at expanding wetlands trails and preserving forest vernal pools in the park.

Review Questions

1. What is the difference between an Output and an Outcome?
2. What does K.A.S.A stand for?
3. What is the importance of using a logic model?

CHAPTER 3: THE BENEFITS (AND DISADVANTAGES) OF TREES

"A fool sees not the same tree that a wise man sees" –William Blake

Chapter Contents:

Introduction

This chapter will discuss the benefits and disadvantages of trees. Trees are a valuable resource and a benefit to the community and world – for construction of homes, as an oxygen source, as a source of recreation, and as a partner in the symbiotic relationships between other plants and animals. However, there are also disadvantages to a poorly placed tree or mismanaged forest.

> **Albert Einstein** "it would be possible to describe everything scientifically, but it would make no sense….as if you described a Beethoven symphony as a variation of wave pressure."

Trees have not only measurable, quantifiable benefits and disadvantages, but also those not adequately addressed through scientific means. Trees have been the source of inspiration for poets, musicians, and artists. How can you measure the worth of a childhood tree climbed repeatedly, or the beautiful beech with lover's initials, or the tree planted in memory of a loved one?

This chapter will generally focus on the urban tree – a tree planted for a specific purpose in a specific location as part of a city or private home landscape – and the urban homeowner. One cannot ignore the importance of the vast amounts of forest and undeveloped land globally to the urban homeowner, areas such as the Amazon rainforest. The trees from the Amazon Basin cover 2.7 million square miles of South America; is estimated to have 16,000 tree species and 390 billion individual trees[1]. More than 20 percent of the world's total oxygen is created by this rain forest, and it is being deforested at an alarming rate.[2].

We also cannot ignore the impact of the solitary tree, grove of trees, a forest, or a planned city park in the US. Throughout our short American history, the planting of trees has been an activity for both recreation and economic value. Andrea Wulf proposed in Founding Gardeners that Washington, Jefferson, and Madison considered themselves farmers first and politicians second.[3] Each planted numerous trees, both native and exotic, on their plantations for economic and aesthetic reasons, scouring the nearby forests for suitable trees to transplant or bringing back seedlings from their foreign travels.

Figure 3-1 Beech Tree. (Courtesy Susan Murchison)

In 2012, according to the US Department of Agriculture (USDA) of the total 2,261 million acres in the US, 819 million acres were forests or woodlands, or 36 percent. Of the total forest land, 56 percent are privately owned. Only nineteen percent can be found in National Forests.[4] "Forests in the United States continue to sequester more carbon than they emit each year, and combined with urban forests, and harvested wood products, offset nearly 15 percent … of total greenhouse gas emissions in 2012."[5]

With much of US forests privately owned, it is important to understand the benefits and costs to the individual owner. Forty percent of the nation's timberland is in the South. "And the South is often referred to as the "woodbasket" of the United States

1. Butler, R. (2017, January 26). *10 Facts about the amazon rainforest.* Mongabay. http://rainforests.mongabay.com/amazon/amazon-rainforest-facts.html
2. Taylor, L. (2012, December 21). *Rain forest facts – the disappearing rainforests.* Rain-tree. www.rain-tree.com/facts.htm#.We5BCGiPLIU
3. Wulf, A. (2012). *Founding Gardeners.* Vintage.
4. United States Department of Agriculture (USDA). (2014, August 1). *U.S. Forest Resource Facts and Historical Trends.* FS-1035.
5. United States Department of Agriculture (USDA). (2014, August 1). *U.S. Forest Resource Facts and Historical Trends*. FS-1035.

because of its extensive timber supply."[6] In addition, the proportion of land in the US classified as "urban" has increased from 2.5 percent in 1990 to 3.6 percent in 2010.[7] Along with the increasing urbanization of the US, it has also been reported that tree cover in urban areas is on the decline.[8],[9]

As the proportion of land classified as urban increases, and the amount of tree cover decreases in cities, it is important to consider and emphasize the benefits (and disadvantages) of trees. According to Kane and Kirwan, the proportion of the US population located in urban areas has grown from 28 to 80 percent from 1910 to 2000.[10]

Trees can be assets or liabilities, depending on the choices made. Careful consideration should be made, and education provided, in their planning, location, planting and maintenance. Unlike the annual flower garden, trees may outlast the planter. In addition, the private homeowner can control their own trees; but a neighbor with a poorly placed tree, an undeveloped forest rezoned for residential development, or the importance of timber in the economy are all considerations to be addressed.

Learning Objectives

1. Understand that a tree or trees have both benefits and disadvantages.
2. Understand the economic, social/aesthetic, community and environmental issues of trees.
3. Understand the local, regional, state, federal and global roles of trees on the urban homeowner.

REVIEW: VCE Master Gardener Handbook 2015 (9/18 update)

- Chapter 16: Woody Landscape Plants

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6. United States Department of Agriculture (USDA). (2014, August 1). *U.S. Forest Resource Facts and Historical Trends.* FS-1035.
7. United States Department of Agriculture (USDA). (2014, August 1). *U.S. Forest Resource Facts and Historical Trends.* FS-1035.
8. Nowak, D. J., Greenfield, E. J. (2012). *Tree and impervious cover in the United States*. Landscape and Urban Planning. 2012a; 107: 21-30.
9. Nowak, D. J., Greenfield, E. J., (2012) *Tree and impervious cover change in U.S. cities.* Urban Forestry and Urban Greening. 2012b; 11:21-30.
10. Kane, B., Kirwan, J. (2009). *Value, Benefits and Costs of Urban Trees.* VCE publication 420-181. http://hdl.handle.net/10919/48050

- Chapter 19: Water Quality and Conservation
- Chapter 20: Habitat Gardening for Wildlife.

The Big Picture

What are the **benefits of urban trees?** According to Kane and Kirwan they can be classified into three categories: ecological (including reduction of air pollution, storm water control, carbon storage, water quality and reduced energy consumption); social benefits (including job satisfaction, hospital patient recovery time, improved child development); and aesthetic value (increased property values).[11]

Relf and Close state that landscaping improves and sustains the quality of life.[12] It enhances the environment (protecting water quality, reducing soil erosion, improving air, lowering summer temperatures, conserves naturals resources, screens busy streets); promotes economic development (increasing property values, increases community appeal, reduces crime, increase tourism revenues, increases job satisfaction, increases worker productivity, and renews business districts); and improves human health (gardening is good exercise, horticulture is therapeutic and landscapes heal).

According to the International Society of Arboriculture (ISA) trees have social, communal, environmental and economic benefits.[13] However, they also require an investment.

We must also consider **other benefits of trees** – those less associated with the quantitative values. If not for the apple tree, would Newton have pondered gravity? Where would the cardinal lay its nest, if not for trees? Where would birds shelter from the snow storm? What of the myriad of insects both within and under the tree? Trees protect what lies underneath through interception of rain, protect soil from erosion and shelter the more fragile understory shrubs and plants.[14] There is a deep symbiotic relationship between trees and the flora and fauna dependent on it.[15] The nuts of the

11. Kane, B., Kirwan, J. (2009). *Value, Benefits and Costs of Urban Trees.* VCE publication 420-181. www.ext.vt.edu.
12. Relf, D., Close, D. (2015). *The Value of Landscaping*. VCE publication 426-721. www.ext.vt.edu.
13. International Society of Arboriculture (ISA). (2011). *Benefits of trees*. ISA and Trees are Good publication. www.isa-arbor.com and www.treesaregood.org.
14. Nisbet, T. (2005, April 1). *Water Use by Trees*. Forestry Commission. www.forestry.gov.uk FCIN065.
15. Huikari, O. (2012). *The Miracle of Trees.* Bloomsbury Press.

acorn, the cone of the pine, and the fruit of the paw paw all provide sustenance, without which wildlife will struggle to survive.

There are **disadvantages to be considered**. The deer not only eat the acorns, but also the homeowner's prized azaleas. The sweet gum provides shade but also gumballs, and the pawpaw produces quantities of desirable edible fruit that on a sweltering summer day can be pungent. And almost any urban tree requires care not only in its selection and planting but in continuing maintenance of the tree and its site. Otherwise, the tree may interfere with important infrastructure and even become a hazard.

This chapter is organized by the size of the community where trees are found. The benefits/disadvantages are discussed within the categories proposed by the ISA – economic, social/aesthetic, community and environmental.

The Private Home Owner

The **economic benefit** of trees is undeniable **for the home owner**. According to Relf and Close, an attractive landscape with trees increases the value of a home by 7.5 percent.[16] Appropriately placed shade trees can lower summer temperatures of the home – thereby conserving energy. Homes sheltered by appropriately placed evergreen screens can reduce heat loss in the winter by blocking winds, thereby conserving energy. According to Litvak and Pitaki landscapes that combine both trees and lawns consume less water than landscapes with only lawns.[17]

We can calculate the benefit of a tree to an amazing degree. Try calculating the benefits of a tree in your area using the iTree calculator here: https://planting.itreetools.org/ *Benefits are estimated based on USDA Forest Service research and are meant for guidance only).*

Trees can also effectively beautify or screen unsightly areas, an aesthetic benefit. According to Appleton, et al.[18] trees can be used to define a private space, or to hide utility boxes. They can control noise from a busy street, and filter light. For the nature lover, a tree encourages wildlife habitats. Trees are said to have a calming effect.[19] They are planted as memorials. Many outdoor recreational

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16. Relf, D., Close, D. (2015). *The Value of Landscaping.* VCE publication 426-721. www.ext.vt.edu
17. . Litvak, E., Pataki, D. (n.d.). *Technical Fact Sheet: Water use by urban lawns and trees in Los Angeles: evaluation of current irrigation practices to develop water conservation strategies.* Urban Ecology Research Lab, Department of Biology, The University of Utah.
18. Appleton, B., Baine, E., Harris, R., Sevebeck, K., Alleman, D., Swanson, L., Close, D. (2015). *Screening*. VCE publication 430-025. www.ext.vt.edu.
19. International Society of Arboriculture (ISA). (2011). *Benefits of trees*. ISA and Trees are Good publication. www.isa-arbor.com and www.treesaregood.org.

activities such as hiking and "just sitting on the back porch are more enjoyable in and around trees."[20] Fruit and nut trees provide edible produce.

MyTree Benefits: Serving size: 1 tree

This is an analysis of a loblolly pine in the Tidewater area of Virginia. (http://www.davey.com/calculator) Benefits are estimated based on USDA Forest Service research and are meant for guidance only: www.itreetools.org

*Positive energy values indicate savings or reduced emissions. Negative energy values indicate increased usage or emissions.
**is not greater than 10 microns

Item	Savings
Carbon Dioxide (CO2) Sequestered	$2.04
CO2 absorbed/stored each year	203.68 lbs
Storm Water	$70.37
Rainfall intercepted each year	7108 gal.
Air Pollution removed each year	$3.10
Ozone	11.44 oz
Nitrogen dioxide	3.88 oz
Sulfur dioxide	2.28 oz
Large particulate matter **	8.33 oz
Energy Usage each year*	$19.20
Electricity savings (A/C)	27.33 kWh
Fuel savings (NG,Oil)	11.97 therms
Avoided Emissions	
Carbon dioxide	238.02 lbs
Nitrogen dioxide	0.71 oz
Sulfur dioxide	10.73 oz
Large particulate matter **	0.27 oz

20. Kane, B., Kirwan, J. (2009) *Value, Benefits and Costs of Urban Trees.* VCE publication 420-181. www.ext.vt.edu.

Figure 3-2 Loblolly Pine. (Courtesy Carol King)

Research conducted by Townsend, et al, indicated that not only did street trees provide significant reduction of stress in a community, but private trees on community streets (those trees owned by a private home owner) augmented that reduction.[21] They stated if community/street tree planting is not an option then encouraging private tree planting and maintenance would have a community benefit.

The environmental benefit of tree planting by the private home owner is significant. Trees protect and improve water quality, reducing nitrate leaching and surface water runoff.[22] It reduces soil erosion, keeping sediment out of streams and rivers and on the property. It improves air quality – one tree can remove 26 pounds of carbon dioxide from the atmosphere yearly. Trees intercept water – falling rain is slowed by the leaves – allowing for better absorption and less run off. Leaves also remove dust and other particulates from the air.[23] Most importantly, they store the carbon removed (sequestration), which reduces the green-house effect that is related to global climate change.[24]

There are also **disadvantages to trees for the homeowner**. Trees can be expensive to purchase and maintain. Ko, et.al., found that in their study of a tree give-away program in Sacramento, California, that only 23% of the trees planted had maintenance that followed guidelines.[25] Trees also are a longer-term investment – often the owner/planter will not be alive or live in the area to see the full maturation of a tree. To some, planting a tree is a blind belief in the future.

Trees also can become hazards to the home in the wake of hurricanes or storms. Leaves need to be raked. Sap drips. Sidewalks, driveways, and brick walls crack if too close to tree roots. Birds leave droppings. Trees can shade a lawn to the point where grass won't grow. Roots protrude from the soil. Trees encourage wildlife. Gumballs and pinecones are hazards to bare feet. However, generally,

21. Townsend, J., Ilvento, T., Barton, S. (2016) *Exploring the relationship between trees and human stress in the urban environment.* Arboriculture & Urban Forestry. 42(3) 146-159.
22. Relf, D., Close, D. (2015). *The Value of Landscaping.* VCE publication 426-721. www.ext.vt.edu.
23. International Society of Arboriculture (ISA). (2011). *Benefits of trees.* ISA and Trees are Good publication. www.isa-arbor.com and www.treesaregood.org.
24. Kane, B., Kirwan, J. (2009) *Value, Benefits and Costs of Urban Trees.* VCE publication 420-181. www.ext.vt.edu.
25. Ko, Y., Roman, L., McPherson, E. G., Lee, J. (2016, June 1) *Does tree planting pay us back? Lessons from Sacramento, CA.* Arborist News. 25(3); 50-54. www.isa-arbor.com

the economic, aesthetic, community and environmental benefits outweigh the disadvantages for the private home owner.

Deep in the Quiet Wood[26]

by James Weldon Johnson

Are you bowed down in the heart?

Do you but hear the clashing discords and the din of life?

Then come away, come to the peaceful wood,

Here bathe your soul in silence.

[...]

The Community and Neighborhood or City

Many of the same benefits to a private home owner apply also to communities, cities or regions. Like a Gestalt, **the urban forest is more than the sum of the individual trees in it**. Cities and communities spend large sums of limited fiscal resources to plan green space on highway medians, to protect and maintain city parks, and to set environmental regulations such as the number of trees to be planted in parking lots.

"The total area covered by urban parkland in the United States exceeds one and a half million acres, with parks ranging in size from the jewel-like 1.7-acre Post Office Square in Boston to the gargantuan 490,125-acre Chugach State Park in Anchorage. And their usage dwarfs that of the national parks—the most popular major parks, such as Lincoln Park in Chicago receive upwards of 20 million users each year, and New York's Central Park gets about 35 million visits annually—more than seven times as many to the Grand Canyon."[27]

26. Johnson, J. W. (1917). Deep in the Quiet Wood. *Fifty Years and Other Poems* (pp. 47). Boston: The Cornhill Company. https://babel.hathitrust.org/cgi/pt?id=uc2.ark:/13960/t7fq9qv3r&view=1up&seq=71&q1=deep%20in%20the%20quiet
27. Trust for Public Land. (2011). *City Park Facts Report.* The Trust for Public Land. www.tpl.org/2011-city-park-factsreport#sm.0001n5hkgg19ntfgeplswf2q79wk8

Figure 3-3 Mariners Museum Park, Newport News. (Courtesy Daina Henry)

In Virginia, according to the Trust for Public Lands, the five largest amounts of acreage in municipal parks can be found in: Arlington (1,784 acres), Chesapeake (56,869 acres), Norfolk (607 acres), Richmond (2,027 acres), and Virginia Beach (24,936 acres).[28] However, Newport News Park, not mentioned in the report, covers 8,065 acres.

For example, according to the Virginia Beach Parks and Recreation website, Virginia Beach has 293 city parks covering 7000 acres; the remainder of the acreage is denoted as natural areas. According to the Virginia Beach City Parks and Natural Areas website: "A natural area is a municipal preservation area whose primary purpose is to preserve the indigenous vegetation and wildlife in order to serve as green infrastructure and as a scenic environment for Virginia Beach residents to enjoy. Natural areas include areas for protection and management of the natural/cultural environment with recreation use as a secondary objective. Recreational use might include passive recreation activities such as hiking, birding, and environmental education, but may also include public waterway access improvements, public fishing opportunities, and trail connections."[29]

Cities across the US have set aside, and continue to set aside, areas for city parks and natural areas. The Virginia Department of Conservation and Recreation reports on their website that "Outdoor recreation supports a high quality of life, attracts tourists, and sustains the well-being of Virginia's residents and guests. According to the Outdoor Industry Association, outdoor recreation in Virginia generates $21.9 billion in consumer spending annually and directly provides 197,000 jobs."[30]

Not only do **urban/city natural areas provide economic benefits**, in terms of tourism, and improved quality of life to residents, these natural areas reduce storm water runoff, improve area air and water quality. Desirable neighborhoods have access to natural areas, streets are lined with trees, and home owners increase their property value with trees and other landscaping. Increased property values then lead to increased revenue for the local cites.

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28. Trust for Public Land. (2015). *2015 City Park Facts Report*. The Trust for Public Land. www.tpl.org/sites/default/files/files_upload/2015-City-Park-Facts-Report.pdf)
29. Virginia Beach Parks and Recreation. (2017). *City Parks &Natural Areas*. Virginia Beach VA. https://www.vbgov.com/government/departments/parks-recreation/parks-trails/city-parks/Pages/default.aspx
30. Virginia Department of Conservation and Recreation. (2017, August 31). *Outdoor Recreation: An economic engine.* Virginia Department of Conservation and Recreation. http://www.dcr.virginia.gov/recreational-planning/

Highways and streets are improved with green medians including trees and shrubs. Research has shown that trees have a traffic calming effect. According to Marritz, street trees play a role in speed control, with street lined trees reducing traffic speed by 8 mph. They also noted that a site in Texas that improved landscape decreased crash rates by 46%; and that a healthy canopy of trees can help reduce stress and road rage.[31]

Dunn (writing for the organization Friends of Frink Park) notes that cars drive more slowly on streets with trees; street trees cut traffic noise; residents walk more on streets with trees; trees improve air quality, and increase property value.[32]

Figure 3-4 Trail in an Urban Park. (Courtesy Carol King)

Neighborhood trees and parks have economic, aesthetic, and environmental benefits. They also have social/community benefits. Beyond the reduction of road rage, and general noise reduction, trees have other public health benefits.

Trails encourage walking, and the medical benefit of walking cannot be argued. Trees have been found to improve attention, decrease asthma and obesity, improve physical and mental health, and have been related to reduced hospital stays. A green canopy provides shade, cooler temperatures, and protection from the sun's UV rays on hot days.

Just as for the private home owner, street and parking lot trees provide shade for cars and residents; they absorb storm water, improve air quality, and store carbon. Parks without trees cannot sustain significant wildlife, at least in Virginia's ecology.

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31. Marritz, L. (2011, October 5). *Trees are a tool for safer streets.* Deeproot. http://www.deeproot.com/blog/blog-entries/trees-are-a-tool-for-safer-streets
32. Dunn, L. (n.d.). *The Benefits of Street Trees*. Frink Park. www.frinkpark.org/trees.htm

Figure 3-5 Storm Damaged Tree. (Courtesy Daina Henry)

Trees and parks do have their disadvantages. Trees can be difficult and costly to maintain, especially after storms. Hurricane and tornado damage of trees can block roads needed for emergency access. They often are the cause of electrical outages – branches and trees taking down power lines. Tree leaves can block storm drains, and are a nuisance for the home and business owner in the fall. Improperly placed berry producing trees can damage homes, cars and businesses. Trees provide shelter for birds and wildlife, which can then leave droppings. They are also a significant source of pollen in the spring and summer for allergy sufferers. However, the pollen is a boon to the car wash industry and allergy medicine producers, but leaves the individual and region under a blanket of misery.

Parks may also have a negative economic impact. They often displace land that could be developed for businesses or homes which would result in increased real estate revenue. An acre of non-taxable trees will never equal the potential for tax revenue income of a business or home.

In summary, just as with the private homeowner, urban trees planted by municipalities and cites have advantages: improved air and water quality, increased tourism, positive health effects, options for recreation, and increased property values. However, poorly placed trees or improper selections can lead to increased maintenance and storm cleanup, power disruptions, blind spots on roads, and clogged storm water drains. Also, in a short-sighted view, every acre without development can have impact on the local or regional tax revenues.

State and National Forests

In Virginia, the Department of Conservation and Recreation is responsible for the 37 state parks. These parks provide numerous recreational opportunities and over 626 miles of hiking. These parks encompass 72,793 acres. The first parks were established in 1933 with the latest with the latest addition in 2021 – the Machicomoco State Park.[33] The economic value of state parks was $222.8 million dollars in 2015 (half from visitor fees.) According to the Virginia Association for Parks, the state parks attract $171 million dollars in "new money" at the cost of $18 million dollars in general

33. Virginia Department of Conservation and Recreation. (n.d.). *History of Virginia State Parks.* Virginia Department of Conservation and Recreation. http://www.dcr.virginia.gov/state-parks/history

funds.[34] Property values around state parks increase by 20 percent. They create over 2500 jobs. State parks host 8.9 million visitors, and almost half of every household in Virginia visit a state park every year.

The Virginia Department of Forestry manages 24 areas for a total of 68,626 acres. The goals of DOF are: manage the forest land for steady supply of timber; provide recreational opportunities; maintain aesthetics; maintain wildlife habitats; create natural reserves; and preserve water quality.[35]

According to the Virginia Department of Forestry, Virginia has 15.72 million acres of forestland, and 62% of Virginia is considered forested. Urbanization and development are the biggest factors in loss of forests. It is also noteworthy that private individuals own more than two-thirds of Virginia's timberland.[36] An interactive version of the map below may be found at: https://dof.virginia.gov/education-and-recreation/state-forests/virginia-state-forests/

Figure 3-6 Virginia Forestry. (Courtesy Virginia Department of Forestry)

The forest resource contributes $17 billion annually to Virginia's economy; supports one of the largest manufacturing industries in the state (lumber); $3 billion dollars in recreational opportunities, and generates 103,000 jobs. Besides their obvious economic benefit, forests provide large watersheds,

34. Virginia Association for Parks. (n.d.). *Virginia State Parks Are…* Virginia Association for Parks. http://www.virginiaparks.org/
35. Virginia Department of Forestry. (2016, November 1). *About the State Forest System.* Virginia Department of Forestry. http://dof.virginia.gov/stateforest/index.htm
36. Virginia Department of Forestry. (n.d.). *Virginia Forest Facts.* Virginia Department of Forestry. www.dof.virginia.gov/stateforest/facts/forest-facts.htm

long term carbon sequestration, and social benefits (scenic beauty, wildlife habitat, and desirable housing locations).[37]

National forests in Virginia fall under the US Forest Service under the US Department of Agriculture. The two managed forests are the George Washington and Jefferson located in the western portion of the state along the Appalachian Mountains.[38]

These two forests contain 1.8 million acres, making up one of the largest blocks of public land on the East Coast. It stretches through Virginia, Kentucky and West Virginia. Virginia's acreage is 1.6 million acres. These forests are home to: 40 species of trees, 2000 species of shrubs and plants, 78 species of amphibians and reptiles, 200 species of birds, 60 species of mammals, 100 species of freshwater fishes and 52 federally listed Threatened or Endangered Species.

Of the 1.8 million acres, almost 40% (689,000 acres) are actively managed to produce timber and wood products. These forests are in 8 watersheds: Potomac, James, Roanoke, New, Big Sandy, Holston, Cumberland and Clinch River. Average surface water discharge to these watersheds is 2.2 million acre feet. There are 82 reservoirs in these forests, 16 of which are used for municipal water supply.[39]

Though this chapter's focus is on the urban tree, it would be negligent not to discuss the impact of state and national forests on the urban dweller. Forests provide one of the largest industries in Virginia. The national and state forests filter water for those not only local, but through the numerous watersheds effects, thereby effecting the water quality of our rivers throughout Virginia. The reservoirs in state and national forests provide our drinking water. Air quality is improved, and carbon is sequestered.

However, the need for land for development must be noted. Large tracts of forested land are attractive to developers. Cities need to expand. Urban sprawl continues outward. The urban dweller is thus influencing and being impacted by their own trees, the neighborhood and street trees, and the trees from far away on rural private, state and national forests.

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37. Virginia Department of Forestry. (n.d.). *Economic Benefits of the Forest Industry in Virginia.* Virginia Department of Forestry. www.dof.virginia.gov/forestry/benefits/index.htm
38. United States Department of Agriculture (USDA). (n.d.). *George Washington and Jefferson National Forests.* USDA Forest Service. www.fs.usda.gov/gwj
39. United States Department of Agriculture (USDA). (n.d.). *George Washington and Jefferson National Forests – Learning Center – About us.* USDA Forest Service. www.fs.usda.gov/main/gwj/learning

The Urban Tree and Climate Change

This chapter will not get involved in the discussion on whether climate change is caused by human factors. However, it is undeniable that climate change is happening. US Hardiness zones have been recently revised with warmer zones reaching further north than previously. Greenhouse gases such as carbon dioxide and methane are increasing in the upper atmosphere. Trees are one means of carbon sequestration. More trees, more carbon sequestered. Trees are much more efficient than smaller plants at sequestration because of their larger size and root structures. According to Earth Talk, trees are means of climate change mitigation.[40]

Unlike state and national agencies responsible for protection and preservation of trees, there is no one international/global agency monitoring and researching the effects of deforestation on climate and humans. The United Nations has created the Billion Tree Campaign "to encourage people, communities, organizations, business and industry, civil society and governments to collectively plant at least one billion trees worldwide each year." The Union of Concerned Scientists warn of the perils of worldwide deforestation and global warming.[41]

Trees[42]

by Joyce Kilmer

I think that I shall never see

A poem lovely as a tree [...]

Poems are made by fools like me,

But only God can make a tree.

No one tree will impact climate change. Taken together, they can possibly mitigate it. The three largest factors in deforestation are: agriculture (the turning of forests into farmland or pasture); logging; and urban sprawl. According to the National Geographic, this deforestation leads to a loss of habitat, and climate change. Forest soil is moist, without a protective canopy, soil dries out; vapor

40. Earth Talk. (2017, March 27). *Which trees offset global warming best?* Thoughtco. www.thoughtco.com/which-trees-offset-global-warming-1204209
41. United Nations. (n.d.). *Plant for the Planet: Billion Tree Campaign.* United Nations. www.un.org/climatechange/blog/2014/08/plant-planet-billion-tree-campaign/
42. Kilmer, J. (1915). Trees. *Trees and Other Poems* (pp. 19). Garden City, NY: Doubleday and Company, Inc. https://babel.hathitrust.org/cgi/pt?id=loc.ark:/13960/t0dv20z4c&view=1up&seq=29&q1=trees

that would have been returned to the atmosphere is lost.[43]
The Food and Agriculture Organization of the United Nations reports that forests cover one third of the worlds land area; a quarter of all medicines come from tropical forest plants (aspirin is derived from a willow tree); produce nutritious foods such as fruits, nuts, seeds (coffee and tea); serve as natural aqueducts, are a carbon sink (removing 2.1 gigatonnes of carbon dioxide annually); provides wood fuel (supplying 40 percent of the worlds renewable energy supply); is a source for rubber and latex; and provides paper.[44]

As technology develops, research on global forests and deforestation has been ongoing through remote sensing via land sat data, the US Geological Survey, NASA, NOAA and the International Union of Forest research Organization.

As you sit and read this manual, note the extensive amount of tree products around you – the chair you sit in; the coffee or tea that you are drinking; the table on which your cup rests; the apple you eat; or the fireplace that warms you on a cold night. The urban homeowner is surrounded by trees, living and dead.

However, choosing an appropriate tree and planting it correctly is not the simple answer to a complex issue. As the research of Ko, et al, Sacramento study showed, giving away trees for planting is not the answer.[45] Only 23 percent followed recommended guidelines for maintenance, leading to significant mortality. City tree life spans are between 10 and 30 years, compared to a rural tree's average life span of 150 years.[46]

According to Roman, even though there has been a major focus on city tree planting, the amount of overall canopy is decreasing. The research reports that life span of the typical street trees is 19 to 28 years with an annual mortality rate of 4-5%.[47] In other words, at a mortality rate of 5 percent, in 20 years all the street trees planted in one year (with an average 19 year life span) would have died. If these numbers are true, then we are not catching up with the loss of trees, but merely are running a Sisyphusian task.

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43. National Geographic. (2017). *Deforestation*. National Geopraphic. www.nationalgeographic.com/environment/global-warming/deforestation
44. Food and Agriculture Organization of the United Nations. (2017, September 13). *Ten things you may not know about forests.* Food and Agriculture Organization of the United Nations. www.fao.org/zhc/detail-events/en/c/1033884/
45. Ko, Y., Roman, L., McPherson, E.G., Lee, J. (2016, June 1) *Does tree planting pay us back? Lessons from Sacramento, CA.* Arborist News, 25(3); 50-54. www.isa-arbor.com
46. United States Forest Service. (n.d.). *Forest Health Monitoring – Chapter 1 – Trees in Cities*. United States Forest Service. fhm.fs.fed.us/pubs/fhncs/chapter1/trees_in_cities.htm
47. Roman, L. (2014). *How Many Trees are Enough? Tree Death and the Urban Canopy.* Scenario Journal. https://scenariojournal.com/artocle/how-many-trees-are-enough/

Correct planting and maintaining of urban trees is not the simple answer. A more coordinated and long term plan for researching the benefits of trees locally, regionally, nationally and internationally will be needed.

What can we, as individuals, do? Dave Nowak from the US Forest Service reports "Common Horse-chestnut, Black Walnut, American Sweetgum, Ponderosa Pine, Red Pine, White Pine, London Plane, Hispaniolan Pine, Douglas Fir, Scarlet Oak, Red Oak, Virginia Live Oak and Bald Cypress as examples of trees especially good at absorbing and storing CO_2."[48] Plant a tree (the right tree!). Encourage others to plant a tree. Educate about the care and maintenance of a tree. As a tax paying citizen, become educated about regional, state and national issues concerning forests.

While the focus in this chapter has been the urban tree and the urban homeowner, it is evident, to quote John Donne, "No man is an island." Trees around the globe, in our country, in our state, in our local municipalities and in our yards all have impacts on the urban individual.

Review Questions

1. ISA categorizes benefits of trees into four broad types. What are they?
2. This chapter discusses trees from the perspective of the urban homeowner – someone who may or may not have a tree in their yard. What benefit does a city park, state park or national forest have to an urban dweller?

48. Earth Talk. (2017, March 27). *Which trees offset global warming best?* Thoughtco. www.thoughtco.com/which-trees-offset-global-warming-1204209

CHAPTER 4: BOTANY OF TREES

"A tree trunk the size of a man grows from a blade as thin as a hair" – Lao Tzu

Chapter Contents:

Introduction

What makes a tree different from a tulip? Why do these plants grow so much bigger, stronger and older than all the rest of the Plant Kingdom? This chapter will explore the processes and structures that define woody plants and, within that group, enable trees to stand out (figuratively and literally). Some of the material has to do with chemical interactions at the cellular level, some with organized assemblages of cells such as the vascular systems, and the rest with externally visible functions such as branch structure and root spread. The end result is to see trees as integrated, complex living entities with extraordinary strength, although they face unprecedented challenges in today's environments. There is so much more to learn, but we can at least start here.

This chapter also serves as a gateway to students' learning to identify trees for themselves and their ability to look at trees within larger, living contexts.

Learning Objectives

1. Understand key plant processes.
2. Understand the difference between herbaceous and woody plants.
3. Understand what sets trees apart from other woody plants.
4. Begin to know how to identify trees.
5. Consider the interactions among trees and with their external environments.

REVIEW: VCE Master Gardener Handbook 2015 (9/18 update)

- Chapter 2: Basic Botany
- Chapter 16: Woody Landscape Plants

Key Plant Processes and Definitions

Photosynthesis is defined as the process by which the chlorophyll in green plants use light energy to convert carbon dioxide and water into organic compounds (producing sugars) and water.[1] It is the first and most fundamental step in the support of plant life and by extension all life on the planet. Generally, it takes place during the daytime when the chloroplasts are able to capture light and open the stomata to allow carbon dioxide to enter the leaf. The sugars produced are distributed throughout the plant to keep all the other processes working and the plant growing. Locations which produce more sugars than they use are **sources**, and those which are net consumers are **sinks**. Different parts of the plant can function as either one, depending on the season and activity at that location. For example, during new leaf formation, the stored carbohydrates adjacent to the roots' growing points are the source of provided sugars, and the leaves are the sink; later on in the growing season the situation is reversed.[2] The oscillating rhythm between roots and shoots is a characteristic of the plant plus the seasonal patterns in its environment.

1. Allaby, M. (2015). *The Dictionary of Science for Gardeners*. Timber Press.
2. Reece, J.B., Urry, L.A., Cain, M.L., Wasserman, S.A., Minorsky, P.V., Jackson, R.B. (2011). *Biology* (9th ed.). Benjamin Cummings.

Respiration is the active process by which plants release the energy needed for their living processes, turning sugar and oxygen into energy and carbon dioxide.[3] Chemically, it is the opposite of photosynthesis. Both photosynthesis and respiration require the leaf stomata to open. Through these openings, and some others (e.g., lenticels on twigs/bark), heat from the sun causes water in the stomata to evaporate, thus creating a passive pulling force on the columns of water coming up from the roots. The polarization of water molecules combines with the ionic charges of the xylem to aid in the upward movement of water. (Think of a slinky moving up the stairs instead of down!) Wind blowing across the leaves can enhance evaporation, as does lower relative humidity of the surrounding air. This **transpiration** process, combined with pressure originating in the roots' water intake, is essentially the engine which makes the whole plant work. The outer limits of what this engine can accomplish are seen in gravity-defying columns in excess of 300 feet tall in giant redwoods.

Trees, on average, are 80% **water** (remainder 19% carbohydrates, 1% everything else).[4] As much as 98% of the water which enters the tree exits via transpiration, so it becomes possible to imagine the tremendous amount of movement generated as the water transports dissolved minerals and sugars and acts as a coolant.[5] The water can move as fast as 100 feet an hour in some species at the height of the growing season.[6] All this is in addition to water's role in the chemical processes already described and its significant role in maintaining **turgor,** or keeping cells fully plumped up against their rigid walls. The importance of the latter task is very obvious when the water-holding vacuoles within the cell membranes collapse under drought stress, leaving the cell walls holding empty balloon skins. The greater rigidity of woody tissue (compared to annuals and perennials) does give woody plants better structural endurance, but a lot depends upon the appropriateness of the specific plant to the site conditions.

Water is so essential that some plants have developed **alternative strategies** in response to harsh conditions of heat and/or drought. In one of the two alternatives, the plants have altered the process to take part of the necessary ingredients into one set of photosynthetic cells, then process the reaction in another set, thereby reducing the evaporation potential. The process with which we are most familiar is generally found in climates with reasonable precipitation. It is called C3 because the initial product of the reaction is a three-carbon compound. The two-cell process forms an initial four-carbon compound and is therefore called C4. Wheat, soybeans, zinnias and roses are C3 plants,

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3. Allaby, M. (2015). *The Dictionary of Science for Gardeners*. Timber Press.
4. Coder, K.D. (2012). *Water and Trees: Understandings for Tree Health.* University of Georgia, Warnell School of Forestry and Natural Resources Outreach Monograph WSFNR 12-11.
5. Capon, B. (1990). *Botany for Gardeners.* Timber Press.
6. Gilman, E.F. (2012). *An Illustrated Guide to Pruning* (3rd ed.). Delmar.

as are virtually all dicot trees.[7] Sugarcane, sorghum and most grasses are C4 plants. Gardeners in Virginia, especially in warmer regions, are familiar with the choice between cool season grasses such as tall fescue (C3) and warm season ones such as zoysia or bermuda (C4): the latter withstand summer heat and drought far better than the former. The second alternative photosynthetic process takes an even more strenuous step to limit the damage from extreme heat and drought. This group of plants, called CAM after the Crassulaceae family of succulents, opens its stomata at night to make the organic acids which are stored until morning for the remainder of the reaction.[8][9] Cacti, yucca and jade plants are in this category. As a general rule in the contiguous US, the temperate East Coast plants, especially trees, are C3. From Oklahoma/Kansas/Nebraska west, the C4 grassland plants dominate until you get to the desert regions, where CAM plants are more likely. Ecologists are becoming increasingly interested in the possibilities of using more C4 plants to address trends toward harsher, warmer weather patterns and increases in CO_2 levels.[10][11]

In addition to water, plants require specific amounts of **salt** in the soil medium around their roots. If there is too little, it is the equivalent of overwatering, causing cells to rupture. If there is too much, the cells shrivel and may die. The 'Goldilocks' amount varies from one type of plant to another but is part of the context that makes a site and plant mutually suitable. Significant changes in soil salinity due to climate change and other environmental factors can be expected to alter the distribution of trees and other plants.

Vascular System. All these wonderful plant processes lead one to expect an appropriately elegant physical structure, and indeed this is so. There are two different ways that trees (and other plants) organize their vascular systems. Monocots, so called because their seeds each contain just one cotyledon (or seed leaf) leaf, have vascular bundles throughout their stems. This means that monocots do not have branches nor woody root systems. Dicots, with two cotyledons inside each seed, place their vascular bundles in a ring near the outside of the trunk. Newer, genetically based research has further divided the dicots based on their evolution (discussed in Chapter Five) but the distinctions are of little practical impact to this chapter's discussion of tree structure and function.

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7. Pearcy, R.W., Troughton, J. (1975). *C4 Photosynthesis in Tree Form Euphorbia Species from Hawaiian Rainforest Sites.* Plant Physiology. www.plantphysiol.org.
8. Black, C.C., Osmond, B.C. (2003). Crassulacean Acid Metabolism Photosynthesis: 'Working the Night Shift.' *Photosynthesis Research*. 76, 329-341
9. Reece, J.B., Urry, L.A., Cain, M.L., Wasserman, S.A., Minorsky, P.V., Jackson, R.B. (2011). *Biology* (9th ed.). Benjamin Cummings.
10. Dimmitt, M.A. (2017) *Plant Ecology of the Sonoran Desert Region.* Arizona-Sonora Desert Museum. www.desertmuseum.org.
11. Orcutt, D. (2016). *How Do Plants Respond to Changing Climatic Conditions?* [Lecture]. Virginia Master Gardener College, Norfolk, VA, United States.

The only monocot trees are palms, so EMG Tree Stewards in Virginia will spend most of their time with dicot trees.

Water, minerals and hormones are moved up the plant by **xylem** tissue, tube-shaped cells which conduct waters and dissolved minerals from the roots through the trunk to the branches, leaves, flowers and fruits. Dicots, and some monocots, have both larger xylem vessels and smaller tracheid tubes, while the dicot conifers have only tracheids.

The second component of plant stems and roots is the **phloem** tissue, which moves sugars up, down and around. Its cells are minimal in structure and aided by companion cells to complete all its functions. In dicots, the xylem is on the inside (nearest the heart) and the phloem is on the outside (nearest the bark).

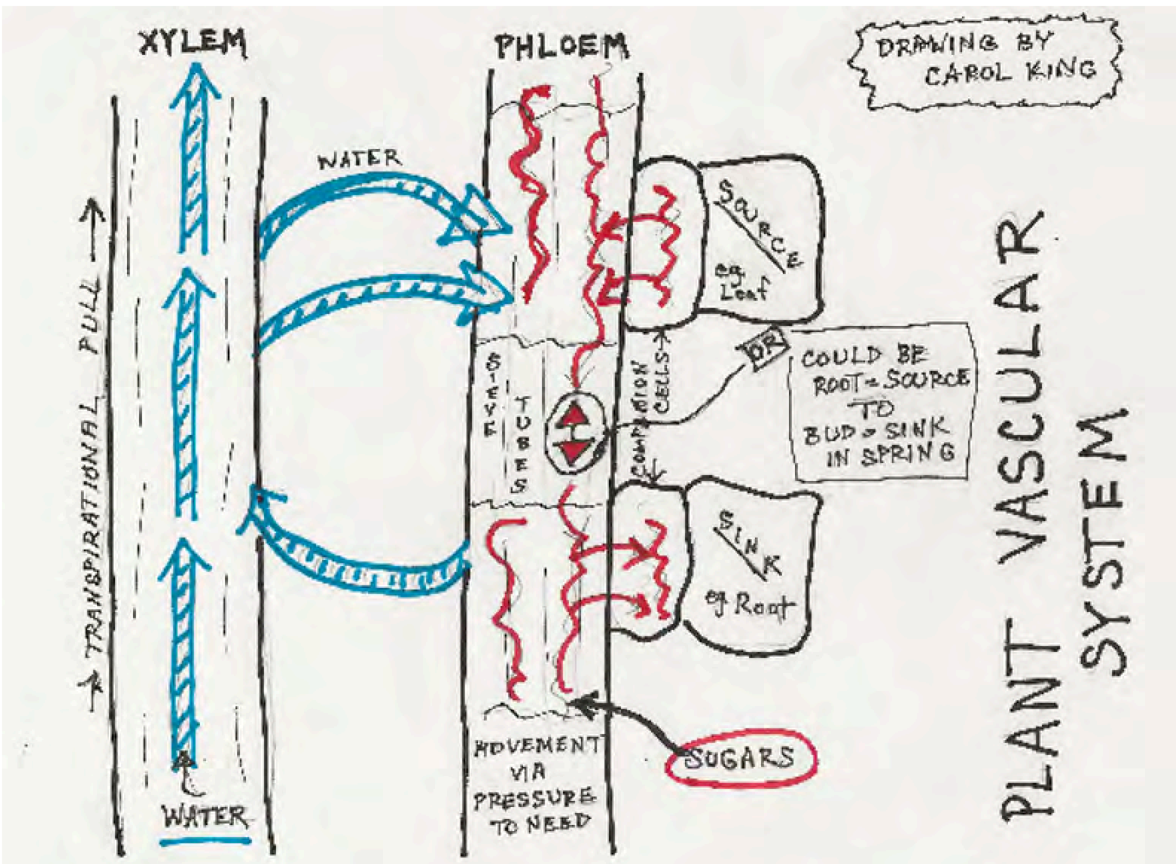

Figure 4-1 Vascular System

The genie in the system is the **meristematic tissue**. This is found between the xylem and phloem and allows new cells to turn into either one, depending on the location and need. The annual growth rings visible in Figure 4-2 show the difference between early growth each year (tending to have larger vessels) and the later part of the year. In good growth years, these rings are often larger than in harsher years, a pattern which has been very valuable to researchers in many fields. The picture is actually a branch rather than a trunk, but the principle is the same.

It is worth noting that dicot trees have both apical meristem and lateral (vascular) meristem, meaning that a tree can produce new cells capable of different roles both in the cambium and in the ends of the branches and roots. This is one of the features that distinguishes them from other plant types.

Figure 4-2 Sycamore Branch Cross Section. (Courtesy Carol King.)

In buds and the root zone of elongation, the meristematic tissue is the beginning of all the plant cells. The next, larger complex of meristematic tissue is the **cambium**, which is constantly renewing both phloem (outside of the cambium) and xylem (inside the cambium), in harmony with the plant's seasonal annual cycle. In dicots the system of vascular tissue is found near the outer edge. Since the new growth in the spring is larger than that in the fall, the annual production of new vascular rings is visible, with that year's growing condition reflected in the size of the ring. In monocots, the vascular tissue is scattered generally throughout the stem, and the phloem activity causes the vascular bundles to expand inside the trunk, gradually pushing the whole structure to a larger dimension.

Rays are a significant part of the woody picture for dicots, radiating from the center to the exterior like slicing a pie. Within the live tissue of the trunk, they are living cells which can store and transport food, and also help with the sealing off of damaged tissue. In the tree as a whole, they function as structural ties to the center of the trunk (tapering from the outside) and thus help stiffen the trunk and make it more stable.[12]

The few monocots that achieve the size and function of trees, such as palms and bamboo, have xylem and phloem joined in bundles rather than rings. Such arrangements can produce notable flexibility, but these plants also rely on fibrous roots systems for additional stability.

Plant Hormones and Tropisms. Plant hormones are chemicals which are produced in small quantities in specialized cells in one part of the plant and transported elsewhere to trigger responses in plant processes. These are also called plant growth regulators (or PGR), since that is what they do. They are fundamental to the functioning of all plants, but some of their effects are especially visible in the life of trees. They control the development of trunk and branch structure and facilitate root growth and leaf abscission, among many other functions. Usually, the plant response depends not so much on the quantity of the chemical as on the interaction with other plant hormones. The subject

12. Mattheck, C., Bethge, K., Weber, K. (2015). *The Body Language of Trees* (1st ed.). KS Druck GmbH.

is one of much study and considerable complexity. The following are the most significant ones for the purposes of Tree Stewards' knowledge, but it is not an exhaustive list.

Auxin was the first plant hormone identified by scientists. The major auxin in plants is indoleactic acid or IAA. It is primarily responsible for **apical dominance**, using cell elongation to promote the growth of the primary stem and branching structure as well as the development of new roots by translocation. It is produced mostly in the ends of the branches and trunks, then travels through the cells to where it is needed. In conjunction with cytokinins (see below), they also suppress lateral buds in the branch tissue below the tips, ensuring that water and nutrients are directed preferentially to the apical tissues. When apical dominance is broken, by cutting off the ends of trunks and branches, the mix of hormones is disturbed and the plant adapts with a new growth strategy. The implications for pruning will be seen in Chapter Nine.

Cytokinins stimulate cell division and differentiation, among other effects. They are produced in actively growing tissues, especially roots and fruits, whence they move to target locations in the xylem sap. As said above, the interaction of cytokinins and auxins keeps cells growing, dividing and differentiating in a healthy pattern.

Gibberellins stimulate stem and leaf growth by enhancing cell elongation and division. When garden vegetables go to flower and then bolt, this is an excess of gibberellin at work. They are also significant in signaling a seed embryo to break dormancy. They are largely produced in young roots and leaves. Gibberellins combined with auxins are also necessary for many plants to develop fruit. Gibberellins are part of a group of chemicals called Plant Growth Regulators (PGR) which can play a valuable role in urban tree maintenance by managing tree growth rates so as to reduce pruning needs and help the trees handle stress.

Abscissic Acid was originally, and erroneously, thought to be involved in bud dormancy and leaf abscission (leaf drop) in deciduous trees, hence the name. Actually, this hormone slows growth, which helps keep dormant seeds safe from premature germination and also helps the plant deal with drought by closing the leaf stomata guard cells.

Ethylene is a plant hormone which is also a gas. It is well known for its importance in the ripening of fruit. When you put part-ripe peaches in a paper bag, you are using ethylene gas to finish the ripening process. This hormone is produced in response to stress, during fruit ripening, as a part of programmed tissue death (leaf drop), and as a part of the natural death cycle of plants.

Tropisms: This is a term from the Greek (tropos = turn) for a plant response which involves organs deviating from a straight growth pattern in response to some kind of stimulus. The most famous of these is **phototropism**, which is the bending of plant stems toward sunlight or equivalent light source. This happens because the cells on the shady side of the stem elongate more than on the sunny side due to the combination of hormonal action. **Gravitropism** or **Geotropism** is the other effect of significance to Tree Stewards: this is how the stem of a plant knows to grow up and the root to grow down. It is not purely gravity, but also hormonal effect upon gravity-influenced cells. When you tie down an upright grapevine or rose cane on a horizontal support, you are tapping into both the gravitropism (which way is up?) and apical dominance (where are we going?) of the plant.

Particulars of Woody Plants versus Herbaceous

Woody plants are defined as perennials which retain a portion of their structure above ground all year long. If the plant is deciduous, it will still keep a live stem or trunk through winter, possibly in a dormant state. For a woody plant to survive external threats over years or even centuries, it must create some kind of a protective layer and wound response strategies. In order to thrive, the plant must continue to grow, adding bulk during the active season. Both of these processes mean additional weight, so the plant must also have a plan for supporting itself against the forces of gravity, wind, and water. The really delicate part of the equation is that the plant must also produce the energy to perform its principal function (from its perspective) of reproduction: cones, flowers, fruits and seeds all take considerable effort to achieve.

So **what is wood**, anyway? Technically, it is secondary xylem, meaning the tissue in rings (dicots) or bundles (monocots) from past seasons' growth. The tissue between the xylem tubes gradually thickens to wood in maturing trees and shrubs. Thus we get the solid, mostly dead heartwood giving dicots their solidity and strength, and also the diffuse pattern of tracheids and surrounding older vascular tissue which leads to the lightweight, flexible nature of monocots such as palm trees and bamboo.

The key materials in making wood are cellulose and lignin. **Cellulose** is a structural polysaccharide, a polymer made of glucose. It is the most abundant organic compound on Earth.[13] It is related to, but not the same as starch, which is a form of glucose essential to other parts of plant functioning. The particular structure of cellulose makes it an ideal material for cell walls: soft yet tough, it is also resistant to tension forces. **Lignin** is a stiff polymer which is key to the function of xylem tubes (think drinking straws). It anchors cellulose fibers and cements them together. In contrast to cellulose, it resists compression. It is the second most abundant natural polymer in the world.[2] The combination of the two is what makes it possible for woody plants to ascend to heights as they grow in girth.

Wood grain is the pattern or orientation of the growth of the secondary xylem and is generally spoken of in connection with lumber production, woodworking, and splitting for firewood. In these contexts, the xylem tubes are often referred to as fibers. Most tree species have a typical pattern, but this, and other wood properties, can be influenced by location and growth condition.[14]

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13. Reece, J.B., Urry, L.A., Cain, M.L., Wasserman, S.A., Minorsky, P.V., Jackson, R.B. (2011). *Biology* (9th ed.). Benjamin Cummings.
14. Bergman, R., et al. (2010). *Wood Handbook, FPL-GTR-190.* Forest Products Laboratory, US Dept of Agriculture Forest Service.

The simplest pattern is **straight grain**, when the fibers run parallel with the vertical axis of the tree or log. **diagonal grain** seen in the sawn wood is the same thing from the tree's perspective, but with the saw at an angle to the log's vertical axis. Trees with knots or other internal obstacles that divert the fibers produce an **irregular grain**, which can be attractive but tricky to work with. Wood with a pattern of small direction changes has a **wavy grain** (apparently more a genetic feature), while trees of many species may develop **spiral grain** (fibers winding around the tree either left- or right-handed) in response to adverse growing conditions involving sustained unequal stress.[15][16]

Finally, a number of species are fairly famous for tending to have **interlocked grain**, which means the fibers grow in one direction one year, then reverse direction the next, repeatedly. Among these are sycamore (*Platanus occidentalis*), blackgum (*Nyssa sylvatica*), sweetgum (*Liquidambar styraciflua*), and many elms (*Ulmus* spp).[17][18][19] Anyone who has ever tried to split any of them for firewood is only too familiar with the difficulties presented by these odd trees. But the pattern seems to be deliberate, hence we may surmise that the trees have a purpose. The wood from such trees can be used for applications which need a resistance to torque, for example. Perhaps the tree is aiming for a similar flexibility itself?

Another key element in the nature of wood is **density**. Greater density comes from a larger proportion of xylem and tracheid cells with thick walls and less void space.[20] Factors behind different densities are both genetic and environmental. The density of any particular species and tree is important for the harvested wood's commercial value and best use. Considering the living tree, greater density means more weight: is the tree then stronger and better able to withstand environmental stresses? The Bristlecone Pine is an interesting case in point. They grow slowly and live fantastically long, up to 5,000 years, in an environment with high drought and wind stress; and their wood is indeed very dense.[21] Yet there are environments where tree wood tends not to be dense: typically more favorable growing environments or moist tropical situations. Trees with rapid

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15. Gilman, E.F. (2012). *An Illustrated Guide to Pruning* (3rd ed.). Delmar.
16. Missouri University of Science and Technology Lecture Notes. Wood Grain. Accessed at http://classes.mst.edu/civeng120/lessons/wood/wod_grain/index.html 10/15/2017
17. Bergman, R., et al. (2010). *Wood Handbook, FPL-GTR-190*. Forest Products Laboratory, US Dept of Agriculture Forest Service.
18. Cassens D.L. (2007). Hardwood Lumber and Veneer Series: Elm. Purdue University Cooperative Extension.
19. Missouri University of Science and Technology Lecture Notes. (n.d.). *Wood Grain*. Missouri University of Science and Technology. http://classes.mst.edu/civeng120/lessons/wood/wod_grain/index.html
20. Bergman, R., et al. (2010). *Wood Handbook, FPL-GTR-190*. Forest Products Laboratory, US Dept of Agriculture Forest Service.
21. National Park Service. (n.d.). *Bristlecone Pines*. Great Basin National Park Nevada. https://www.nps.gov/grba/planyourvisit/identifying-bristlecone-pines.htm

growth habits (weeping willows, e.g.) generally have less dense wood so they can compete early on, but they are not usually long-lived.

Particulars of Trees versus Other Woodies

Woody plants include not just trees but shrubs, vines and ground covers. Vines and ground covers clearly have different survival strategies and don't seem to have potential to become trees. Shrubs are another matter, and indeed some woody species can be either trees or shrubs depending upon the variety, climate zone, and site circumstances.

The **definition of a tree** is a woody perennial plant, typically having a single stem or trunk, growing to a considerable height and having lateral branches at some distance from the ground. In contrast to a vine, it has a self-supporting structure. The Virginia Big Trees data base determines a tree by the minimum measurements to qualify for inclusion: 13 feet in height and trunk circumference of 9.5 inches, measured at 4.5 feet above the ground (DBH, or Diameter at Breast Height). Any species with mature measurements below these minimums can be considered a shrub. While this is not a definitive formula, it is a useful way to differentiate trees and shrubs. It is worth noting that in the horticultural world, some normally shrubby plants as wax myrtles and viburnums can be trained to a tree form with single stems and clearly defined crowns.

Roots

Roots are the foundation of a tree, literally and functionally. They anchor the plant (no small feat of engineering); bring in water and nutrients for the entire structure; and store food to allow the tree to survive harsh times such as winter. Roots are also a location for hormone synthesis and soil symbiosis. Although roots tend to be among the last parts of a tree most people think about, they are routinely the source of many problems in the urban landscape, mostly in the form of damage to infrastructure (sidewalks and building foundations) and from a safety aspect (trip hazards). When a tree's roots are compromised by poor soil conditions, excessive water or salts, or mechanical injury (just a short list), then the upper part of the tree will eventually pay the price.

The first thing a tree seed does upon germinating is to send out an absorbing root with lots of root hairs behind a little root cap. Keep in mind that the activity in the absorbing roots is paramount to the tree's overall success, and yet these roots can be measured in millimeters and require a microscope to see. These single-cell root hairs are the primary intake mechanism for water and minerals throughout the life of the tree: they are found in the zone behind the root cap and before the root starts to become woody. In terms of function, they are the primary source of water and minerals from the soil. As the root lengthens and enlarges, the root hair zone remains just behind the newest, small tip. Thus the **absorption roots** are found at the outskirts of the main roots, especially in the first several inches to foot of the soils surface, where water and nutrients are most available.

Trees and Sidewalks

When selecting street trees for sites that are largely paved, major consideration should be given to the expected root system depth as well as the tree's known tolerance for hypoxic conditions. Caution is warranted with most if not all maples, many ashes, and the American elm. Willows, poplars and silver maples are not just shallow rooted but can be destructively invasive near water or sewer pipes.[22][23]

In dicots, the first woody root to develop is generally a **tap root**, which extends downward to anchor the new tree. Most trees do not continue the tap root once the Lateral Roots begin to grow. In some species, this appears to be genetic, for example maples.[24] In others, this can be a response to oxygen, water and mineral levels in the soil horizons due to water saturation, extreme compaction or soil chemical concentrations.[25] In nurseries, tree seedlings usually have their tap roots cut in order to keep their root balls at a manageable size. There is some art to doing this properly: current research has looked at the better effect of air pruning young seedlings (containers with holes in the sides or soft fabric containers, for example) instead of mechanically chopping off the root end.[26]

Lateral roots grow at right angles to the trunk and ideally extend straight outwards, as seen in the photograph below by Dr. Ed Gilman of a good quality young root structure. The lateral roots provide the greatest stability to the tree and extend the greatest distance from the trunk: depending on the species, soil and site conditions, as much as 3

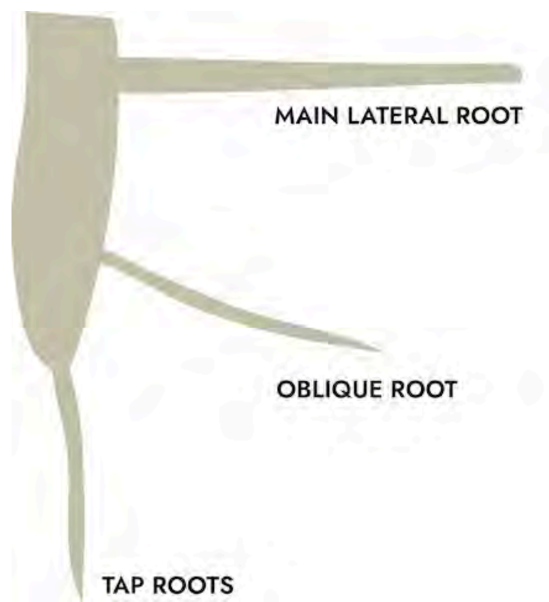

Figure 4-3 Ideal Root Arrangement

22. Harris, R.W., Clark, J.R., & Matheny, N.P. Arboriculture. Fourth Edition. Upper Saddle River NJ: Prentice Hall; 2004
23. Rindels, S. (1995). Sidewalks and Trees. *Iowa State Extension Horticulture and Home Pest News,* 3-31.
24. Gilman, E.F. (2017). *Tree Root Growth After Planting* [Power Point Presentation]. Hort.ifas.ufl.edu.
25. Urban, J. (2008). Up By Roots. International Society of Arboriculture.
26. Gilman, E.F. (2012). *An Illustrated Guide to Pruning* (3rd ed.). Delmar.

times the canopy spread.[27] In trying to estimate the full root zone of a mature tree, one should look at the trunk diameter as well as the conditions under which the tree has grown.

Sinker roots may be sent down from laterals for additional anchoring. There may also be **oblique roots** which originate in the root flare and create additional stability by growing at an angle downwards. If one visualizes shallow root structures as the foot of a wine glass on a dinner plate, then those with oblique roots are more like the foot of the wine glass on a plate set upon a shallow bowl.[28]

The trunk flare or root collar is the interface between the trunk and root system. This area functions as a shock absorber because of the annual growth rings that are up to twice the size of the annual growth rings further up the trunk. Since the root collar is supposed to be right at ground level (roots below and trunk above, with the flare visible), it is also an area of great importance to a tree's survival. The unfortunate practices of planting too deeply, piling mulch up around the trunk and using weed-eaters right around the base make tree failure due to trunk girdling all too common in urban settings.

Stem girdling roots are laterals which have chosen to grow too close to the trunk, or may be adventitious growths from a poorly organized root system. They may also be a legacy from container-grown problems with small circling roots which were left uncorrected. As the girdling root increases in diameter, it compresses the phloem and disrupts water flow in the xylem by breaking the cambium layer.

Generally, though, **most tree roots are in the top 3 to 6 feet of soil**, closer to 3 feet in the human environment. There are trees which do put down deep tap roots due to genetics, plus soil and water. Most oaks, walnuts and hickories fall in this category. Also, trees which survive in watery environments (bald cypress *(Taxodium distichum)*, for example) may have to put down fairly deep roots. The bald cypress uniquely has roots which protrude above the water or soil, probably to access oxygen.

27. Gilman, E.F. (2017). *Tree Root Growth After Planting* [Power Point Presentation]. Hort.ifas.ufl.edu.
28. Harris, R.W., Clark, J.R., Matheny, N.P. (2004). *Arboriculture* (4th ed.). Prentice Hall.

Figure 4-4, Bald Cypresses. (Courtesy Carol King)

Figure 4-5, Bald Cypress Knees. (Courtesy Carol King)

The **root plate** is the shallow complex of large roots, small roots and soil that adheres around the base of the trunk. It is usually three to five times the diameter of trunk. It is largely responsible for holding the trunk upright.[29][30] The root plate is associated with **buttress roots**, which shore up the trunk by extending the root flare without making it dense, as seen in the northern red oak at right below. Gothic cathedrals use this principle to spread the load of the roof across a wider span, as also with athletic stadiums.

Figure 4-6 Support arches at Virginia Tech Stadium. (Courtesy Carol King)

29. Gilman, E.F. (2012). *An Illustrated Guide to Pruning* (3rd ed.). Delmar.
30. Mattheck, C., Bethge, K., Weber, K. (2015). *The Body Language of Trees* (1st ed.). KS Druck GmbH.

Figure 4-7 Northern Red Oak Buttress Roots. (Courtesy Carol King)

Buttress roots act as stabilizer bars for the tree. They extend through the root plate (6 to 8 feet past the trunk flare, for many mature trees), then the roots decrease drastically in diameter (from 8 to 10 inches to 2 to 4 inches). This point of decrease is known as the **zone of rapid taper**. Root systems normally heave or fail at this zone. When trees fall over, the root plate is then visible: a failure of roots but also of the soil. This can happen from swampy conditions in a forest (Figure 4-8) or from wind stress when the roots are not stable (Figure 4-9).

Figure 4-8 Loblolly Pine in a Swampy Situation. (Courtesy Carol King)

Figure 4-9 Leaning Black Cherry Felled by Storm. (Courtesy Carol King)

One more type of root is worth watching for: **Adventitious Roots** may form when the trunk is buried in soil or mulch. They are less well attached than the roots which develop naturally in the course of the tree's growth, and they will keep some water and nutrients from the lateral roots which are in root system proper.

Here is an interesting question: **Do dicot roots have rings?** The answer is yes, which makes sense if one considers that the vascular system runs the length and breadth of the tree. This means the water which enters the xylem in the roots must connect to that which feeds the smallest leaf, and similarly for the phloem. However, the wood of the roots is not subject to the same stresses as that above ground and does not develop as robustly. They have more thin-walled live cells than do trunks, and they do not have pith. They are thus less cold hardy than woody tissue aboveground. Also, roots are more likely to encounter obstacles (rocks, sidewalks, patches of nutrient or water discontinuity) and have to grow around them.

Regarding monocots, the vascular system has to include the roots in some mechanically consistent way, which means that the many distributed vascular bundles can only form a lot of small root connections from the base of the trunk, without a root flare or woody branching. This is called **a root-stem transition zone**. Such trees have an entirely fibrous root system which operates at a shallow level: but the trunks are lighter and more flexible because they do not have the weight of the dicot annual ring-layering.[31][32][33][34]

Identification by Roots: Roots are not usually a help to the EMG Tree Steward trying to identify a species of tree. First, they are often not easily visible. However, a shallow rooting pattern, especially in good soil, may be somewhat of a clue. Plus, there may be some information to be gleaned: color (yellow for white mulberry), or odor (root beer for sassafras), and odd growth (bald cypress knees, for example).

Any current discussion of roots is not complete without the **rhizosphere.** Definition: the region of soil that surrounds, and is affected by, plant roots.[35] It includes not only all the important soil constituents (see Chapter Six) but also the activity of the small fungi, known as **mycorrhizae** which live symbiotically with the tree roots. These fungi combine with the small absorption roots, sending hypha into and between the root cells to enhance the roots' intake of water and minerals. In return, the fungi get some of the food the leaves have made, including sugars, as well as keeping some of their soil harvest for themselves. Root turnover and root exudates play an important role in carbon cycling, soil chemistry and food web nourishment.

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31. Ali, A.D., Burkhart, L. Jr. (2017). Palms: Woody Giants of the Monocots. *Arborist News.* 26(4): 12-20
32. Capon, B. (1990). *Botany for Gardeners*. Timber Press.
33. Harris, R.W., Clark, J.R., Matheny, N.P. (2004). *Arboriculture* (4th ed.). Prentice Hall.
34. Reece, J.B., Urry, L.A., Cain, M.L., Wasserman, S.A., Minorsky, P.V., Jackson, R.B. (2011). *Biology* (9th ed.). Benjamin Cummings.
35. Allaby, M. (2015). *The Dictionary of Science for Gardeners*. Timber Press.

While we are in the Rhizosphere, this is a good time discuss an interesting function by which plants seek to obtain an advantage for their survival and reproduction. **Allelopathy** "involves a plant's secretion of biochemical materials into the environment to inhibit germination or growth of surrounding vegetation." The Black Walnut (*Juglans nigra)* is the best known example, observed back even to Roman times. The chemical juglone is found in all parts of the black walnut tree, but its effect is mainly from roots and decomposing leaves, killing off any of the selected plants which cannot tolerate the chemical. There are other trees which produce allelopathic chemicals to a lesser degree, including hackberries (*Celtis* spp), sycamore (*Platanus occidentalis*) and black cherry (*Prunus serotina*).[36]

Trunks and Branches

Trunk and Branches are the next and probably most studied element of dicot trees. This is where we see wounds, pest damage, and overall tree failure when the structure is not up to the load being placed upon it. This also where we see the bark providing protection against temperature extremes and invasion by pests.

Compartmentalization is a process by which a dicot tree sets boundaries around injured or decayed wood so as to protect healthy remaining wood from disease-causing organisms. The most broadly accepted model (though not the only one) is modified from that proposed in the 1980s by Dr. Alex Shigo: Compartmentalization of Damage in Trees or CODIT. It is complex and involves both chemical and physical steps. When the tree is wounded, air rushes into the vascular system, followed by bacteria and fungi. If the wound is caused by branch removal, severing part of the vascular system, then sudden auxin loss may also be a factor.[37][38]

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36. Appleton, B. (2015). *The Walnut Tree: Allelopathic and Tolerant Plants.* VCE Publication 430-021.
37. Dujesiefken, D., Liese, W. (2015). *The CODIT Principle: Implications for Best Practices*. International Society of Arboriculture.
38. Gilman, E.F. (2012). *An Illustrated Guide to Pruning* (3rd ed.). Delmar.

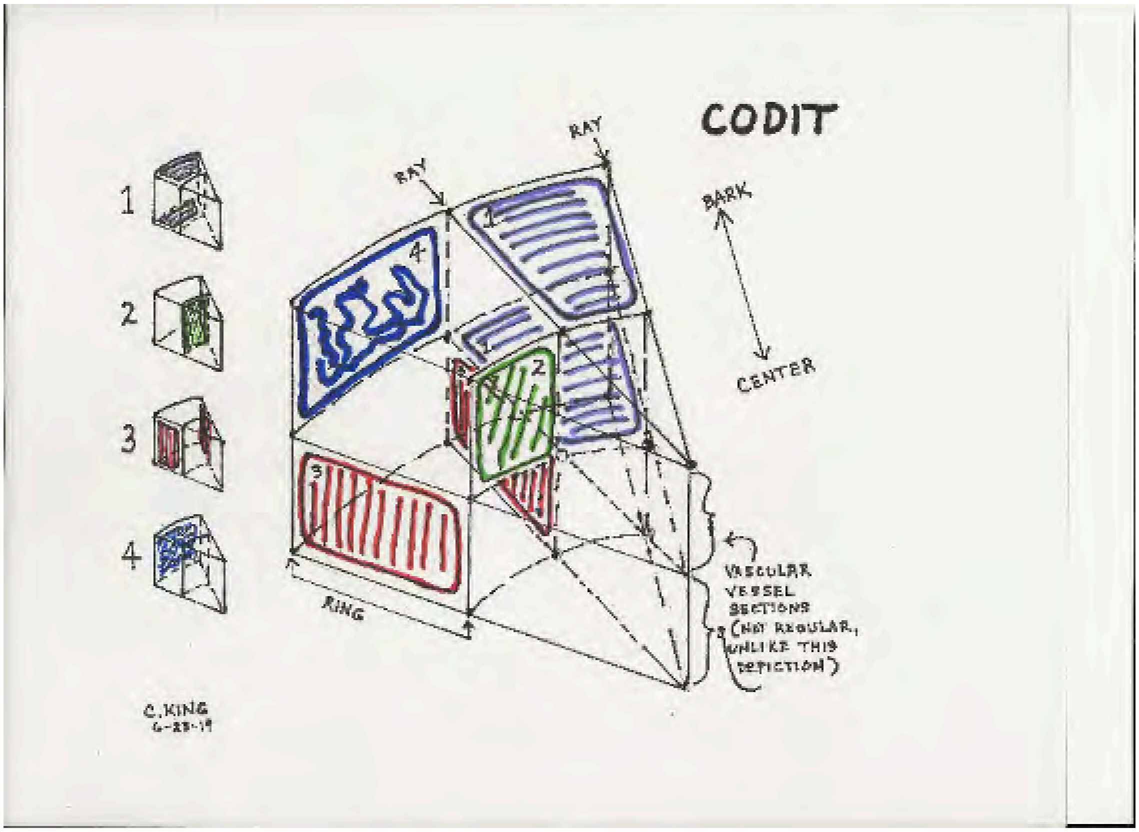

Figure 4-10 Simplified CODIT View. (Courtesy Carol King.)

In the CODIT model, the tree then uses stored energy (at a cost to its other functions) to (1) plug the vessels above and below the damage, (2) cause the live cells in the ring lying between the injury and the center of the trunk to produce chemicals toxic to fungi, (3) stiffen the rays on either side of the wound with a wax-like chemical and, finally, (4) form a barrier zone from the cambium along the outermost growth ring at the time of the wound. This last barrier will remain in that ring but can spread around in the ring over time. The four walls are listed in increasing order of strength, hence it is easier for disease to spread vertically than to break through into the interior, across the rays or through the outer wall.

- Wall 1: stops upward movement of decay. Weakest Wall.
- Wall 2: stops inward movement of decay.
- Wall 3: stops lateral spread of decay.
- Wall 4: new growth ring. Strongest wall chemically but weakest structurally because Walls 1 to 3 usually result in a pocket of decay.

Not all trees can succeed in erecting all four walls. Trees under stress have less energy to spare, and some wounds are too severe to fully enclose. The process walls off any sugars stored in the wounded zone, and the tree also loses a portion of its productive tissue forever. Also, Wall 4 is chemically strong but structurally brittle, so may subsequently crack if stressed in a way the tree isn't used to.[39]

Trees vary in their ability to compartmentalize, both individually based on vitality and as species. This should be one of the criteria in selecting trees for urban street sites or high-traffic areas.

Reaction wood. The main component of dicot trunks and branches is the wood formed by the annual rings, which are influenced by genetics, weather, and the productivity of the tree's internal processes (water, food, and so on). Trees are able to react to tropisms and constant wind load by forming reaction wood. Reaction wood is an increase in cellulose or lignin between annual growth rings on one side of the branch or trunk. There are two types of reaction wood. The function of **Tension wood** is to 'pull up' the branch or tug on the trunk. This tissue has a larger component of cellulose (which resists tension but doesn't handle compression well). **Compression wood** has a complementary role. Its function is to 'push up' the branch or trunk. It has a larger portion of lignin, which resists compression but doesn't handle tension well.[40] Figure 4-11 shows compression on the underside of a pine branch. The combined picture of a stable tree with basic wood plus compression and tension wood helps us understand why trees can survive many years in a tough spot, yet fail when a sudden storm brings pressure loads from an unexpected direction.

Figure 4-11 Compression Wood in Pine Branch. (Courtesy Carol King)

39. Gilman, E.F. (2012). *An Illustrated Guide to Pruning* (3rd ed.). Delmar.
40. Mattheck, C., Bethge, K., Weber, K. (2015). *The Body Language of Trees.* (1st ed.). KS Druck GmbH.

The **bark** is one of the three preset defense barriers dicot trees have developed to aid in longevity. The others are: **pith**, which is central nonvascular tissue inside of the vascular ring system, and the **branch attachment system**, composed of the branch bark ridge, branch collar, branch protection zones and other aspects of the tissue complex where the branch joins the trunk. The former performs various specialized functions while the latter supports the branch and tries to keep branch infection from reaching the trunk.[41][42]

The **trunk** is the main vertical weight-bearing mechanism for the entire tree. From an engineering perspective, a single straight shaft would be more efficient, but the tree would probably not be able to find room for enough leaves to support itself. So the branching function, and particularly the way the branches attach to the trunk, are critical to the development of trees as we know them (again, dicots). The attachment must provide a ready flow of the vascular system yet also support the ever-increasing weight of the branch. The patterns of xylem growth show layers growing around the attachment point and stiffening into wood as the trunk and branch.

The diagrams in Figure 4-12 show how the vascular system goes up the trunk into the lower side of the branch. Then tubes on the upper side of the branch bend round and continue on up the trunk. At the junctures of trunk and branch the layers from each alternate as the tree grows. The right diagram shows one of the disadvantages of a narrow branch angle, trapping wood and bark into a divisive wedge which can lead to problems later.

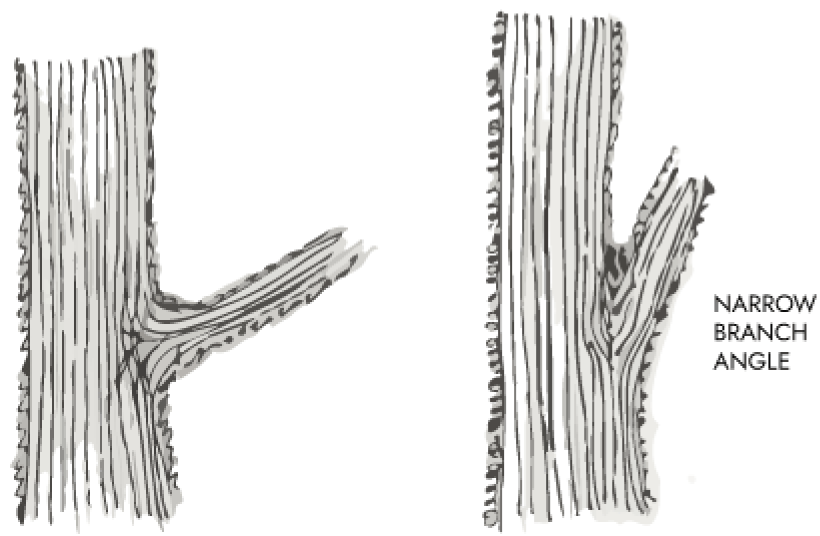

Figure 4-12, Branch Attachments. (Courtesy Carol King.)

41. Gilman, E.F. (2012). *An Illustrated Guide to Pruning* (3rd ed.). Delmar.
42. Reece, J.B., Urry, L.A., Cain, M.L., Wasserman, S.A., Minorsky, P.V., Jackson, R.B. (2011). *Biology* (9th ed.). Benjamin Cummings.

There will be a **branch collar** at the base of the branch where the wood makes an abrupt turn downward and forms overlapping layers with the trunk xylem. If the branch angle is proper (as at left above) this will make a zone of especially strong chemical and physical support. In order for this process to work, the branch must be smaller in diameter than the trunk; if they are the same size, neither one can encompass the other's xylem, so the union will not work well. So, not only are co-dominant stems mechanically weak, but biologically weak as well. The relative size of branch and trunk is called **aspect ratio**. 1:3 is considered ideal for strength. Anything larger (1:2 or 1:1) is not as stable an attachment.[43][44]

There is one more consideration in branch health: the **timing of the formation of the branch**. If a branch develops at a natural time in the tree's life cycle, the start of the attachment point will be deep within the trunk when both have achieved proper size. By contrast, a later shoot that arises from a pruning or other cut will have a much shallower level of attachment and be inherently weaker. **Water sprouts** are a case in point due to the fact that that are vertical, fast growers and usually form at perpendicular angles to the parent branch. Storms, pests, and physical injuries are some of the causes of sprouts.

Figures 4-13 and 4-14 show good development of an original branch in a red maple and an older red maple with a proper branch below some new ones which have grown from the cambium around a cut-off branch above it. The newer branches will be weakly attached and fragile until the tree grows around that point.

43. Gilman, E.F. (2012). An Illustrated Guide to Pruning (3rd ed.). Delmar.
44. Harris, R.W., Clark, J.R., Matheny, N.P. (2004). *Arboriculture* (4th ed.). Prentice Hall.

Figure 4-13 Good Branch Attachment. (Courtesy Carol King)

Figure 4-14 New Branch Attachment. (Courtesy Carol King)

Crown Form is the essential shape of the tree. The words crown and canopy are often used interchangeably, but there is a difference. Crown is the totality of the leaves and branches measured from the lowest branch to the topmost growth. Canopy is the mass of leaves and small twigs within the crown.[45] Excurrent crowns feature a dominant central leader with many horizontal branches. Decurrent crowns have several codominant branches, leading to a rounded or flat-topped appearance. An individual tree's genetics, influenced by its environment, will often produce characteristic patterns identifiable from a distance.

Branch Structure is an important component of tree strength and health. We have seen that a wider angle of attachment is better mechanically, plus it can also give more leaves a chance to get sunlight. The genetic branching pattern is one key consideration in tree selection, particularly if it is to be a lone landscape tree. The environment in which the tree is growing may require extra attention to the balance between branches and trunk: this is particularly true for trees in the open (wider, lower branches) and those in crowded or highly trafficked areas (narrower branches and trunks cleared higher).

Hollow trunks in dicots are caused by some kind of disease or wound, but the tree may be able to survive nonetheless. Assuming the infection has been contained, the tree's vascular system is on the outside so can function perfectly well. The tree will have less structural bulk and weight, but if the cylinder wall is intact, it is mechanically sound. Dr. Gilman advises that "a tree trunk can loose [sic] up to about 70% of its wood cross-sectional area in the center and still retain about two-thirds of its strength provided there are no openings in the trunk."[46]Some trees are also prone to having hollow trunks, such as older forest-grown basswoods (*Tilia americana)*.[47] Turning briefly to the monocots, the structure lends itself to creating a hollow, flexible cylinder, as in bamboo.

Identifying Trees by Trunks: There are three aspects to consider: structural patterns, bark and twigs.

Structural patterns have been discussed earlier in this chapter, but it is worth thinking about your first impression when you look at the tree. Is the trunk straight? How tall compared to its girth? Is there a tendency to multiple leaders? Are the branch angles narrow, more level, or even drooping? You might even observe a tendency to sucker, which could be a clue.

Bark is often hard to identify, but certain trees have very distinctive textures and colors: this can even be the principal ID feature, as in American persimmon (*Diospyros virginiana*) whose dark, blocky bark can be seen as almost charcoal-like; the smooth blue-gray bark of the American beech (*Fagus grandifolia*) pictured in Chapter Three; and the corky 'warts' which distinguish the hackberries (*Celtis* spp).

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45. Harris, R.W., Clark, J.R., Matheny, N.P. (2004). *Arboriculture* (4th ed.). Prentice Hall.
46. Gilman, E. F. *Landscape Plants: Tree Structure Basics: Structural Defects: Hollows and Cavities.* University of Florida Extension. http://hort.ifas.ufl.edu/woody/Cavity.shtml
47. Iowa State University Forestry Extension. (n.d.) *Tree Identification: American Basswood.* Iowa State University Forestry Extension. https://www.extension.iastate.edu/forestry/iowa_trees/trees/basswood.html

Twigs are specifically the last year's growth in a branch. Comparing twigs with growth from previous years can help estimate a young tree's vigor. In addition, depending on the species, twigs and young branches may have special ID features. These are often of greatest importance in the winter.

As an aid to understanding the parts of a winter twig, Fig 4-15 may be helpful. Not all twigs have all the features shown, and there is considerable variety in the actual appearance of each feature among different species.

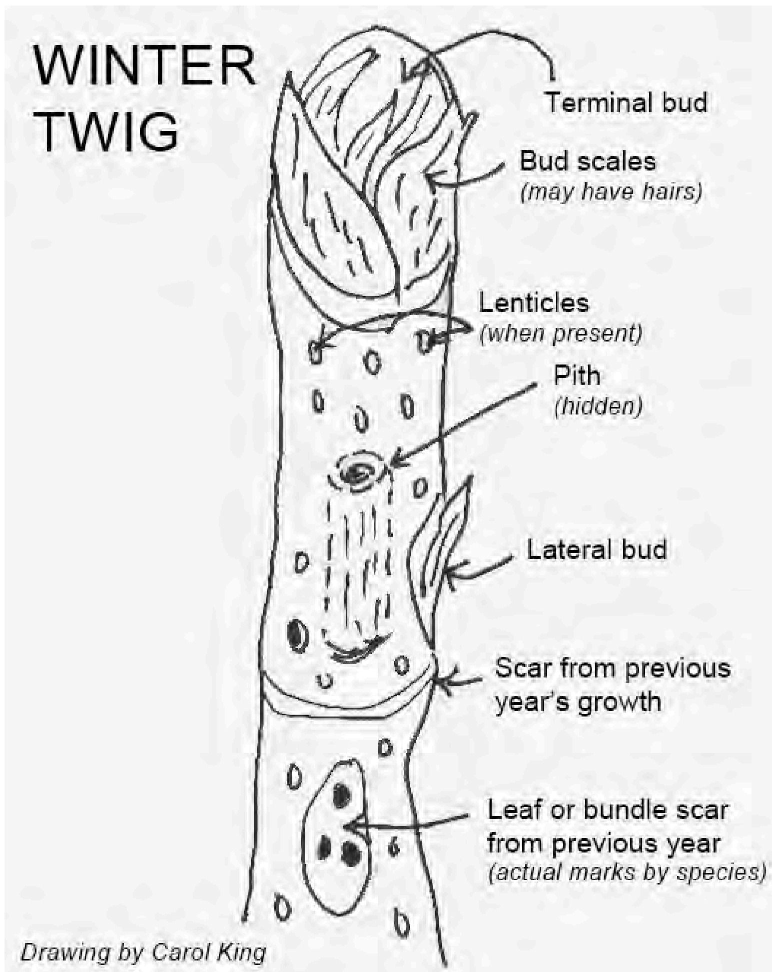

Figure 4-15 Generalized Winter Twig. (Courtesy Carol King)

Twig color and relative size are the first things to notice, then the **pattern of buds**. Buds may be located at the actual end of the twig (**end bud true**) or offset from the very end of the twig (**end bud false**). They may have **scales** (seen with a hand lens). Tthe shape may be distinctive: beech buds (*Fagus grandifolia)* are long and narrow, like a paint brush. Tulip poplar buds (*Liriodenron tulipifera)* look like a duck's bill, and magnolia buds are typically fuzzy. Or their arrangement may be informative: oaks generally have clustered end buds.

Figure 4-16 End Bud True: Copper Beech. (Courtesy Carol King)

Figure 4-17 End Bud False: Honey Locust. (Courtesy Carol King)

Figure 4-18 Beech Bud. (Courtesy Carol King)

Figure 4-19 Tulip Poplar Bud. (Courtesy Carol King)

Figure 4-20 Saucer Magnolia Bud. (Courtesy Carol King)

Two further twig features may also be useful in winter ID.

Leaf or bundle scars are what is left on the twig after the leaves have fallen. The pattern of the vascular system connections to those leaves is highly distinctive and can tell, for example, the difference between the shield shape of a green ash (*Fraxinus pennsylvanica*) and the smiley face of a white ash (*F. americana).*

Figure 4-21 Green Ash. (Courtesy Carol King)

Figure 4-22 White Ash. (Courtesy Carol King)

Figure 4-23 Black Walnut Pith (Courtesy Carol King)

Pith is the center of the twig and is one of the last ID features consulted, as most are pretty much straight cylinders of woody tissue. However, for those trees with some distinctive pith, this may be worth checking. One example is the black walnut (*Juglans nigra)*, which has an unusual dark brown, chambered pith. An unusual feature found in some trees can be helpful: **wings**. These may be distinctive corky growth in the twigs and young branches of the winged elm (*Ulmus alata*) and juvenile sweetgums (*Liquidambar styraciflua*). Note that there are other sorts of wings found on trees and shrubs: this word also describes the green leafy tissue along racemes of the winged sumac (*Rhus copallina),* for example.

Figure 4-24 Winged Elm. (Courtesy Carol King)

Figure 4-25 Winged Sumac. (Courtesy Carol King)

Crown and Leaves

The **crown** can be indicative of species at a distance: oval, round, pyramidal, weeping, taller than broad or broader than tall. Many tree field guides will have a sketch of the tree's normal silhouette or a description of the geometric shape (as a lone tree).

Figure 4-26 Ginkgo vs Live Oak (Courtesy Carol King)

Leaves are arranged on their stems in **alternate, opposite or whorled** patterns. This is genetic, although variants may occur within a genus norm (as the *Cornus alternifolia* or alternate-leafed dogwood differs from its more common opposite leafed relatives *Cornus florida* et al). Whorls are much rarer but are a wonderful ID clue if found. The next most important distinction among leaves is whether they are **simple or compound**. This is a matter of looking for a bud in the place where the leaf or leaflet joins the next part of the structure (known as an **axil**). A leaf has a bud at that axil: it might be a swelling in the stem or a very obvious pointy bud, but there is an indication that this is a node. If you do not see such a node, go up to the next juncture, and so on.

Figure 4-27 Alternate, Simple: Stewartia. (Courtesy Carol King)

Figure 4-28 Opposite, Simple: Dogwood. (Courtesy Carol King)

Figure 4-29 Compound Leaf Goldenrain Tree. (Courtesy Carol King)

The example above of a compound leaf reveals another of the many variations possible among leaves. In this case, the entire 'frond' to the right is one leaf (bud at the axillary join with the twig), and the leaves are alternate. But the leaflets that make up the leaf are arranged oppositely. The devil is often in the details!

Beyond these first differentiations, the variety of possible leaves becomes very complex. Any competent field guide will have an introductory section with illustrations of **leaf shapes, margins and veination** (the pattern of how the veins are formed in the leaf).

Reproductive Systems

Generally, plants aim to reproduce themselves, so their strategies for making seeds are usually among the most varied and interesting of their behaviors. Flowers and fruits are only available for view in specific parts of the growing season (cones possibly longer), but when seen they can give particular insight into that tree's larger pedigree. A good example is the rose family (Rosaceae), including apples, cherries and hawthorns, with sepals and petals in open groups of five. Chapter Five will provide much more detail on tree family relationships.

For **gymnosperms**, this means creating cones both male and female, which with wind pollination produce seeds. No flowers or fruit is needed, but the pollination process is quite wasteful of resources: witness the deluge of pine pollen every spring. For species identification, it is useful to know how many years the cones stay on the tree, as well as their size, shape and placement.

Ginkgos are not in either category, but rather a throwback to 190 million years ago, when there were many species of them all over the then-continents. Ginkgos have broad leaves but their 'fruits' are actually naked seeds with an outer fleshy layer, no flower involved. They differ from the gymnosperms in that the sperm swim a short distance in the fertilization process, which is an evolutionary throwback to ferns and mosses.[48]

Angiosperms are defined as "flowering plants" so this is an extremely broad topic. All angiosperm trees have flowers, though they may be very small and unnoticed. The American elm (*Ulmus americana)* has tiny flowers leading to small, flat green fruits with seeds in the very early spring. Many people do not even realize the elms even have flowers. In contrast, there are full scale festivals to celebrate the cherry blossoms just a month or so later. If we value our trees, we will understand their cycles and needs and plan accordingly.

A last word about tree identification: There are three main parts to the task. The most significant is surely to observe and be able to recognize the character and features of that species and perhaps even that individual tree. The next part is to learn about, or discover, relationships to other living things related to that species or particular tree. This means noting or looking for the other plants which typically grow well in company, as well as insects and birds which rely on those trees: in effect, what community is this tree part of? Lastly, there is knowing its accepted name: first, so you can communicate with other people about it; second, that you may learn something from the name itself. Common names may refer to a characteristic, such as the eastern red cedar's rusty, shredded bark. Then the botanical name tells you where it falls in a taxonomic hierarchy: *Juniperus virginiana* is not even remotely a cedar, but actually a juniper.

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48. Crane, P. (2013). *Ginkgo: The Tree that Time Forgot*. Yale University Press.

There is a human response to the naming of a tree: Nancy Ross Hugo in Seeing Trees says "We take psychological possession of the things we can recognize. To me, getting to know a tree is like getting to know a human being—the more you know, the more the relationship deepens, and a person's (or tree's) capacity to surprise never ends."[49]

Connections between Tree Physiology and External Factors

One of the most useful things to know about a tree species is where it originally came from, known as **provenance**. For example, Mediterranean trees tend to be tolerant of heat and drought, meaning that olives tend to do well in the US West, and their colder-hardy relatives (ash and fringe tree) have been good urban trees in the dry overbuilt cities of the temperate East and Midwest (at least until the emerald ash borer, another topic). Tropical trees grow without much seasonal variation and may deal with more abundant moisture, which may be reflected in root systems and wood grain. The soil of origin may hold clues to the preference for a preferred pH range, nutrient needs, and useful companion plants. As with the discussion of C3/C4/CAM photosynthesis, knowledge of the evolutionary conditions which produced a particular tree may help predict success in a challenging situation. It is also important to consider the factors which make native trees develop where they are. These factors include the habitat interface with insects and other animals (which may change under urban stress) and sun angle at latitude (which doesn't change).

One of the big divides in trees is how they cope with **freezing temperatures**. In live xylem (trees not dormant or otherwise protected), freezing water can introduce air bubbles. **Cavitation** is the descriptive name for air bubbles in the conducting cells of the vascular system and can be very injurious to the tree.[50] The inability to protect from freezing limits the range of many plant species.

Trees in Groves and Forests. Most trees prefer to grow in company, at least in groves if not in forests. If they start out as small shoots together, or as shoots among a group of more mature trees, their stems will adjust to each other to share the available resources. Sun seekers will be thinner, straighter and taller as they reach for the sky.[51] Understory trees fill in and will stay relatively small, even shrubby depending on the species. The roots will tend to grow into a community arrangement with their attendant fungi. One result of a grove/forest growth pattern is **collective stability** in adverse weather conditions.

Alternatively**, Lone Trees,** which are set out to grow in the open, by themselves, will have broader canopies and thicker trunks than their forest cousins. Each such tree has to arrange for its own stability in wind and storms, meaning people must take care not to injure its naturally wide-spreading

49. Hugo, N.R. (2011). *Seeing Trees.* Timber Press.
50. Gilman, E.F. (2012). *An Illustrated Guide to Pruning* (3rd ed.). Delmar.
51. Gilman, E.F. (2012). *An Illustrated Guide to Pruning* (3rd ed.). Delmar.

roots. If the lone tree is in a confined landscape, then extra care is needed to give this tree a chance. Understory trees planted in the open face a double challenge: adapting to more sun than they evolved for, and living an unnaturally solitary life. Plant breeders do make a wide variety of cultivars of particular favorites (for example redbud, *Cercis* spp), so it is worth researching the basic tree type and what differences the breeder has made. In general, maintenance programs for lone trees are more demanding, and more necessary, than for those in groves and forests.

Nursery trees grow in circumstances more like the lone tree, even though there may be a lot of them in one location. Either they are in containers or, if in the ground, their roots will be cut before they are dug up in order to have a manageable size root ball. Best practices call for making a part of this cut ahead of time so the cut roots can form new absorption roots within the ball: but the tree is still all alone. It will have to make up the lost root spread before it can really function properly in the landscape.

In a natural setting or urban park/large garden, a properly chosen tree's genetic longevity should give time for it to adjust to being transplanted. However, the paved city environment and common street tree practices mean that even well-chosen trees often don't have enough space and are subject to life-limiting threats such as poor soil, lack of water and the probability of mechanical assault (weedeaters, cars, etc). There are trees which are better suited to harsh conditions than others, and proper planning and care will also improve the odds of tree survival. Hence, the urban tree lover needs to (1) select wisely, (2) plant good quality nursery stock (3) in enough space or engineered soil, and (4) follow a plan of extended care sufficient to give the tree a chance to survive into maturity.[52] If such urban trees can be planted so their roots can mingle and their trunks and canopies can be mutually supportive, so much the better.

Figure 4-29 Urban Trees in a Grove. (Courtesy Carol King)

52. Urban, J. (2008). *Up By Roots*. International Society of Arboriculture.

Finally, one last word about how it all fits together. The analogy of a baseball diamond is used here by permission of arborist Renee Frith, who has this explanation: If you (the tree) are the batter, you will need the bat, the ball, fast legs and all your skill to get to first base; then you will need energy reserves from photosynthesis to take you to second base; you will need to be properly hydrated to get to third base (especially if you steal it); and then if all goes well, you achieve your object and score the run by reproducing.

Happy Trees to All!

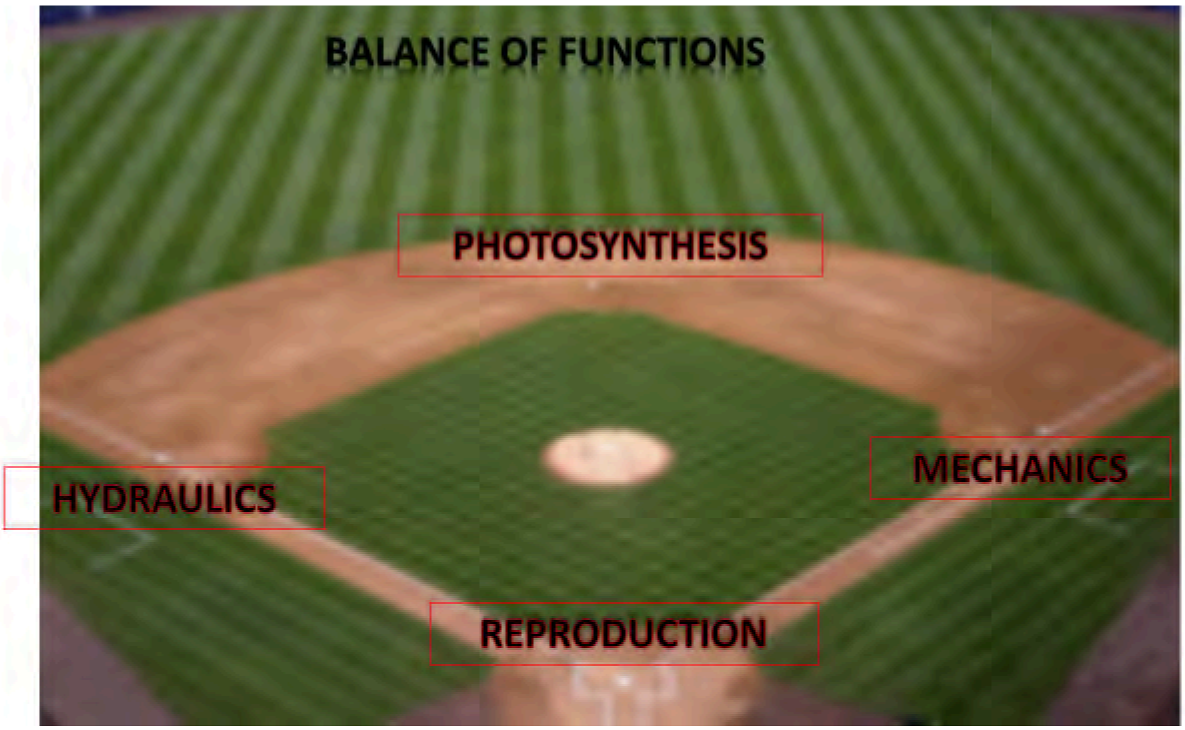

Figure 4-30 How Trees Play Baseball. (Courtesy Renee Frith)

Review Questions

1. What is the connection between photosynthesis, respiration and transpiration?
2. Look around your home, garden, school or office: are there any C4 or CAM plants?
3. Find a wooden board or table with visible rings (pine is great). Can you tell which direction was the bark/outer edge?

4. Where are auxins made, and what are some of the things they do?
5. Why are adventitious roots in dicot trees undesirable?
6. Describe a good branch attachment structure.
7. If a palm tree trunk is injured, can the tree compartmentalize the wound?
8. In most Virginia settings, what are two advantages of planting trees in small groves versus alone in the landscape?

CHAPTER 5: TREE TAXONOMY, IDENTIFICATION, AND MEASUREMENT

"The wonder is that we can see these trees and not wonder more." – Ralph Waldo Emerson

Chapter Contents:

Introduction

There are many ways of identifying trees. This chapter describes dichotomous keys, the taxonomy of trees, and tree families. Dichotomous keys are a scientific method where the user is led through a series of choices that ends with the selection of a specific tree. Trees may be understood in terms of where they are located in the hierarchical categorization of living things (taxonomy). Tree families share certain common characteristics: understanding those characteristics enables the user to more readily identify specific trees. As later discussed in Chapters Eight and Ten, tree identification is particularly important for Tree Stewards because it is an essential element of selecting the right tree for the right place and a critical aspect of determining tree disorders, associated causal agents, and appropriate courses of action.

The chapter concludes with descriptions of the National and Virginia Big Tree Programs and provides guidelines for measuring trees.

Learning Objectives

1. Understand the use of dichotomous keys to identify trees.
2. Be familiar with the taxonomical approach for classifying plants and the points at which major changes occurred in plant characteristics.
3. Have an awareness of the concept and significance of tree families.
4. Understand the use of observable characteristics as quick identification aids for trees.
5. Be familiar with the Big Tree program at the national and state levels.
6. Identify the three dimensions of trees and know how to measure them.

REVIEW: VCE Master Gardener Handbook 2015 (9/18 update)

- Chapter 2: Basic Botany, Taxonomy: Biological Classification, Anatomy: Plant Parts and Functions
- Chapter 16: Woody Landscape Plants, Plant Nomenclature, Woody Plant Categories

Dichotomous Keys

A dichotomous key is a scientific tool for identifying trees. Dichotomous keys also exist for identifying other items in the natural world such as various types of living things or even rocks. Any dichotomous key leads the user through a series of steps where at each step the user must select among two choices. A common first step for trees is:

- Leaves are needle or scale-like, go to x
- Leaves are broad and flat, go to y

The selection at each step leads to a designated next step ultimately resulting in the identification of the tree.

There is no single dichotomous key for trees. Keys may be simple or complicated. Some keys, such as the one in *Tree Finder: A Manual for the Identification of Trees by Their Leaves*, are based solely on characteristics of the leaves.[1] Others may include traits such as bark, twigs, leaf scars, buds, and

1. Basic Biology. (May 21, 2015). *Basal Angiosperms*. https://basicbiology.net/plants/angiosperms/basal-angiosperms

seed production (size and shape of cones, acorns, etc.). The power of any key is only as good as the set of plants that it includes. However, in general, the more trees included in the key, the more complicated the key.

The ability to correctly identify a tree based on a dichotomous key is limited by the accuracy of the user's observations, the ability of the user to understand the choices posed by the key, the season of the year (a key based on leaves is not very useful for identification in winter), and the scope of the key. The tree of interest may not be included. For example, the dichotomous key in Common Native Trees of Virginia will not help identify a zelkova.[2] While zelkovas are increasingly planted in Virginia, they are native to East Asia and thus not included in a book on native Virginia trees.

Taxonomy of Trees

The various types of trees may be understood in terms of the related groupings (taxa) to which they belong and the similar characteristics that are shared within their group. All living things are classified into hierarchical categories based on shared characteristics. The contemporary method for classifying living things into taxonomies was developed by Carl Linnaeus in the 1700s. At that time, living things were grouped based on observable forms and structures. Over time classifications have changed as knowledge and scientific tools change. DNA analysis, chromosome numbers, isozymes (proteins produced by particular genes), and nucleic acids sequences are examples of new techniques used in more recent years. Different taxonomists may draw different conclusions. Taxonomies from different sources may not completely agree in their terminology. Taxonomy information in this section is based on the classification scheme for plants as used by the US Department of Agriculture (USDA) Plant Database.[3] See Table 5-1.

The utility of the various taxonomy levels varies with the kingdom. For example, when studying insects significant characteristics are captured in orders.

Academic researchers deal with division, class, and order. These classification levels are most frequently impacted by the use of current scientific methods. For practical applications the focus tends to be on the family level and below. In contrast to division, class, and order, plant families are quite stable.[4] Families are important in gardening because plants within a given family generally share comparable cultural requirements and similar insect and disease problems. Pest management and cultural techniques are frequently discussed at the family level. Plants within

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2. Virginia Department of Forestry (2016). *Common Native Trees of Virginia Tree Identification Guide.* Virginia Department of Forestry Publication P00026. www.dof.virginia.gov
3. United States Department of Agriculture (USDA) (n.d.). *PLANTS Database.* USDA Natural Resource Conservation Service. https://plants.usda.gov/java/
4. Ware, S. (January 22, 2020). *Taxonomy of Trees* [Powerpoint]. Peninsula Tree Steward Class.

some families may share common characteristics in appearance, leaf shape, seed form and structure, and growth habit. Other families may exhibit much more diversity. The Digital Atlas of Virginia Flora primarily focuses on the family level and below.[5]

Table 5-1 Taxonomy schema for plants

Classification Division	Distinguishing Characteristics
Kingdom	Structural Organization (Single cell/multi-cell, whether nucleus is enclosed in a membrane) Method of Nutrition (Absorb, photosynthesize, or ingest food)
Subkingdom	Whether plants have a vascular system or not
Superdivision	Whether plants produce seeds or spores
Division	Whether seeds are naked (non-flowering) or encased (flowering)
Class	Areas of commonality based on important, more detailed, similarities within subsets of each division.
Subclass	Further sub setting into groups with like characteristics.
Order	Further sub setting into groups with like characteristics. All names for orders end in "ales."
Family	A group of individuals directly related by descent from at least one common ancestor. (Dictionary of Forestry [6]) Based on commonality of distinguishing characteristics especially those inherent in their reproductive structures (flowers, fruit, seed). All names for plant families end in "aceae."
Genus	Groupings based on commonality in fundamental traits such as flowers, fruits and sometimes, roots, stems, buds and leaves. Members of a given genus have more characteristics in common with each other than other groupings within the same family.
Species	A group of similar interbreeding individuals sharing a common morphology (external and internal structure of plants), physiology and reproductive process. There is generally a sterility barrier between species or at least reduced fertility in interspecies hybrids. (Dictionary of Forestry [7])

A note about the terms subkingdom and superdivision in Table 5-1: A common taxonomy categorization hierarchy is kingdom, phylum, division. Instead of phylum this chapter uses subkingdom and superdivision because it is at those levels that basic plant characteristics diverge.

5. Virginia Botanical Association. (2017). *Digital Atlas of Virginia Flora.* http://www.vaplantatlas.org
6.
7.

The end result of the taxonomy of living things is a two-part scientific name composed of the genus and species and called the “binominal nomenclature.” The taxonomical classification of a given plant and even its binominal nomenclature may change as more is understood about a given plant.

Further detail within species is provided by variety, cultivar, and hybrid, as defined in Table 5-2. Note that while the terms in Table 5-1 are hierarchical, that relationship does not hold for these terms. A cultivar is a type of variety, not a subset. The hybrid could result from mating different varieties, cultivars, or species.

Table 5-2 Sub classifications below species

Classification Division	Distinguishing Characteristics
Subspecies	A geographically isolated variant within a species.
Variety	A grouping within a species, usually not geographically isolated, having distinct, though often inconspicuous differences and breeding true to those differences. A variety may be naturally occurring, managed, or a hybrid. A category based on fewer correlated characters than are used to differentiate species or subspecies, given a Latin name preceded by "var."
Cultivar	A linage in a species that has been selected for a specific attribute and is distinct, stable, and uniform when propagated. Cultivars are usually propagated by asexual means, such as grafting, to preserve genetic makeup.
Hybrid	A cross between two species that results in a viable new plant. May occur in nature or artificially.

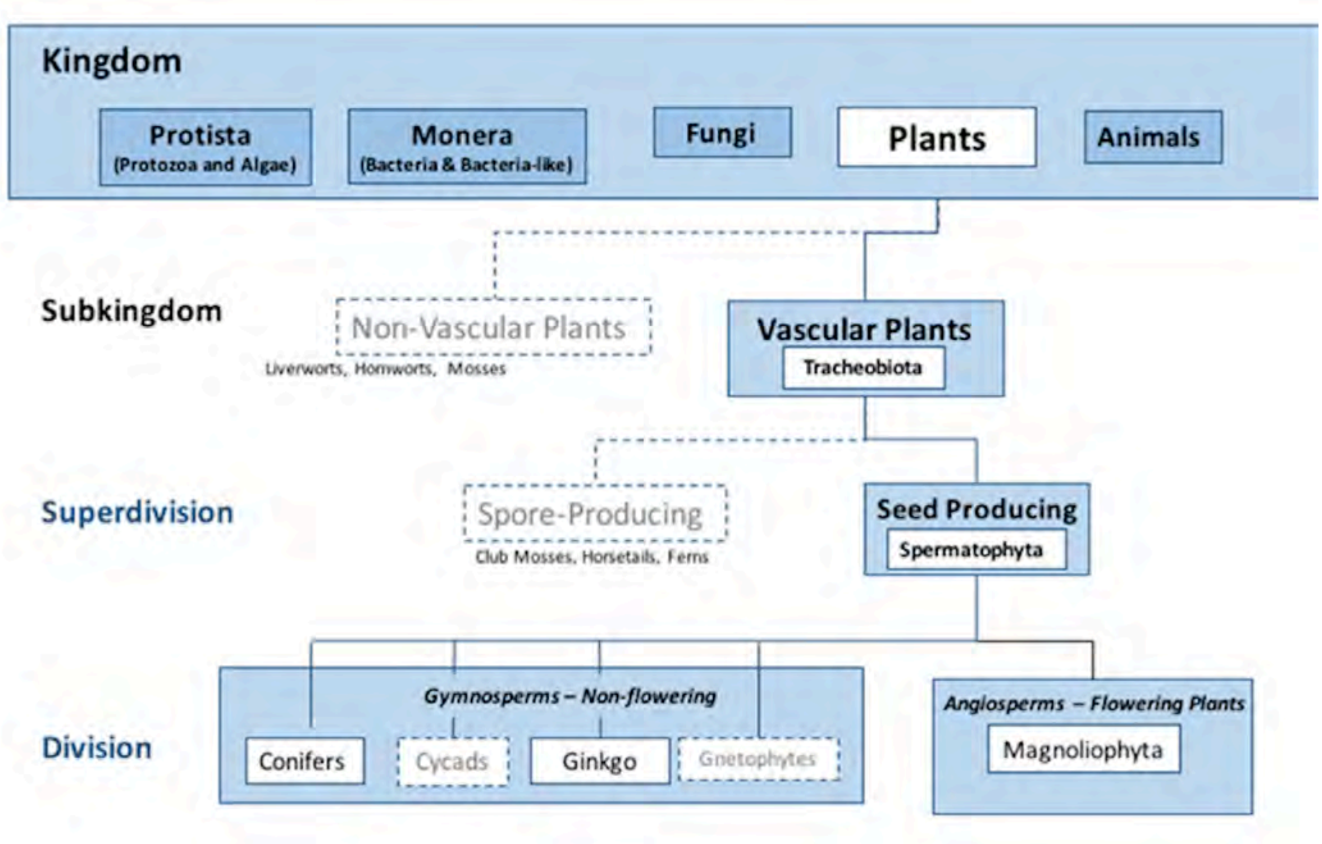

Figure 5-1 Taxonomy of Trees through the Division Level (Courtesy Patsy McGrady)

An important grouping for trees occurs at the division level. At that point, plants are separated into gymnosperms (non-flowering plants that produce naked seeds not enclosed in an ovary) and angiosperms (flowering plants with seeds enclosed in an ovary).

Gymnosperms include the Conifers, Cycads, Ginkgo, and Gnetophytes Divisions. The only Cycad native to eastern North America is a shrub native to Florida and SE Georgia. The only Gnetophyte in eastern North America is a shrub that grows in Texas and Oklahoma. Since our focus is trees, these two divisions are not addressed further. The taxonomy of Conifers and Gingko gymnosperms from division to family is provided in Figure 5-2.

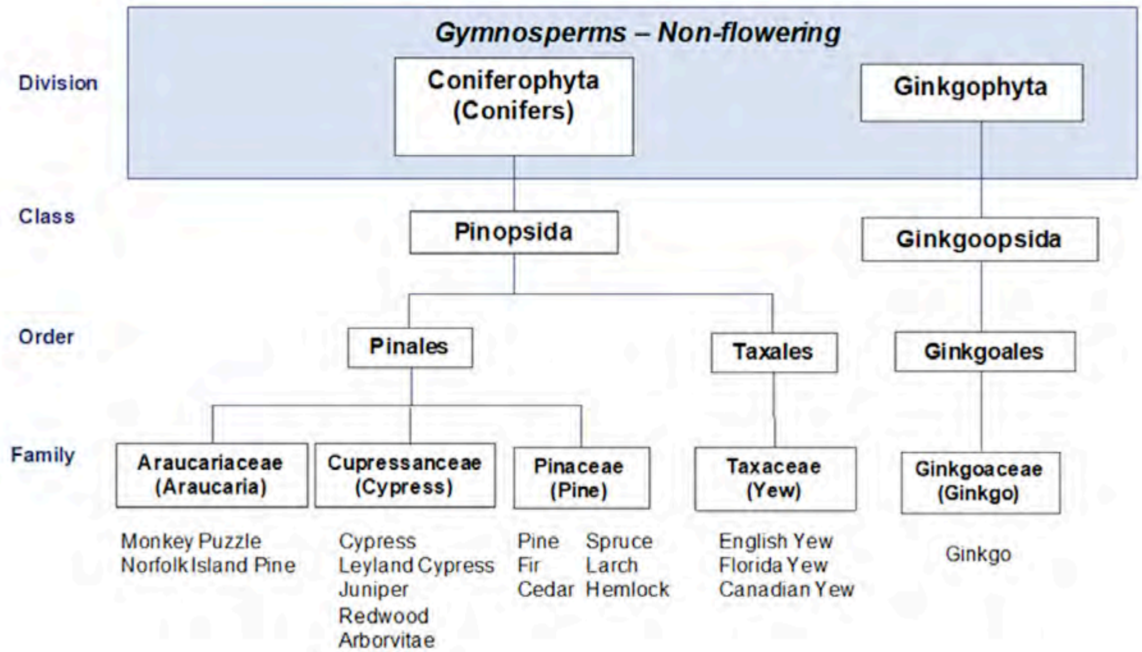

Figure 5-2 Taxonomy of Gymnosperms (Courtesy Patsy McGrady)

The Pinales Order contains two additional families that are not addressed here because they do not include trees relevant in our area. It is interesting to note that the ginkgo tree is the only living species within the Ginkgophyta Division. The ginkgo has existed for over 200 million years and is considered a living fossil.

> Several types of trees within the Pine Family have multiple cotyledons within their seeds and may be referred to as polycots.

All angiosperms are contained in the Magnoliophyta Division and have traditionally been subdivided into monocots and dicots. This has been a morphological classification, that is, the classification is based on the form and structure of the plants, such as the usual number of flower parts, the number of cotyledon (embryonic first leaves of a seedling) inside the seed, and additional related characteristics. Chapter Four discusses many of these characteristics in more detail.

- Monocots have a single seed leaf within the seed. Most monocot flowers have flower parts in sets of three, so that there may be three or six petals. Leaf veins are usually arranged in parallel. The vascular bundles of monocots vary in size and are scattered throughout the stem and, therefore, cannot form annual rings of hardened tissue, i.e. wood. This limits the strength of their stems. The only trees within the Monocot Class are palms (Arecaceae Family).
- Dicots, as traditionally defined, have two seed leaves with flower parts that usually occur in multiples of 4 or 5. Leaf veins are netlike. Vascular bundles are uniform in size and arranged in a ring around the stem of the plant. This enables dicot trees to form wood from annual rings of hardened tissue.

The scientific consideration of dicots has become more complicated due to recent advances, especially in the ability to evaluate plants based on DNA and also to study plants at a molecular level: this is called phylogenetic classification. This more recent research has modified the traditional monocot/dicot grouping for taxonomical purposes into monocot, eudicot, and basal angiosperms to better reflect the evolution of the plants. A distinguishing structural characteristic of eudicots is that their pollen grains have three grooves. The pollen of both monocots and basal angiosperms have only one groove. While this structural characteristic is observable, it is not observable by the naked eye as are the monocot/dicot characteristics discussed above and in Chapter Four.

Scientists now believe that the initial primitive angiosperms were dicots; monocots evolved out of that group. Monocots now account for about 22% of all plant species. Palms are the only major type of tree that is a monocot. Most of the remaining dicots evolved into eudicots.[8] Eudicots make up 75% of flowering species and contain the largest proportion of tree families. The remaining 3% of flowering species are considered basal angiosperms,[9] a group of the most primitive flowering plants. Magnolias, tulip trees, paw paws, and sassafras trees are basal angiosperms.

An illustrative taxonomy of angiosperm trees from division to family is provided in Figure 5-3. Note that the taxonomy of angiosperms includes an additional level of classification "subclass" not used in the gymnosperm taxonomy. The subclasses, orders, and families with relevant trees tend to be broader and more numerous than those levels in the gymnosperm taxonomy. Only one categorization line is shown for each relevant subclass.

Under the Dicots, the gray circle shows basal angiosperms; the yellow oval shows eudicots.

The monocots contain four additional subclasses that do not contain relevant trees. The dicots contain two additional subclasses for a total of six. One subclass (Asteridae) includes tree families and the other (Caryophyllidae) does not. There are many more orders and families with relevant trees that are not shown in table 5-3 It is good to remember that the focus here is just the trees. The angiosperms also contain very large numbers of shrubs, perennials, and annual flowers.

8. Watts, M.T. (1998). *A Manual for the Identification of Trees by Their Leaves.* Nature Study Guide Publications.
9. Basic Biology. (May 21, 2015). *Basal Angiosperms.* https://basicbiology.net/plants/angiosperms/basal-angiosperms

Angiosperm taxonomy

Division	Angiosperms - Flowering Plants	Angiosperms - Flowering Plants	Angiosperms - Flowering Plants	Angiosperms - Flowering Plants	Angiosperms - Flowering Plants	Angiosperms - Flowering Plants
Class	Monocots	Dicots	Dicots	Dicots	Dicots	Dicots
Subclass	Arecidae	Magnoliidae	Hamamelididea	Rosidae	Dilleniidae	Asteridae
Order	Arecales	Magnoliales	Fagales	Rosales	Malvales	Scrophulariales
Family	Arecalcaceae (Palm Family)	Magnoliaceae (Magnolia Family)	Fagaceae (Beech/Oak Family)	Rosaceae (Rose Family)	Tillaceae (Mallow Family)	Oleaceae (Olive Family)
Examples	Palm Palmetto	Tuliptree Magnolia	Chestnut Beech Oak	Serviceberry Apple Plum Cherry Pears	Hibiscus Basswood Linden	Fringetree Ash Olive

Tree Families

Tree families and trees discussed below were selected based on their prevalence in this area, economic/historical/ornamental value, environmental importance, and likelihood of problems. Given the large number of trees that are either native or have been planted in this region, the selection below is necessarily subject to modification based on one's local experience.

The intent is to provide information on observable characteristics to help Tree Stewards in identifying trees and providing right plant/right place tree selection and care. The discussion focuses on observable and distinguishing, non-technical characteristics associated with a family, genus, and species. In general, the discussion does not go into scientific aspects that are not readily observable. One of the easiest tree guides to use (for native trees) is VDOF's Common Native Trees of Virginia.[10]Except as noted, the black and white illustrations accompanying the family paragraphs are copied from this book, with kind permission from the Virginia Department of Forestry. They are the work of Juliette Watts of the US Forest Service.

The native growing range for trees indigenous to Virginia can be found in Common Native Trees of Virginia. For trees indigenous to North America, the native growing range is provided at the USDA

10. Virginia Department of Forestry. (2016). *Common Native Trees of Virginia Tree Identification Guide.* Virginia Department of Forestry Publication P00026. www.dof.virginia.gov

Plant Database website.[11] Trees of Eastern North America also provides ranges.[12] The Digital Atlas of Virginia Flora website notes Virginia counties in which a given species has been observed.[13]

The stated number of genera and species in a family can vary based on the source of the information. This document uses the numbers provided in Trees of Eastern North America. Also, stated expected heights and diameters of trees vary based on the source of the information. For trees native to Virginia, this document uses the height and diameter provided in Common Native Trees of Virginia. For other trees, height and diameter is based on information in Trees of Eastern North America. The terms tall, medium, and short are applied to tree heights as follows: tall – 45 feet and greater, medium – 25-45 feet, short – 25 feet and under.

Gymnosperms

Cypress Family (Cupressaceae)

The Cypress Family is composed of cone-bearing plants with male (pollen) and female (seed) cones either on separate plants (dioecious) or on the same plant (monoecious). In most Cypress species, the seed cone is small and woody but some have small fleshy cones that look like berries. While some species may be deciduous, most members of the Cypress Family are evergreen with leaves that are either scale like or needle like. When needle like, the needles may cover the twig or be flattened and two-ranked (leaves arranged in two vertical columns on opposite sides of the stem). The bark is fibrous and furrowed and may be peeled off in long, thin strips. Generally, the wood contains resin, is aromatic, and is rot-resistant. Given its resistance to decay, the wood is frequently used for construction and fence posts.

There are 19 genera within the Cypress Family. Key representative genus and trees of interest in this area are discussed below.

1. Genus *ChamaecyparisSpach* – False Cedar

The trees in this genus are sometimes referred to as false cedars or new world cedars to distinguish them from the true cedars in the Pine Family, discussed below. Common characteristics are:

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11. United States Department of Agriculture (USDA) (n.d.). *PLANTS Database*. USDA Natural Resource Conservation Service. https://plants.usda.gov/java/
12. Nelson, G., Earle, C., Spellenberg, R. (2014). *Trees of Eastern North America, Princeton Field Guides*. Princeton University Press.
13. Virginia Botanical Association. (2017). *Digital Atlas of Virginia Flora*. http://www.vaplantatlas.org

- Tiny, scale-like leaves that overlap like shingles and form flat sprays like a fern.
- Distinctive, small cones that remain on the tree long after their seeds are gone.
- Aromatic wood.

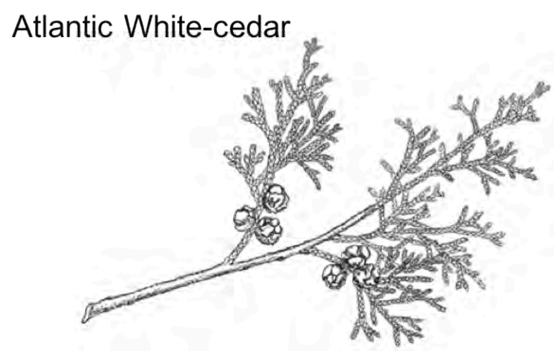

Figure 5-3 Atlantic White-cedar (Juliette Watts, USDA Forest Service, as published in VDOF's Common Native Trees of Virginia)

The **Atlantic White-cedar (*Chamaecyparis thyoides* (L.) B.S.P.)** is found in southeast Virginia and favors swampy habitats. It is generally of medium height with a 1 to 2 feet diameter trunk. It looks very similar to the more common eastern redcedar but the needles are blue-green with small, round (¼ "diameter) woody cones with a waxy grayish coating.

2. Genus *Juniperius* L. – Junipers – Junipers are evergreen, have scale-like leaves that are pointed and prickly, and have fleshy cones that look like berries. The genus contains many shrubs and some trees.

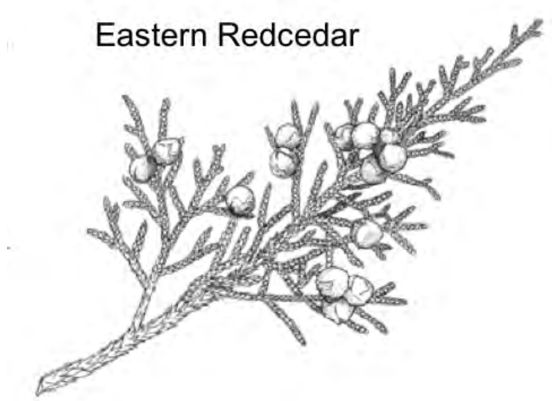

Figure 5-4 Eastern Redcedar (Juliette Watts, USDA Forest Service, as published in VDOF's Common Native Trees of Virginia)

The most common juniper tree in our area is the **Eastern Redcedar (*Juniperus virginiana* L.)**. With a medium height and a trunk of 1 to 2 feet in diameter, it is the largest and most tree-like of the junipers.

The eastern redcedar grows throughout most of the eastern United States on a variety of soils and is able to thrive where few other trees are found. The fleshy, berry-like cones appear only on female trees. Cones are small, ¼ to 1/3 inch in diameter. Cones start out as green and turn blue when they mature. It is one of the longest-lived of North American conifers and has been known to live almost 800 years. Its aromatic wood is used to line closets and chests.

3. Genus *Taxodium* Rich. This genus contains three species of large trees that are extremely flood tolerant. The needle-like leaves, 0.2 to 0.8-inch-long, are borne spirally on the shoots, twisted at the base so as to appear in two flat rows on either side of the shoot. The seed cones are shaped like globes, 0.8 to 1.4 inches diameter. The male (pollen) cones are produced in pendulous racemes, and shed their pollen in early spring.

Bald Cypress

Figure 5-5 Bald Cypress (Juliette Watts, USDA Forest Service, as published in VDOF's Common Native Trees of Virginia)

Bald Cypress (***Taxodium distichum***) is the most familiar species within this genus. It is a tall, deciduous conifer with a trunk that can be as large as 3 to 6 feet in diameter. Needles occur flattened and two ranked on its twigs. The tree frequently naturally occurs near water and is considered the characteristic tree of southern swamps. Its unique characteristic is knobby wooden knees. The purpose of the knees is not known but are thought to provide additional oxygen to the plant. The tree generally does not produce knees in a non-wet environment.

4. Other

Other well know trees within the Cypress Family that Tree Stewards likely will want to be knowledgable of are:

- Arborvitae
- Leyland Cypress
- Cryptomeria
- Dawn Redwood
- Giant Sequoia

Pine Family (Pinaceae)

All members of the Pine Family are monoecious (both male and female parts on a given plant). The bark varies across the species. Leaves are either simple needles or needles occurring in bundles of 2-5. Cones are usually woody with many scales.

There are 9 genera in the pine family. Key representative genus and trees of interest in this area are discussed below.

Quick ID Tip: "Firs are friendly and spruces are scratchy" from a park ranger in Glacier National Park.

1. *Genus Abies* Mill. – Fir. Firs have needlelike leaves, arranged in a spiral but often appearing 2-ranked. The needles are generally soft to the touch. Firs live in regions that are covered in snow many months of the year, generally at elevations from sea-level to 6500 feet.

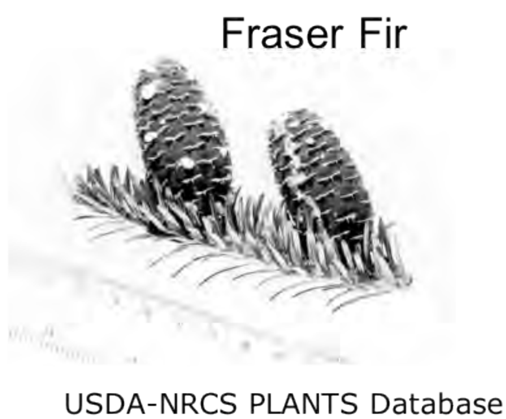

Figure 5-6 Fraser Fir (Courtesy USDA NRCS)

Fraser Fir (*Abies fraseri*) is the only native fir in the Appalachian mountains. It is a medium height tree with a trunk around 20 inches in diameter. The fraser fir is usually found in stands with red spruces in small areas in the south Appalachians that include areas in Tennessee, North Carolina, and Virginia. The twig is covered by red hairs with needles that are approximately ½ .to 1 inch long. Cones may be 1.5 to 2.5 inches long.[14]

14. Nelson, G., Earle, C., Spellenberg, R. (2014). Trees of Eastern North America, Princeton Field Guides. Princeton University Press.

2. *Genus Picea* A. Dietr. – Spruce. Spruces look very similar to firs but have stiff, usually sharp-pointed needles. Their native habitat is mostly in the mountains at high altitudes.

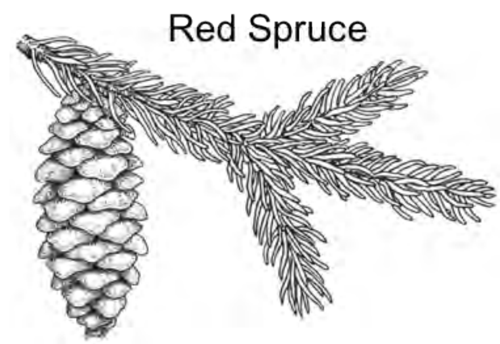

Figure 5-7 Red Spruce (Courtesy USDA NRCS)

Red Spruce (*Picea rubens* Sarg.) A tall tree with a trunk that could be 3 ft in diameter, the red spruce is found in small scattered areas at elevations above 4000 feet in the west of Virginia. Needles are ½ to 5/8 inches long, pointed and attached to the twig on tiny raised pegs. Cones are 1 ¼ to 2 inches long, light reddish-brown, and shiny with smooth edged scales. Cones drop their first winter. The wood is light, somewhat soft and elastic. Example uses are lumber, pulpwood, and musical instruments.**3. Genus*Pinus* L. – Pine.** Pines are evergreen trees with needle shaped leaves occurring in bundles of 2-5. Representative pines of interest are discussed below.

Figure 5-8 Loblolly Pine (Juliette Watts, USDA Forest Service, as published in VDOF's Common Native Trees of Virginia)

Loblolly Pine (*Pinus taeda*) Tall and straight trees with trunks of 2 to 3 feet in diameter. Needles are 6-9 inches long, three needles per cluster. Lower branches self-prune as the tree grows and ages. Cones are narrowly oblong, 2 to 6 inches long, and stay on the tree for a year after maturing. Loblollies are native to the eastern part of Virginia and are the most abundant tree in the Virginia coastal plain.[15] They are also the most important commercial timber tree in the state. The wood is used for lumber, paper pulp, plywood, poles, pilings and fuel.

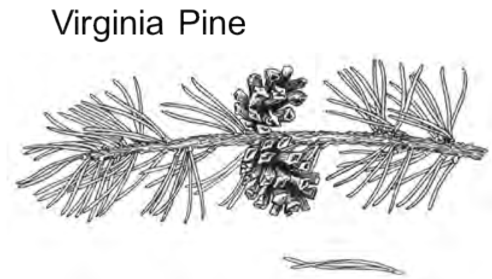

Figure 5-9 Virginia Pine (Juliette Watts, USDA Forest Service, as published in VDOF's Common Native Trees of Virginia)

Virginia Pine (*Pinus virginiana* Mill.) A tall tree, somewhat smaller than the loblolly, with trunks of 12 to 14 inches in diameter. Needles are 1 ½ to 3 inches long, two needles in a bundle,. Needles are usually twisted. Cones are egg shaped, 1 ½ to 2 ¾ inches long. Cones mature in two years but stay on the tree several years before falling. The wood warps easily and is used for rough construction and paperpulp.

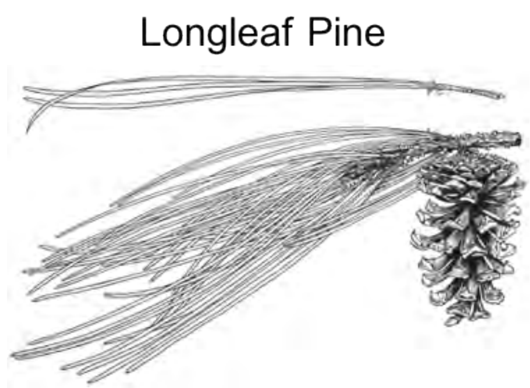

Figure 5-10 Longleaf Pine (Juliette Watts, USDA Forest Service, as published in VDOF's Common Native Trees of Virginia)

Longleaf Pine (*Pinus palustris* Mill.) Tall with trunks of 2 to 2.5 feet. This tree has the longest needles and largest cones of any pine in the eastern part of North America. Needles are 8 to 15 inches long with three in a cluster. Cones are cylindrical, 6 to 10 inches long. Cones mature in two years and drop from the tree after releasing their seeds in the fall.

15. American Forest. (n.d.). *Champion Trees National Register.* http://www.americanforests.org/explore-forests/americas-biggest-trees/champion-trees-national-register/

The longleaf seedling appears to be a clump of grass and only develops a stem after several years. The tree prefers to grow in acidic, infertile soils and likes sandy soils. It is very adapted to fire, generating seedlings best when fire burns off the fallen needles, clearing the understory but not harming the mature trees.

Before European settlement, longleaf pines dominated the coastal plain from Virginia to Texas. Today they are found only in isolated sections. Heavy cutting of the trees for commercial use, combined with fire suppression, has lead to significant reduction of the species. Restoration efforts are ongoing in Virginia. American's Longleaf Restoration Initiative (ALRI) was formed in 2007 to restore longleaf pine ecosystems. It is lead by the USDA Forest Service, Department of Defense, and U.S. Fish and Wildlife Service with participation from various public and private organizations across nine southern states.[16]

Other well known trees within the Pine Family that Tree Stewards likely will want to be knowledgeable of are:

- Shortleaf Pine
- Eastern White Pine

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16. America's Longleaf Restoration Initiative (ALRI). (n.d.). *American's Longleaf*. http://www.americaslongleaf.org/home/
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Other well known trees within the Pine Family that Tree Stewards likely will want to be knowledgeable of are:

- Shortleaf Pine
- Eastern White Pine

4. GenusTsuga – Hemlock. Hemlock needles are arranged in a spiral on the twig but appear to be 2-ranked and flattened. There are only 7 species worldwide with only 2 species, **Eastern Hemlock (*Tsuga canadensis*)** and **Carolina Hemlock (*Tsuga caroliniana*),** in the Virginia/North Carolina area. When crushed the foliage smells a bit like the European native poisonous herb called hemlock and thus the name.

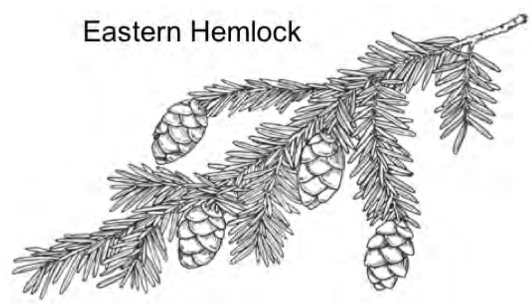

Figure 5-11 Eastern Hemlock (Juliette Watts, USDA Forest Service, as published in VDOF's Common Native Trees of Virginia)

Eastern Hemlock (*Tsuga canadensis*) A tall tree with a trunk 2 to 4 feet in diameter, the eastern hemlock is found primarily in the western portion of Virginia. Needles are short, 1/3 to 2/3 inch long, with two pale lines on the lower surface. The ¾ cones grow on the tip of branchlets.[21]

5. Genus *Cedrus* – True Cedar. True cedars are native to the mountains of the western Himalayas and the Mediterranean region and are adapted to mountain climates.[18] They have rather short evergreen needles occurring primarily in dense clusters at the end of short woody pegs. This tufted arrangement of needles is only seen in true cedars and larches. Large, barrel-shaped cones sit on the top of branches and have thin scales that fall apart when mature. They are generally very large (tall and wide) trees and are planted in parks and public areas in the United States and especially in the Pacific Northwest. Most true, old-world cedars seen in North America are ornamentals.

18. American Conifer Society (2020, September 4). *10 Types of Cedar Everyone Should Know.* https://conifersociety.org/conifers/articles/types-of-cedar-trees/

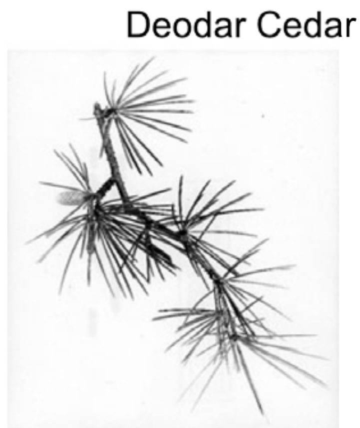

Figure 5-12 Deodar Cedar
(Courtesy USDA-NRCS)

Deodar Cedar (*Cedrusdeodara*) is frequently seen in this area and is rumored to be naturalized in North Carolina, South Carolina, and Georgia. Its needles are 1-2 inches long, grouped in clusters with individual needles on the branch tips. There is a noticeably droop in the branch tips and leader.15

Other true cedars include the **Atlas Cedar** (***Cedrus atlantica*)** and **Cedar of Lebanon (*Cedrus libani*).** Both trees have needles about 1inch long with a stiff branching habit.

Angiosperms

While all angiosperms flower, not all flowers are notable. This is especially true for trees that are angiosperms.

Birch Family (Betulaceae)

The Betulaceae family includes birches (*Betula*), alders (*Alnus*), hornbeams (*Carpinus*), and hazels (*Corylus*). The trees are deciduous and have simple, alternate leaves that are generally thin with serrated edges (saw-like teeth) and pinnate veins (major veins branching off from a central vein). The trees are monoecious with male and female catkins forming on the same plant. A catkin is an elongated cluster of single-sex flowers bearing scaly bracts, usually lacking petals.

Figure 5-13 Hophornbeam Leaf (Courtesy Carol King)

Figure 5-14 Filbert Catkins (Courtesy of Carol King)

There are 6 genera in the Birch Family. Key representative genus and trees of interest in this area are discussed below.

1. Genus *Betula* – Birch. Birches usually have smooth bark, dark brown to silvery white, that often peels into plates or papery layers. Trees often have several trunks.

Figure 5-15 River Birch (Juliette Watts, USDA Forest Service, as published in VDOF's Common Native Trees of Virginia)

River Birch (*Betula nigra* L.) is the only birch native to the Coastal Plain in the southeastern United States. It can be a tall tree and is often divided into several trunks. The trunks may be 1 to 3 feet in diameter. The bark peels back in papery layers. The leaves are 1 ½ to 3 inches long with an oval to triangular shape and doubly serrated edges. The wood is quite hard and close-grained but the tree is seldom harvested. It is commonly planted for erosion control situation such as stream bank restoration and is frequently used as an ornamental tree in home yards.

2. Genus*Carpinus* – Hornbeams and **Genus *Ostrya*** – **Hophornbeam**.

The **American Hornbeam (*Carpinus caroliniana* Walt.)** and **Eastern Hophornbeam** (***Ostrya virginiana* (P. Mill) K. Koch.)** are both native in this area. While they are very similar and both belong to the Birch Family, they belong to different genera. Both are small trees growing 20 to 30 feet and can have a single trunk or multiple trunks. Both trees have leaves that are alternate, simple, 2 to 4 inches long with doubly toothed edges. The leaves of the American hornbeam are oval and long-pointed while the leaves of the eastern hophornbeam are oblong with narrow tips. The trunk of the American hornbeam is smooth and rippled, resembling well-defined muscles. This leads to alternate common names of ironwood or musclewood. The fruits of the American hornbeam are 4 to 6 inch hanging clusters of slightly folded, 1 inch, 3-lobed leafy bracts; each bract contains a ⅓ inch ribbed nutlet. These clusters somewhat resemble the samaras (helicopter seeds) of maples.

However, the hophornbeam has fruits hanging in clusters of leafy, oval, papery sacs 1½ to 2½ inches long, with each sac containing a 1/4 inch nutlet. These clusters of papery sacs resemble hops and thus the name Hophornbeam.

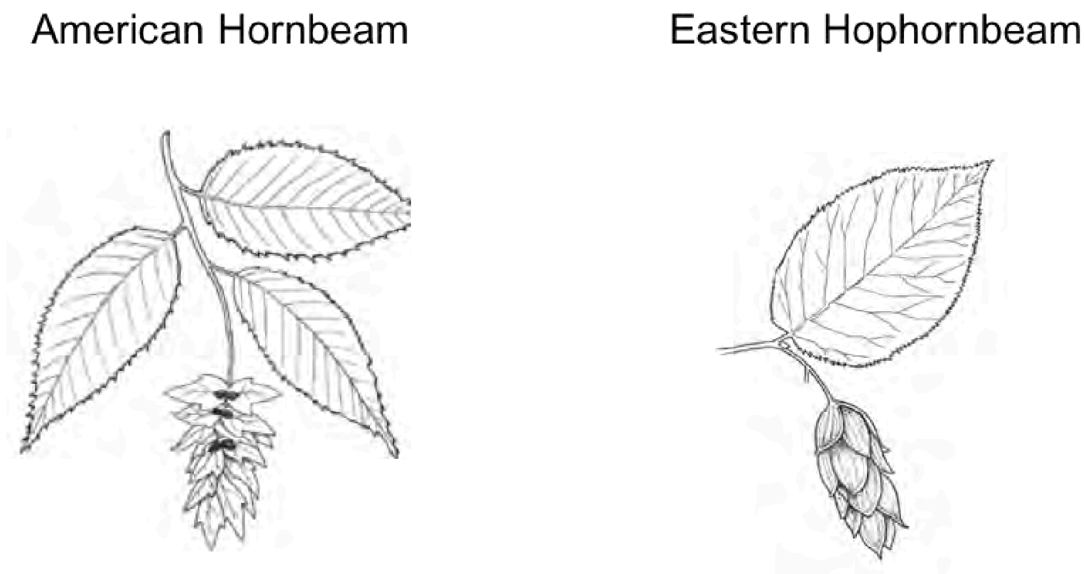

Figure 5-16 American Hornbeam and Eastern Hophornbeam (Juliette Watts, USDA Forest Service, as published in VDOF's Common Native Trees of Virginia)

The wood of both trees is strong and durable but is seldom harvested.

Bean or Pea Family (Fabaceae)

The Fabaceae Family is the third largest plant family and contains approximately 730 genera. More than 45 genera of trees exist north of Mexico across North America. All members have compound leaves, mostly pinnately or bipinnately compound. However, the leaves of some species, such as the redbud, are unifoliate, that is they are theoretically compound but have only one leaflet and therefore appear to have a simple leaf. The unifying feature of the family is that the fruit is a legume, that is multiple seeds reside in a pod that opens along two sides. Roots often have nitrogen-fixing bacterial nodules. This document addresses one genus and two species in other genera within the *Fabaceae* Family.

1. Genus *Gleditsia* – Locusts. Locusts are medium height, single trunk trees with pinnate or bi-pinnate compound leaves. The compound leaves alternate and within the compound leaf, leaflets also alternate. A distinguishing characteristic is thorns that occur on the trunk and/or branches. Fruits are flattened legume pods with one to multiple seeds. Two species are native to North America.

Honey Locust (*Gleditsia TriacanthosL.*) The leaves are pinnately compound, 5 to 8 inches long, with 15 to 30 leaflets. However, the leaves can also be bipinnately compound with 4 to 7 pairs of minor leaflets. Leaflets are elliptical and ½ to 1 ½ inches long. Trunk, large branches and twigs have branched thorns that are strong and sharp. Small greenish-yellow flowers are fragrant and appear on 2 to 3 inch hanging clusters in late spring. The seed pod is 6 to 8 inches long and flattened. The pod matures in late summer and early fall, becoming dry and twisted. Seeds are oval, dark brown and 1/3-inch-long with multiple seeds in each pod. Because the wood is hard, strong, and moderately resistant to decay, it is sometimes used for fence posts and crossties. The tree may be planted for erosion control and windbreaks. Thornless varieties are available and are commonly chosen for planting in urban landscapes.

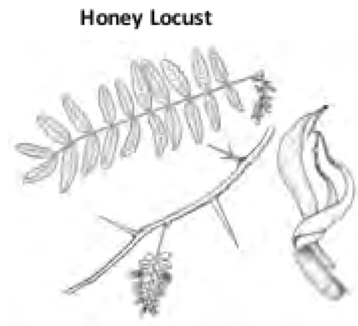

Figure 5-17 Honey Locust (Juliette Watts, USDA Forest Service, as published in VDOF's Common Native Trees of Virginia)

2. Other Genera

Eastern Redbud (*Cercis canadensis* L.*)* is a short tree, frequently multi-stemmed, that grows as an understory tree generally at the edge of a forest. It is one of the most common ornamental trees. In spring, it is covered with very small (½ inch) pink to purple flowers that resemble the flowers of a pea. The flowers occur in clusters along the twigs and small branches and appear before the leaves. Leaves are alternate, heart shaped, and smooth edged, 3 to 5 inches long and wide. While the leaves appear to be simple, they are an example of the infamous unifoliate. Although the wood is heavy and hard, it is not strong and has little commercial value.

Figure 5-18 Eastern Redbud (Juliette Watts, USDA Forest Service, as published in VDOF's Common Native Trees of Virginia)

Mimosa (*Albiziz julibrissin* Durazz) is a lovely small tree with smooth gray-brown bark. It was introduced from Asia in the late 18th century. The leaves are alternate, bi-pinnately compound, 10 to 20 inches long with a feathery appearance reminiscent of ferns. Fragrant flowers appear in the form of showy pink fluffy heads in mid to late summer. The fruit is a flat pod, 5 to 6 inches long, and turns a light brown. The single trunk is short, sending out branches at a low height and spreading into a wide V-shape crown that makes it an excellent climbing tree for children. Unfortunately, the seeds germinate easily across a wide range of conditions making the mimosa far too good at reproducing itself. It is treated as invasive and commonly considered a trash tree. So sad.

Figure 5-19 Mimosa Leaves, Blooms (Courtesy leoleobobeo Pixabay)

Other trees in the Fabaceae Family that the Tree Steward may find interesting include:

- Yellowwood
- Black Locust
- Kentucky Coffeetree
- Golden Chain Tree

Beech or Oak Family (Fagaceae)

The Fagaceae Family contains deciduous and evergreen woody plants with simple leaves arranged alternately. The leaves may have entire, toothed, or deeply lobed leaf margins. Flowers are typically unisexual with male and female flowers appearing on the same plant (monoecious) in catkins (elongated cluster of highly reduced unisexual flowers). Fruits are nuts within a scaly or spiny cap.

There are 9 genera in the Beech/Oak Family. Key representative genus and trees of interest are discussed below

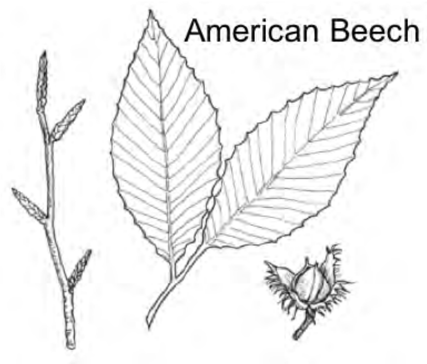

Figure 5-20 American Beech (Juliette Watts, USDA Forest Service, as published in VDOF's Common Native Trees of Virginia)

1. Genus *Fagus* – Beech. Beeches have smooth bark that is either silvery gray or blue-gray, though some species develop shallow furrows and ridges. Leaves are simple, elliptic or ovate, with margins that are bluntly or sharply toothed. The leaves have lateral veins that are parallel and terminate in the tip of a marginal tooth. The fruit is two nuts in a four-valved prickly capsule. Beeches are tardily deciduous trees. Many have a tendency to retain their leaves in a dry, lifeless state through the winter, especially when young.

American Beech (*Fagus grandifolia*) is a common understory tree in the Coastal Plain. It can grow to be fairly tall with a trunk of 2 to 3 feet. It can be easily identified by its smooth silvery bark. The leaves are coarsely toothed with 9-14 pairs of lateral veins. Buds are distinctly elongated and torpedo-shaped.

2. Genus *Quercus* – Oak. Though the Mid-Atlantic representatives of the genus are typically deciduous, many evergreen species occur throughout the world's warmer temperate and tropical regions. There are more local species, at least 16, of oak than any other genus.[19]The fruit of all oaks is the familiar acorn which is botanically identified as a nut covered by a cap of scales. Any plant that produces an acorn is an oak. The size and shape of the acorn and its cap is specific to the species of oak. The leaves are arranged alternately and vary in shape. Many are conspicuously lobed, but others have simple leaves without lobes. The bud scales overlap and most oaks feature a cluster of buds at the terminal end of each stem.

Oak wood is heavy, strong, hard, close-grained and durable. It is used for lumber, furniture, and flooring.

The majority of oak species are placed in either the Red Oak group or the White Oak group. Red Oaks have a bristle on the tip of their lobes and their acorns require two years to ripen. White Oaks do not have bristles. Their acorns ripen in a single season and are sweeter (have less tannin) than acorns from trees in the Red Oak group. White Oaks generally are slower growers than Red Oaks. The Sawtooth Oak is neither in the Red or White group but is considered an intermediary between the two groups.

19. Watts, M.T. (1998). *A Manual for the Identification of Trees by Their Leaves*. Nature Study Guide Publications

White Oak (*Quercus alba* L.) is the most common oak in Virginia forests. It is a tall tree with a trunk that can be 3 to 4 feet in diameter. Leaves are alternate and simple, 4 to 7 inches long, with 7 to 10 rounded lobes. The sinuses between the lobes may be shallow to deep, almost reaching the midrib; this can give the leaf a very different appearance even among trees of the same species. The acorn is light chestnut brown, ¾ inch long, with a bowl-shaped cap that covers ¼ of the acorn. The cap detaches at maturity. The wood is close-grained, strong, and durable. Uses include furniture, flooring, and fuel. The wood is well suited for whiskey and wine barrels because it is highly water-tight due to the presence of a substance called tyloses in the wood vessels.

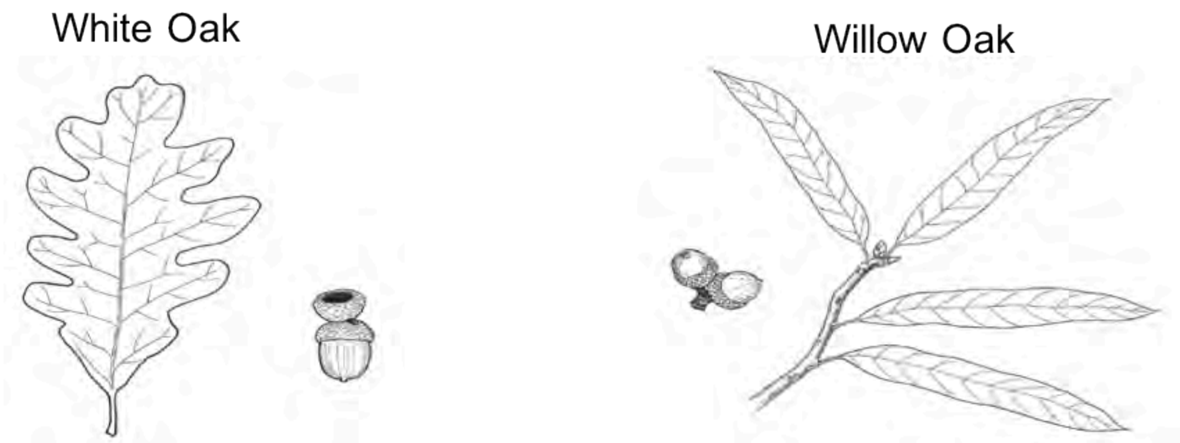

Figure 5-21 White Oak and Willow Oak (Juliette Watts, USDA Forest Service, as published in VDOF's Common Native Trees of Virginia)

Willow Oak (*Quercus phellos* L.) is long lived, fast growing, and frequently planted in public spaces. The tree has an erect trunk that is medium to tall in height with a diameter of 1 to 2.5 feet, sometimes considerably wider in the taller specimens. Leaves are alternative, simple, and narrow oval (lanceolate) with a bristle tip, making them members of the Red Oak group. The acorn is small (¼ to ½ inches) and tan. The cap covers ¼ of the acorn nut and is flat, thin, and scaly. The wood is heavy and strong, but coarse-grained. It is used for rough construction and pulpwood.There are many oak species. Examples include:

- Southern Red Oak
- Northern Red Oak
- Swamp Chestnut Oak
- Live Oak
- Sawtooth Oak
- Water Oak
- Overcup Oak
- Scarlet Oak
- Pin Oak

3. Genus*Castanea* – Chestnut. Chestnuts have alternate leaves with bristle-tipped marginal teeth and conspicuous parallel lateral leaf veins. The trees produce large, sweet, edible fruit. The nuts are enclosed in a spiny, prickly capsule that may contain up to three nuts. There are 4 native species in North America. Of particular note is the greatly missed American chestnut.

Figure 5-22 American Chestnut (Juliette Watts, USDA Forest Service, as published in VDOF's Common Native Trees of Virginia)

American Chestnut *(Castanea dentate)* used to be a tall tree that was a dominant species in forests in much of Virginia. Trunks could be quite large with diameters up to 4 feet. In the early 1900s chestnut blight was introduced into eastern North America. By 1940 the chestnut had disappeared as a major tree in American forests. Today the plant can be found as sprouts from the stumps of dead American chestnut trees. The sprouts may get up to 20 feet in height and may live as long as 40 years. They do not produce fruit.

Another common tree in the Chestnut Genus is Allegheny Chinkapin, *Castanea pumila*.

Walnut Family (Juglandaceae)

The Juglandaceae Family contains mostly trees and has 13 native species in eastern North America plus three nonnatives. All members have pinnately compound leaves and are usually odd-pinnate, that is they have a terminal leaflet at the end of the leaf. While the compound leaves are alternate; within the compound leaf, the leaflets are opposite. Flowers are tiny. The fruit presents itself as a nut surrounded by a husk that has developed from the fruit wall. The seed is large, oily, and often edible. Nuts mature late summer to fall. This document addresses two genera.

1. Genus *Juglans* – Walnut. The leaves of walnut trees usually have a spicy scent. Twigs are covered with hairs that have an enlarged gland at the tip. The fruit is shaped like a globe or ovoid surrounded by a green husk that turns black as it dries and does not split. In addition to providing edible nuts, walnuts provide dyes and lumber used in furniture and cabinets.

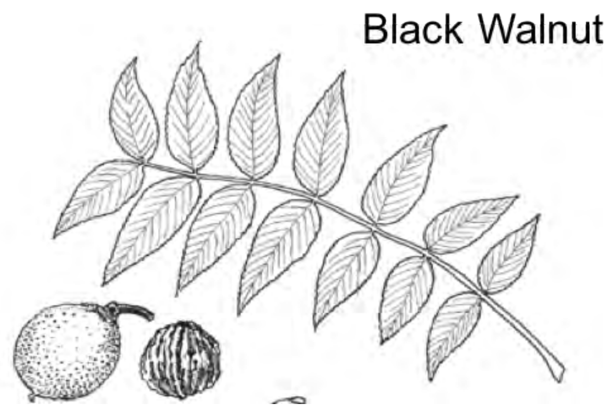

Figure 5-23 Black Walnut (Juliette Watts, USDA Forest Service, as published in VDOF's Common Native Trees of Virginia)

Black Walnut (*Juglans nigra* L.) can be medium to tall in height with a diameter of 2 to 3 feet. Leaves are odd-pinnately compound. The terminal leaflet is often much smaller than the side leaflets. Frequently the terminal leaflet is lost so that the compound leaf appears even-pinnate. The compound leaves are long, 12 to 24 inches, with 10 to 24 leaflets. The leaflets are 3 to 3.5 inches long, finely toothed, with a narrow oval shape tapering to a pointed tip (lanceolate). Yellow-green flowers appear in spring with male flowers appearing in 2.5 to 5.5 inch catkins and female flowers on short spikes at the tip of branches. The nuts are encased in thick green husks that do not split. The husks turn black as they dry. The nut inside has a black shell that is wood-like, thick and furrowed. The nut meat is difficult to extract from the shell but has a delicious and distinctive taste when added to baked goods. The heartwood is of superior quality and value and is used for fine furniture and cabinetwork. Sometimes one hears the statement, "Nothing grows under walnut trees." That is not quite true. Black walnuts secrete a toxic chemical called juglone that prevents some plants from growing near them. Examples of susceptible plants include azalea, rhododendron, mountain laurel, blackberry, blueberry, apple, tomato and potato.
Other trees in the *Juglans* genus that the Tree Steward may find interesting are:

- English Walnut
- Butternut

***2.* Genus *Carya* – Hickories.** Each compound leaf has 3 to 21 leaflets arranged opposite each other with a conspicuous terminal leaflet. The leaflets are usually hairy although sometimes the hairs only occur on the axis of the vein on the lower surface. The fruit is a nut enclosed in a husk that may be either thick or thin. In contrast to members of the *Juglans* genus, whose husks do not split, husks of hickories split when mature.

Pecan (*Carya illinoensis* (Wangenh) K. Koch) is a tall tree with long compound leaves usually having from 9 to 15 leaflets, 12 to 18 inches long. Occasionally there may be only 5 to 7 leaflets. The leaflets are relatively long and narrow oval-shaped tapering to a pointed tip (lanceolate) with toothed margins. The base of the leaflet is often asymmetric. Twigs are fuzzy, especially when young. Fruits are husk-covered nuts, 1 ½ to 2 inches long. Sutures (lines of fusion) are narrowly ridged and separate the husk into four sections. The thin husk splits to the base revealing a dark brown, ellipsoid nutshell. The kernel is edible and is used in baking or roasted as a snack.

Figure 6-24 Pecan Leaf and Nuts (Ryan Armbrust, Kansas Forest Service, Bugwood.org)

Mockernut Hickory (*Carya alba* Nutt) (formerly *Carya tomentosa* Nutt.) is a medium to tall tree. Compound leaves are 9 to 14 inches long with 7 to 9 finely toothed leaflets of differing sizes and obovate-elliptic in shape. The leaflet on the tip is the largest. The lowest pair of leaflets are the smallest. Occasionally there are only 5 leaflets. Leaflets are dark green on the top with sparse hairs. The underside is orange-brown and hairy. Leaves are aromatic when crushed. The fruit is an oval, husk-covered nut. The husk splits almost to the base when mature forming four sections. The nut is 1 ½ to 2 inches long with a very thick shell and is sweet. The hard, strong wood has a number of uses to include tool handles, furniture, charcoal and smoking of meats.

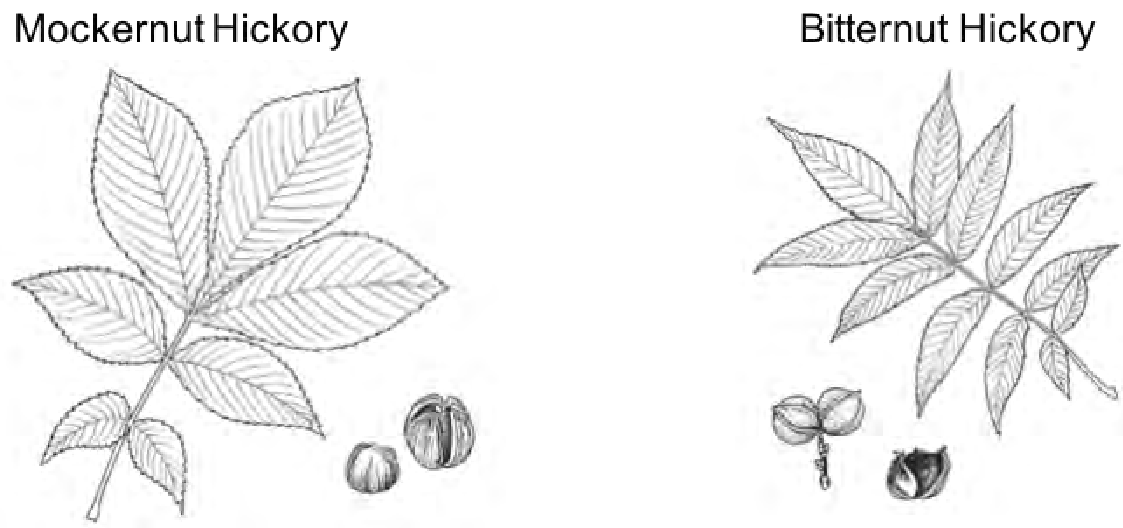

Figure 5-25 Mockernut Hickory and Bitternut Hickory (Juliette Watts, USDA Forest Service, as published in VDOF's Common Native Trees of Virginia)

Bitternut Hickory (*Carya cordiformis* (Wangenh.) K. Koch) is a medium height tree. The compound leaves have 7-9 finely toothed leaflets, with a narrow, long oval shape tapering to a pointed tip (lanceolate). The top of the dark yellow-green leaflet may be hairless or hairy. The underside is paler and covered with resinous scales. The 4-ribbed nutshells have a thin husk and are 1 ¼ inches long, round and slightly flattened. Nutshells split from the middle to a sharply pointed tip. The nuts are bitter. The hard, strong wood has a number of uses to include tool handles, furniture, flooring, and smoking of meats.

Other trees in the Carya genus that the Tree Steward may find interesting are:

- Shagbark Hickory
- Pignut Hickory

Magnolia Family (Magnoliaceae)

"The Magnolia Family is an ancient family, dating back more than 100 million years in the fossil record. The flowers have retained some ancestral characteristics, where the sepals, petals, stamen, and pistils are arranged in a spiral on a cone-like receptacle, rather than in concentric rings as they are in most other plant families."[20]

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20. . Elpel, T.J. (2013). *Botany in a Day: The Patterns Method of Plant Identification* (6th ed.). Hops Press, LLC.

Trees in the Magnolia Family have showy flowers that are white, cream, or yellow tinged. The pistons in the middle of each flower grow into a cone-like structure that contains the seeds.

There are two tree genera of significance to Virginia in the Magnolia family. Both genera and selected trees of interest are discussed below

1. Genus *Liriodendron* – Tuliptree (*Liriodendron tulipifera*) is the only species in this genus. Tuliptree, aka tulip poplar, yellow poplar, is one of the most common trees in Virginia forests and one of the largest and most valuable hardwood trees in the United States. It is also one of the easiest to identify. The large leaves (4 to 6 inches) are shaped like tulips and are the only tree leaf that is concave in the middle leaf top. In spring, after the leaves appear, the tree produces tulip-shaped flowers that are creamy yellow with blotches of orange and measure 2 to 3 inches across. The pistils in the center of the flower evolve into a 3" cone-like cluster of woody, wing-like seeds. The seeds break away in the fall but leave behind a spike that resembles wooden flowers. In the winter after the leaves fall, the tree can be identified by these wooden flowers. The tree has a straight trunk and is one of the tallest hardwood trees in the forest, typically growing to 90 to 110 feet. This fast-growing tree produces light, soft wood that is easily worked. Uses for the wood include lumber, plywood, paper pulp, and fuel.

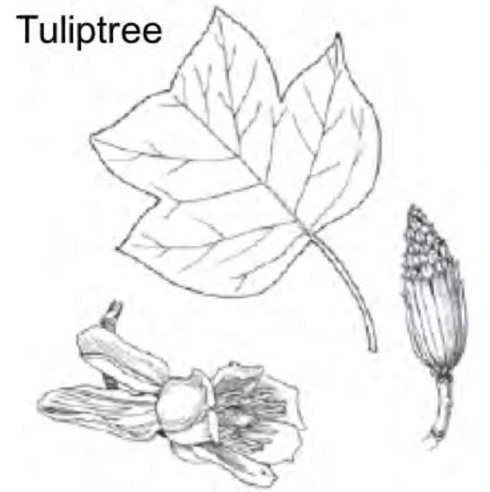

Figure 5-26 Tuliptree (Juliette Watts, USDA Forest Service, as published in VDOF's Common Native Trees of Virginia)

2. Genus*Magnolia*– Magnolia*.* Leaves are simple, typically elliptical, obviate, or ovate. Most leaf edges have entire margins, that is the edges are smooth without teeth or lobes; but some have slightly undulating edges.[21]The top of the leaf is deep green with the backside a lighter green or somewhat silvery color. Leaves can be quite large on some species and are deciduous or persistent depending on the species and location. Magnolias have solitary flowers that are showy, creamy white and often very fragrant. The center of the flower matures into a cone-like structures containing red, pink, or orange-coated seeds. The seeds can separate from the cone-like structure to dangle on a threadlike attachment.

21. Nelson, G., Earle, C., Spellenberg, R. (2014). *Trees of Eastern North America, Princeton Field Guides*. Princeton University Press

Southern Magnolia (*Magnolia grandiflora*) has thick leathery very stiff leaves with brown on the underside. Leaves can measure 4 to 12 inches long and 2.5 to 4 inches wide. The tree is evergreen with a pyramidal shaped crown. The flowers can be 6 to 10 inches wide. It is probably one of the most recognizable trees in Virginia.

Figure 5-27 Magnolia flowers (Joy Viola, Northeastern University, Bugwood.org)

Sweetbay Magnolia (*Magnolia virginiana*) may have a single trunk or multiple trunks. Leaves are elliptical with smooth edges and a blunt point and measure 4 to 6 inches long. They are shiny bright green above and pale or whitish below and not as thick as the leaves of the Southern Magnolia. When crushed they release a pleasant, spicy odor. The tree sheds its leaves later than other trees in the fall. Further south it may be almost evergreen. The white flowers are smaller than those of other native magnolias and measure 2 to 3 inches across. The wood is soft and not of significant commercial value. The tree is often grown as a landscape tree.

Figure 5-28 Sweetbay Magnolia (Juliette Watts, USDA Forest Service, as published in VDOF's Common Native Trees of Virginia)

Other well know trees with which Tree Stewards likely will want to be familiar are:

- Star Magnolia
- Saucer Magnolia
- Cucumber Magnolia, aka Cucumber Tree
- Fraser Magnolia, aka Umbrella Magnolia

Rose Family (Roseaceae)

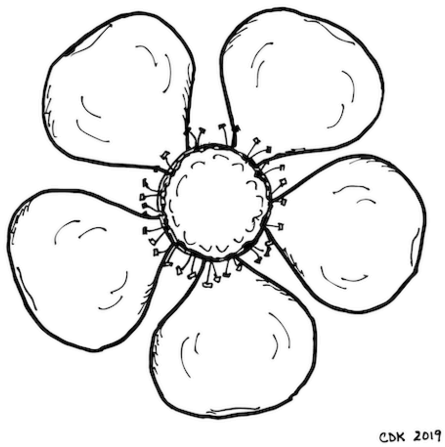

Figure 5-29 Notional Rose Family Flower (Courtesy Carol King)

The *Roseaceae* Family contains a variety of fruits of which many are edible. The fruits vary from fleshy to false fruits (fruits not formed from the ovary), dry seeds, capsules, or follicles. Leaves are alternate but diverse in shape. They may be simple or compound with edges that are entire, toothed, or lobed. Plants in the Roseaceae Family have flowers that most commonly have five petals and five sepals. In rare cases the flowers may have three to ten petals. Flowers generally have a fuzzy looking center surrounded by stamens. Stamens are usually numerous and occur in whorls, with a minimum of five and additional stamen occurring in groups of five.

These are 50 genera of the Roseaceae Family in North America, north of Mexico. Most of these occur in eastern North America. Because of the large number of plants of interest in this family, they will be discussed at the subfamily level instead of the genus level. The subfamily is a grouping just below family and just above genus. These are taxonomical differences in the way the genera are grouped into subfamilies. This paper uses the groupings as defined in Botany in a Day.[22] The most relevant subfamilies and genera are discussed below. Some do not contain trees but are included because of other well known plants in them.**1. Rose Subfamily (Rosoideae)**. Plants often have stipules, a leaf-like appendage, at the base of the leaf stems. A stipule is one of a pair of structures at the base of the petiole of a leaf. They are usually small, green, and leaf like, but may be modified into scales, bristles, or spines. [23] Of the 15 genera in the rose subfamily, the three below are of the greatest interest.

Genus*Rosa*– Rose. Includes 105 species of roses. Most roses have more than five petals, a condition known as doubling. Doubling occurs when some or all of the stamens become modified to look like petals. These petal-like structures are called petaloids. Examples of species roses include Bourbon rose, Cherokee Rose, damask rose, tea rose, and climbing rose.

Genus*Fragaria* – Strawberry

Genus*Rubus* – Raspberry, blackberry, boysenberry

22. Elpel, T.J. (2013). *Botany in a Day: The Patterns Method of Plant Identification* (6th ed.). Hops Press, LLC
23. Nelson, G., Earle, C., Spellenberg, R. (2014). *Trees of Eastern North America, Princeton Field Guides.* Princeton University Press.

2. Almond Subfamily (Amygdaloideae)

- Plum group: Fleshy fruits are drupes, meaning they have an outer skin covering a fleshy layer surrounding a stony center that contains the seed. Fruits have an indentation that appears to be a seam down one side. Two genera belong to the plum group.

> **Genus*Prunus* – Plums and Relatives.** Familiar plants include plum, cherry, apricot, peach, nectarine, and almond.

- Apple group: Fleshy fruits are pommes, meaning they have a compound ovary and multiple seeds. The bottom of the fruit contains a five-pointed star that is the remains of the flower. Twelve genera belong to this group.

> **Genus *Malus* –** Apple and crabapple
>
> **Genus *Pyrus* –** Pear and ornamental pear
>
> **Genus *Amelanchier* –** Serviceberry

Other well know trees in the apple group with which Tree Stewards likely will want to be familiar are spread across various other genera and include:

- Quince
- Flowering Quince
- Photinia
- Pyracantha
- Hawthorn
- Mountain Ash

Willow Family (Salicaceae)

The Salicaceae Family includes 50 to 60 genera, five genera occur in North America of which three are native. Most members have alternate, simple leaves with a toothed edge. Stipules are often present. A common characteristic relates to their flowers. The flowers do not have petals and sepals are greatly reduced or absent. Flowers are borne on catkins that appear with or before the emergence of new leaves. Trees are unisexual, that is male and female parts occur on separate trees. Plants in this family have a strong affinity to water and tend to prefer moist sites. Plants in the Willow Family contain varying amounts of organic compounds (glycosides, populin, salicin, and methyl salicylate) which provided the basis for aspirin. The compounds are strongest in the inner bark, but also present in the leaves. This document considers two genera that includes poplars, cottonwoods, aspen, and willows.

1. Genus*Populus* – Poplars, Cottonwoods, Aspen. Trees are deciduous and medium to tall height. The bark is smooth and pale on young trees but on older trees the bark can become darker, thick, and deeply furrowed. As characteristic of the family, the leaves are alternate, simple, and toothed. In addition to these common family characteristics, leaves in this genus are heterophyllous, that is leaves from different parts of the twig can have different forms. There are seven species in eastern North America.

Figure 5-30 Eastern Cottonwood (Juliette Watts, USDA Forest Service, as published in VDOF's Common Native Trees of Virginia)

Eastern Cottonwood (*Populus deltoids* Bartr. Ex Marsh) is a tall tree that can be 3 to 4 feet in diameter. It characteristically lives along river borders, floodplains, and other moist, well-drained sites. Leaves are triangular and somewhat heart-shaped with pinnate veins. Twigs are yellowish and have a bitter aspirin taste. The fruit is a small capsule, ¼ inch long, that appears on female trees and splits to release many tiny, cottony seeds. The wood is soft and lightweight and often warps when dried. Example uses are for baskets, rough lumber, fiberboard, plywood, and paper pulp.

Other trees in the *Populus* genus that the Tree Steward may find interesting include:

- Bigtooth Aspen
- Lombardy Poplar
- Quaking Aspen
- White Poplar (invasive)

2. Genus*Salix* – Willow. Many of the willow species have leaves that are lanceolate, long, narrow, with a pointed tip. In addition to the flowers having no petals, they also have no sepals. The willow contains salicylic acid and is known for its aspirin-like ability to treat headaches, fevers, and inflammations of the joints. There are about 30 tree-like species in eastern North America occurring from sea-level to above the timberline.

Figure 5-31 Weeping Willow Tree (Rebekah D. Wallace, University of Georgia, Bugwood.org)

Weeping Willow (*Salix babylonica* L.) is a generally small tree that can reach 40 to 50 feet. The tree is thought to have originated in China. While it no longer occurs in the wild, the weeping willow is naturalized in many places in eastern North American. It needs to grow in a moist area. The crown is usually rounded with long, flexible branches that gracefully droop toward the ground. The fruit is a one inch long cluster of light brown valve-like capsules, containing many fine, cottony seeds, and maturing in late May to early June.

Other trees in the *Salix* genus that the Tree Steward may find interesting include:

- White Willow
- Black Willow
- Pussy Willow

Soapberry Family (Sapindaceae)

The Sapindaceae Family contains approximately 150 genera of trees, shrubs, and woody vines distributed primarily in tropical and subtropical areas, but extending into the north temperate region. The observable characteristics such as leaves, flowers, fruits, and seeds vary considerably across the family. At various times during the 20th century, there was discussion in the scientific community about the relation of the Aceraceae (Maple) and Hippocastanaceae (Horse Chestnut) Families to Sapindaceae. In the 21st century taxonomists officially moved maples and buckeyes/horse chestnuts into the Soapberry Family. This move was based on DNA evidence and phylogenetic theory, i.e. the theory of the evolution of a genetically related group of organisms. While this move is generally accepted, the USDA Plant Database does not reflect this change and continues to show Aceraceae as the Maple Family and Hippocastanaceae as the Horse Chestnut Family. This document presents maples and buckeyes/horse chestnuts as genera within the Soapberry Family.

1. Genus *Acer* – Maple. Maples have tiny, inconspicuous flowers in the spring. The fruit/seed are winged samara, usually in joined pairs and designed to be carried by the wind. The samaras are colloquially called "helicopters." The time when the samaras are produced varies according to the species. For example, red maples produce samara before the leaves come out in the spring. Other species produce samara after the leaves appear later in the season. Leaves are opposite and most, but not all, are palmately lobed. Leaves have 3 to 5 lobes with coarsely toothed edges. The characteristics of the wood vary according to species. For example, red maples produce cream colored wood that is soft and rather weak and is used for furniture and paper pulp. Sugar maples produce pale brown or pink wood that is heavy, strong, and close grained and is used for flooring as well as furniture. Wood from silver maples is soft, brittle, and weak and is used for boxes, furniture, and fuel. There are 15 species of maples in eastern North America of which 9 are native.

Red Maple (*Acer rubrum* L.) is one of the most common and abundant trees in eastern North America forests. The U.S. Forestry service has noted dramatic increases in the number of red maples in eastern North American forests since the 1970s, with the red maple replacing other species (generally not considered a good thing). These increases have been achieved primarily for two reasons. First, the species grows in a wide variety of conditions from swamps and wetlands to dry uplands, tolerating the widest variety of soil conditions of any North American forest species. Second, the tree is not tolerant of fire and the suppression of fire has enabled the proliferation of the species in the forests.[24] The tree is considered an understory tree in forests but can grow up to 90 feet tall.The species gets its name, red maple, from the red flowers, samara, leaf stems, and fall color. Flowers appear in the spring before leaves appear and are red, attractive but very small. The red flowers are followed by reddish, paired samara which give the impression of flowers from a distance. Individual samaras are relatively short (½ to ¾ inches) compared to the samaras of other maple species. Leaves appear after the samaras. Leaves have 3 to 5 lobes and are coarsely, but finely, toothed. The leaf stem is often red. In the fall, the leaves turn brilliant scarlet, orange or yellow.

24. Alderman, D.R. Jr., Bumgardener, M.S., Baumgras, J.E. (September 1, 2005). An Assessment of Red Maple Resource in the Northeastern United States. N*orthern Journal of Applied Forestry*. 22(3). https://www.nrs.fs.fed.us/pubs/7698

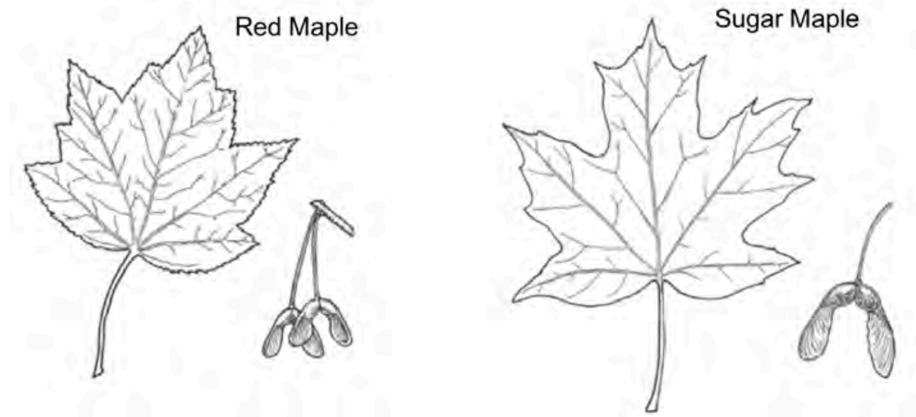

Figure 5-32 Red Maple and Sugar Maple (Juliette Watts, USDA Forest Service, as published in VDOF's Common Native Trees of Virginia)

Sugar Maple (*Acer saccharum* Marsh) is a tall tree with tiny yellow-green flowers clustered and hanging from 1 to 3 inch threadlike, hairy stems. The flowers appear with or slightly before the leaves. Samaras are 1 inch long. The leaves have lobes separated by rounded, shallow sinuses. In the fall, the leaves turn brilliant scarlet, orange or yellow. The sweet sap of sugar maples is used to make maple syrup and maple sugar.

Silver Maple (*Acer saccharinim* L.) is a medium to tall tree that was popular as a yard tree in the mid-20th century. Flowers are greenish to reddish in dense clusters and appear in the spring long before the leaves. The samaras are longer (1.5 to 2.5 inches) than those of the red and sugar maples. Leaves have 5 main lobes with deep sinuses. Lobe edges are coarsely toothed. The species gets its name from the silver underside of the leaves. The leaves turn yellow in the fall.

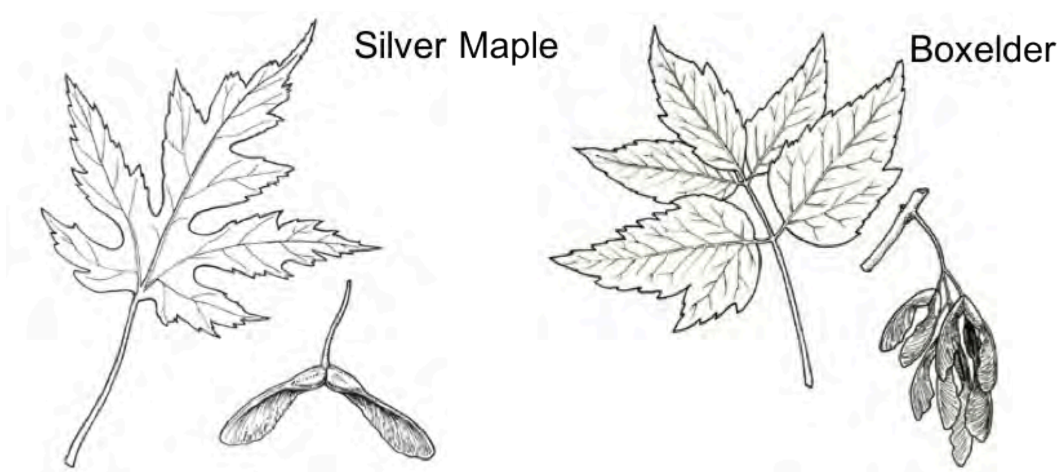

Figure 5-33 Silver Maple and Boxelder Maple (Juliette Watts, USDA Forest Service, as published in VDOF's Common Native Trees of Virginia)

Boxelder (*Acer negundo* L.) is a medium height tree that is frequently multi-stemmed. Unlike the previously discussed maples, male and female flowers of the boxelder occur on separate trees.

Flowers are yellow-green in drooping clusters, appearing in late spring before or with new leaves. The samaras also appear in drooping clusters. The most distinguishing characteristic is the pinnately compound leaves that commonly have 3 leaflets, but sometimes 5 and rarely 7 to 9 leaflets. This is a distinct difference from the other maples that have simple leaves. The form of the boxelder leaf reminds one of a simple maple leaf that has been cut apart to form leaflets. The leaflets are coarsely toothed. The 3-leaflet form resembles poison ivy. In the fall, the leaves turn yellow.Other maples with which Tree Stewards may want to be familiar include:

- Striped Maple
- Black Maple
- Japanese Maple
- Norway Maple (introduced from Europe, considered invasive in the Northeast)

2. Genus*Aesculus* – Buckeyes and Horse Chestnuts. Buckeyes and horse chestnuts generally are of medium height. They can be recognized by their palmately compound leaves with 5 to 11 leaflets occurring opposite each other on branches. The edge of the leaflets is toothed. Flowers are elongated, often cone-shaped terminal clusters that appear after new leaves. The fruit is produced in pear shaped or rounded green or brown leathery capsules that usually have 1 to 3 large seeds and occasionally 4 to 6. At maturity, the seed capsule commonly splits into 3 parts.

Yellow Buckeye (*Aesculus flava* Ait.) has leaves that are 10 to 15 inches long with 5 to 7 oval leaflets, each 3 to 7 inches long. The flowers are pale yellow-orange in large, showy upright 4 to 8 inch clusters. The flower petals have two different lengths. The fruit is 2 to 3 inches long with 1 to 3 brown nuts with a spot on one side. The nuts are poisonous to eat. The wood is light, soft, and close-grained and is sometimes used for pulpwood and woodenware.

3. Genus *Koelreuteria* – Goldenrain Tree. Genus is native to Asia, but all three species have been introduced into the United States. Only one is significant as a landscape tree in Virginia.

Goldenrain Tree (*Koelreuteria Paniculata* Laxm) is a short tree with a spread equal to its height. Leaves are pinnately (or partially bi-pinnately) compound, 8 to 14 inches long and with 9 to 15 leaflets. The compound leaves are alternate but the leaflets are opposite and have irregular serrations or lobes. The tree has showy, large bright yellow flowers that appear on 10-15-inch-long panicles (a loosely branched flower cluster in a somewhat pyramidal form).

Figure 5-34 Goldenrain Trees in Bloom (Courtesy Carol King)

Figure 5-35 Goldenrain Tree Leaves (Courtesy Carol King)

Note: The golden shower tree (*Cassia fistua*) is very similar in size and appearance to the goldenrain tree but is a member of the Fabaceae Family. It has evenly compound leaves with showy yellow flowers. While the flower panicles of the goldenrain tree appear to be held somewhat stiffly and frequently upward, the flowers of the golden shower tree appear to droop downward.

Additional Trees Worthy of Note

Ginkgo (*Ginkgo biloba* L.) is sometimes called a living fossil. The tree essentially has not changed for more than 200 million years. In the distant past, there were other ginkgo-like plants but these plants no longer exist. The ginkgo is now the only plant in its genus (Ginkgo L.), family (Ginkgoaceae), order (Ginkgoale), class (Ginkgoopsida), and division (Ginkgophyta). One has to go all the way back to the superdivision (Spermatophyta – the point at which seed producing plants and spore producing plants separate) to find a taxonomical category where there are other plants in addition to the ginkgo.

Figure 5-36 Ginkgo Tree Structure and Fall Leaves (Courtesy Carol King)

At the division level, flowering plants (angiosperms) split off into the *Magnoliophyta* Division. All four divisions of non-flowering plants are considered gymnosperms. However, the ginkgo does not adhere to several of the criteria that apply to other gymnosperms. The form of the seeds, growth form, and foliage differ substantially from other gymnosperms. Stubby, short pegs protrude from the twigs. From these pegs, clusters of leaves grow.

Figure 5-37 Ginkgo Pegs (Courtesy Carol King)

The leaves appear to have more in common with angiosperm trees than the needles and scale-like leaves of conifers. The ginkgo does not have flowers. Its leaves are shaped like fans with a radiating pattern of veins. No other tree has a similar shaped leaf or similar vein pattern. The seed of the ginkgo is produced on female plants. While the seed is considered naked, it has a fleshy covering, unlike the hard seeds of other gymnosperms. This covering has a foul odor, like rotten meat, when it drops to the ground. The seeds themselves are edible and are a delicacy in many parts of Asia.

The ginkgo can be a tall tree and is resistant to pollution. Males are frequently used as street trees. The leaves turn bright yellow in the fall. Most of the leaves fall from the tree in a short span of time rather than over several days or weeks.

Figure 5-38 American Holly (Juliette Watts, USDA Forest Service, as published in VDOF's Common Native Trees of Virginia)

American Holly (*Ilex opaca* Ait.) is a medium height tree with a diameter of 1 to 2 feet. It is a very common understory tree in Virginia forests. The evergreen leaves are alternate, simple, leathery, glossy green and stiff. They are elliptical, 2 to 4 inches long, with 1 to 7 large, sharp, spine-tipped teeth. The bark is light gray and smooth throughout the life of the tree. Male and female flowers are on separate trees. Female trees produce ¼ inch bright red berry-like fruit that matures in October and persists on the tree over winter.

Sweetgum (*Liquidambar styraciflua* L.) Is a relatively tall tree that can be 2 to 3 feet in diameter. Leaves are alternate, simple, palmately lobed, and star-shaped with 5 to 7 lobes. Leave edges are finely toothed. The fruit is a distinctive brown spiny ball containing about 50 seeds. While the wood is heavy and moderately hard, it does not stand up to weather. Example uses include interior finish, paper pulp, and plywood.

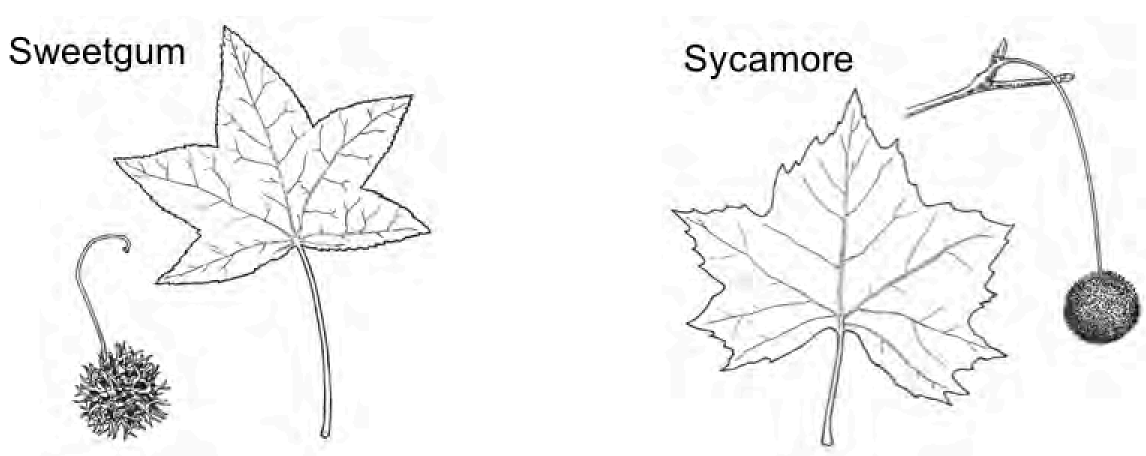

Figure 5-39 Sweetgum and Sycamore (Juliette Watts, USDA Forest Service, as published in VDOF's Common Native Trees of Virginia)

Sycamore (*Platanus occidentalis* L.) is a tall tree that can be up to 4 feet in diameter or sometimes even wider. Leaves are alternate, simple, palmately shaped with 3 to 5 lobes. Leaf edges are large toothed. The fruit is a ball, about the same size as the sweetgum ball. However, the sycamore fruit is tightly packed with winged ½ inch seeds surrounded by fine hairs. The fruit matures in late fall and disperses its seeds in late winter. The most distinguishing characteristic is the mottled brown, green and tan bark that peels readily and looks like camouflage. The tree does not put on a show for fall. It is one of the first trees to start losing its leaves. Leaves dry up and turn a pale yellow and brown dropping from the tree. The camouflage-looking smooth bark does provide winter interest for the bare tree. While the wood is hard and moderately strong, it decays quickly in the ground. Example uses are chopping blocks, particle board, and paper pulp.

Black Tupelo (*Nyssa sylvatica* Marsh.) is generally seen as a medium height tree, 1 to 2 feet in diameter. It is also called Blackgum. Occasionally it can reach up to 100 feet high and 4 feet in diameter. The leaves are alternate, simple, 2 to 5 inches long, shaped as an elongated oval with a pointed tip and a smooth edge. As the season progresses, the green leaves often develop purple spots. The leaves are arranged on the twig in such a way that they appear to be a whorl at the end of the twig. Trees are most commonly either male or female, but occasionally may be bisexual. Flowers are tiny, greenish yellow, and are not ornamentally significant. They appear with the leaves, in clusters on stalks up to 1 ½ inches long. Tupelo produces a berry-like fruit (drupe); each having a single seed and measuring about ½ inch across. The drupes appear in clusters on stalks less than 1 ½ inches and ripen in late September or early October. In the fall, the leaves turn scarlet and provide beautiful color. The wood is tough, hard to work, and easy to warp. Example uses are rough flooring and pulpwood.

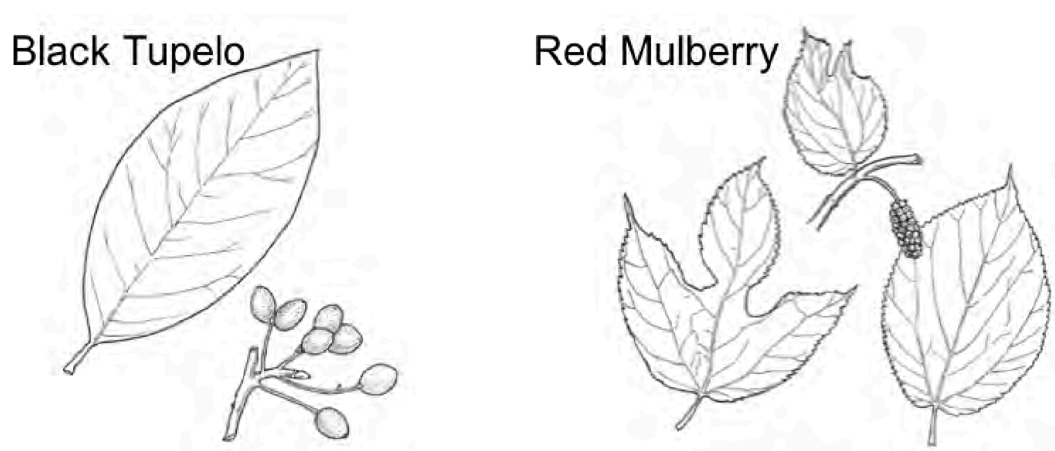

Figure 5-40 Black Tupelo and Red Mulberry (Juliette Watts, USDA Forest Service, as published in VDOF's Common Native Trees of Virginia)

Red Mulberry (*Morusrubra* L.) is of medium height with a 1 to 2 feet trunk and prefers a rich, moist soil. Leaves are alternate, simple, 3 to 5 inches long, with toothed edges. Leaves can have multiple shapes: oval, one lobe (mitten shaped), or 3 or more lobes. The leaves of young trees tend to have more lobes. Mature trees tend to have mostly leaves with no lobes. The leaves have stiff hairs on the top that make them rough to the touch; however, the underside can feel downy. Flowers are pale green, tiny, and clusters on 1 to 2 inch catkins (male) or 1 inch catkin (female). Male and female flowers may be on the same or separate trees and appear with the leaves in the spring. The mulberry fruit looks like a small blackberry that starts out red and then ripens to deep purple in mid-summer. The fruit is sweet, juicy, and edible. They also make a mess where they fall under the tree. The wood is light, soft, and not strong but quite durable. Examples of uses are fencing and barrels.The white mulberry (*Moras alba*) is the main food source for silkworm caterpillars. In the early colonial period, white mulberries were brought to the United States in the hope of establishing silk production. This was unsuccessful but white mulberry became naturalized throughout the southern states.

Big Tree Program

American Forests, a non-profit conservation organization, sponsors the National Big Tree Program and maintains the Champion Trees National Register. The register contains information on American's biggest trees, the largest recorded living specimens of each tree type measured by height, trunk circumference, and crown spread. Trees species must be either native or naturalized in the continental United States to be eligible. The continental United States includes the 48 lower states and Alaska but not Hawaii. The National Register of Big Trees has been maintained by American Forests since 1940 and currently contains over 700 Champion Trees.

The following formula is used to calculate a point score for each tree:

Trunk Circumference (in inches) + Height (in feet) + 1/4 Average Crown Spread (in feet) = Total Points

The current list of National Champion Trees is available online at:

> http://www.americanforests.org/explore-forests/americas-biggest-trees/champion-trees-national-register

Several states, counties, and cities maintain their own list of local Champion Trees. Virginia has consistently ranked in the top five states for national champion trees. The Virginia Big Tree Program is a educational program of the VCE, coordinated by the Department of Forest Resources and Environmental Conservation at Virginia Tech. The Virginia Big Tree Register maintains information on the five largest specimens of over 300 native and naturalized tree species. The Virginia website provides photographs of the trees, their location, the names of the individuals who nominated them, and in some cases, the name of landowner. The Virginia website is:

> http://bigtree.cnre.vt.edu/search.cfm

How to Measure Trees

Trees are commonly measured by three parameters: height, girth, and crown spread.

Height is the vertical distance from the base of the tree to the highest sprig at the top of the tree. The base point is the point at which the tree germinated. If the tree is on a slope, the base point is the ground level halfway between the upper and lower sides of the tree.

Girth is a measurement of the circumference of the tree measured at 4.5 feet above ground level. If there are significant branches below this height, then the girth should be measured at the narrowest point below the lowest branch and that height noted. If there is a burl or protuberance at the measurement height, then the girth should be measured immediately above the protuberance or at the narrowest point of the trunk below the protuberance and that height noted. If there are multiple trunks, measure with a tape measure around all trunks at the 4 ½ feet height.

Crown spread measures the footprint of the crown of the tree expressed as a diameter. The simplest approach is to take measurement along the longest axis of the crown from one edge to the opposite edge. A second measurement is take perpendicular to the first lie through the central mass of the crown. The two measurements are then averaged to reach a number for crown spread.

More in-depth discussions of taking tree measurements can be found in the following publications: American Forests Champion Trees Measuring Guidelines Handbook and The Tree Measuring Guidelines of the Eastern Native Tree Society.[25][26]

Review Questions

1. There is one standard recognized dichotomous key to identify trees. (T/F)
2. Why is the family level of taxonomy classification important in gardening.
3. A group of living things can interbreed if they are in the same ____________ (level of taxonomy).

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25. Leverett, R., Bertolette, D. (2015). *American Forests Champion Trees Measuring Guidelines Handbook.* https://www.americanforests.org/wp-content/uploads/2014/12/AF-Tree-Measuring-Guidelines_LR.pdf
26. Blozan, W. (October 1, 2004). *The Tree Measuring Guidelines of the Eastern Native Tree Society.* http://www.nativetreesociety.org/measure/Tree_Measuring_Guidelines-revised1.pdf

4. What is the difference been gymnosperms and angiosperms?
5. What is the difference between monocots and dicots?
6. The division of familiar trees that are gymnosperms are called _________.
7. What are the differences and similarities between the Cypress and Pine Families?
8. The most obvious common characteristic of the Fabaceae Family is ___________.
9. The _______________ is well-known tardily deciduous tree with smooth silver bark.
10. What tree genus has with a wide diversity of leaf shapes, can be either evergreen or deciduous, and a large number of species in Virginia?
11. What once dominant tree species has been devastated by a blight and now is only seen as sprouts from stumps?
12. Pinnately compound leaves are characteristic of what tree family?
13. What are the two most ancient tree families, one dating back 100 million years and the other going back 200 million years? Contrast the primary characteristics of these two families.
14. Many of our most common fruits come from plants in the _____________ family.
15. Aspirin is made from compounds found in trees from the ______________ family.
16. Maples were traditionally considered a tree family but now are a genus within the ___________ family.
17. What tree is the only species remaining in its family?
18. What two tree species both produce 1 inch seed balls? Contrast the balls.
19. The largest trees of their species are documented in what registry?
20. What are the three dimensions measured for trees?

CHAPTER 6: SOIL PROPERTIES AND MANAGEMENT

"The dirt on Virginia soil"

"To fertilize or not to fertilize, that is the question." (With apologies to Shakespeare)

Chapter Contents:

Introduction

Our Virginia soils differ based on soil forming factors and physiographical location. Geological impacts of the tectonic plate interactions, weathering, climate, hydrology, ocean level, and human utilization of the land has changed the particle sizes, mineral content, and microflora of soils across the state. This chapter provides an overview of the formation of natural Virginia soils, nutrient content, and characteristics of the soils, their geographical distribution, and the effects of human interventions: farming, silviculture, and urban/city development on the soil.

Due to previous land utilization or urban/city development activities, soils often need to be amended to adjust the pH, balance the nutrients, reduce soil compaction and design drainage issues in order to promote vigorous disease-free tree growth.

Learning Objectives

Upon completing this chapter, the student should be able to:

1. Identify physiographical provinces of Virginia,
2. Identify soil types, and their properties
3. Determine the soil type, mechanical manipulations, and nutrient amendments that will be required to support successful tree growth in a natural or urban/city (landscaped or managed) site based data obtained by soil analysis.

Review: VCE Master Gardener Handbook 2015 (9/18 update)

- Chapter 3 Soils and Chapter 4 Nutrient Management and Fertilizers.

Soil Formation and Properties

Soil properties are the effects of physical, chemical, and biological processes determined by the parent material, climate, topography, organisms, time, and human intervention.

Physical Properties

Texture indicates the relative content of various sizes of particles in the soil. Sand is 0.05 mm – 2mm (Made of small rock fragments from the size that fits inside of your fingerprint grooves to less than about 1/8 inch.), silt is 0.002 mm – .05 mm (even smaller rock fragment particles), and clay is <0.002 mm (a microscopic secondary mineral that has complex structure and is very attractive to water and nutrients and other ions in the soil. Iron oxides are clays as well.). Texture influences the ease with which soil can be worked, the amount of water and air it holds, and the rate at which water can enter and move through soil. Texture is considered to be a permanent property. Total surface area increases as particle size decreases. Clays have higher surface area than sands.

Structure refers to the arrangement of soil particles into units called soil aggregates. An aggregate possesses solids, pore space, microbes, animal organisms, and sometimes live roots. Soil structure can be permanently damaged or destroyed by plowing or compaction but can also be restored with rough physical processes such as freeze-thaw or wet-dry cycles or through the addition of organic matter and the activity of organisms that increase pore space.

Figure 6-1 Sand, silt, clay and organic matter bind together to provide structure to the soil. The individual units of structure are called peds. (John A. Kelley, USDA Natural Resources Conservation Service, via Soil Science on Flickr)

Texture + structure influence = soil behavior

Organic Matter consists of plant and animal residues at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized and exuded by soil organisms. Stable, highly decomposed organic matter is called humus.

Compaction is the process in which a stress applied to a soil causes loss of pore space, such as equipment traffic on wet soils. The measure of soil bulk density, which is the ratio of dry weight of a soil sample divided by its volume, determines the bulk density or compaction. As the dry weight increases relative to the volume, porosity in the soil decreases and compaction increases. This situation restricts root, air and water movement and leads to plant stress. Urban soils tend to be moderately to heavily compacted because of the amount of traffic they receive during construction or landscaping.

Drainage removes excess free water from the soil. Water-filled soil pores may become depleted of oxygen over time and the water prevents air and oxygen from getting to plant roots from the atmosphere.

Color is mainly produced by the minerals (or lack thereof) and water present and by the organic matter content. In general, darker colors indicate higher humus content; redder colors indicate higher iron oxide content and good drainage; and gray colors indicate long-term water saturation.

Odor of productive soils (aerobic) should smell fresh, clean and pleasant or have little odor at all. If the soil smells like ammonia or has a rotten egg odor that is a good indication there is poor drainage or lack of oxygen in the soil (anaerobic).

Temperature is the measurement of the warmth in the soil. Ideal soil temperatures for most plants are 65 to 75 F.

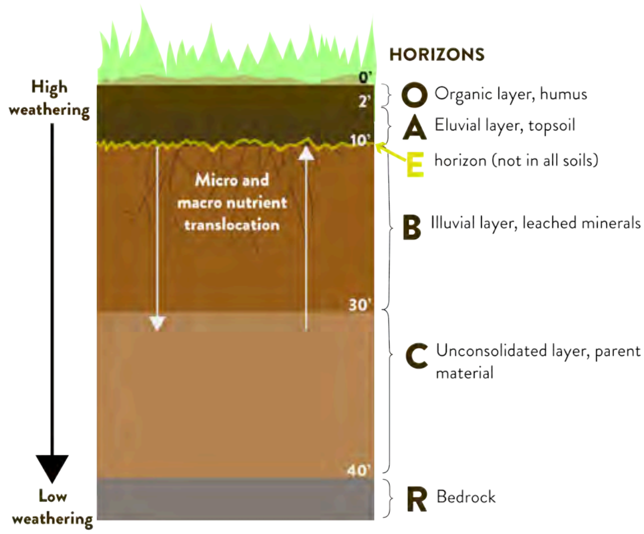

Figure 6-2 Soil horizon diagram

The layers of soil are called horizons. They are not in any finite order. Nature and man often change the order. Soils develop from the chemical and physical weathering of rocks. Soil profiles typically have a top layer of decaying organic matter formed by leaves and other debris deposited by plants. This layer is also called the 'O' horizon. Below organic matter is topsoil, the 'A' horizon, which can range in depth from a few inches to several feet. This layer consists of decomposed organic matter and minerals. It is usually dark brown or reddish brown in color. This is where most tree roots concentrate for healthy growth, due to nutrients, oxygen, and water. 'B' horizon is the mineral subsurface. It is an accumulation of clay, soluble salts and/or iron.' C' horizon is the parent material of the area usually glacial till, sediments, and bedrock.

Figure 6-3 This photo was taken in Pima County, Arizona. The soil is formed from granite rock and creep material on a 35% slope at an elevation of 7,240 feet. The soils support sparse stands of Ponderosa Pine. (Stan Buol, USDA Natural Resources Conservation Service, via Soil Science on Flickr)

All tree roots require three soil elements: water, oxygen, and soil compaction levels low enough (or with void spaces sufficiently large enough) to allow root penetration. If all these conditions are met, and the tree has the genetic potential, roots can grow to great depths. Under ideal soil and moisture conditions, roots have been observed to grow to more than 20 feet (6 meters) deep.[1] In many urban/city planting sites ideal root-growing conditions often require restoration efforts.

In most soil profiles, the largest numbers of roots are found in the 'A' and 'B' Horizons.

Chemical Properties

There are 17 known **essential elements** for plant nutrition. In relatively large amounts, the soil supplies nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur. The majority of these

1. Schneider, C. (2014). *Encouraging Urban Tree Growth with Organic Soil Amendments*. Soil Science Society of America. www.soils.org

elements are taken up by plants in ionic form, many of which are cations which have positive charges. Nutritional cations include potassium (K^+), calcium (Ca^{++}), magnesium (Mg^{++}), and ammonium (NH_4^+). Other cations include hydrogen (H^+) and sodium (Na^+). Aluminum (Al^{3+}) is also a potentially toxic cation that is more readily taken up as pH becomes more acidic. Phosphorus forms many net negatively charged compounds called anions. An example is $P_2O_5^{-2}$, a dehydrant.

Cation Exchange Capacity (CEC)

The Cation Exchange Capacity (CEC) is a measure of the net negative charge per unit of clay. Nutrient cations are readily attracted to clay particles which have a net negative charge. A water molecule's positive polar ends are also attracted to clay. Humus also has a high CEC and may also be adsorbed to clay. If the CEC is too low, cations and water are not adsorbed strongly and are easily drained or leached away. Soils with little clay, such as sand textures, and highly weathered clays and oxides have very low CEC. The CEC determines a soil's ability to adsorb nutrients, and is related to potential fertility. Although many factors affect cation exchange between the clays or humus and the plants, we are most interested when nutrient cations and anions are exchanged across root cell walls and taken into the root. The plant root releases hydrogen ions, which then replaces the cations in the soil for uptake into the plant. Uptake of phosphate anions requires some energy expenditure by the plant.

pH is a measure of the acidity and alkalinity in soils on a scale of 1 to 14. The optimal pH range for most trees is between 5.5 and 6.5.

Salinity is the salt content in the soil. Sulfates, carbonates, and chlorides are salts.

Heavy Metals are lead, chromium, arsenic, zinc, copper, cadmium, mercury and nickel. "They rarely cause problems with plants at the levels found in urban soils."[2] Heavy metals such as zinc and copper are also micronutrients essential to plant health and development.

2. Gilman, E. (1997). *Trees for Urban and Suburban Landscapes*. Delmar Publishers.

Biological Properties: Aerobic, Anaerobic, Fauna, Microflora

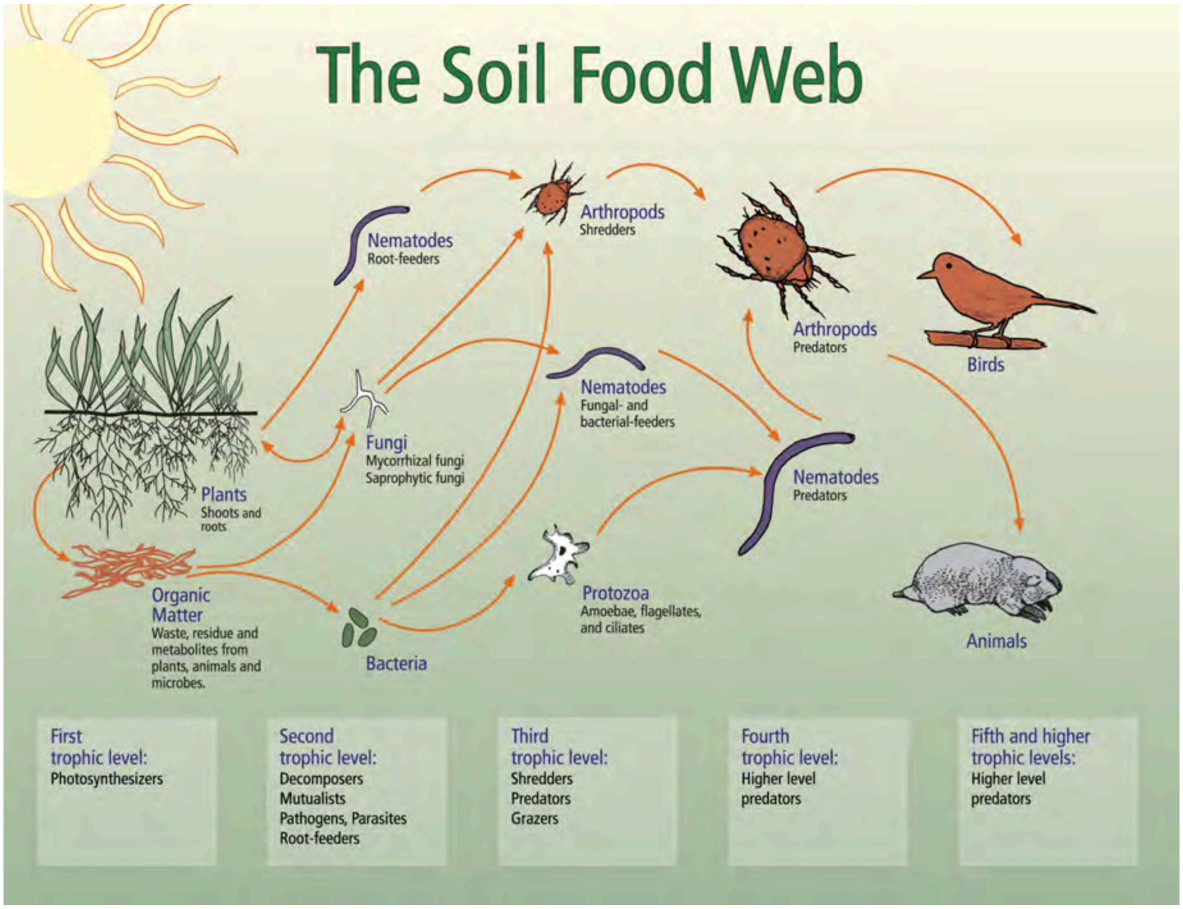

Figure 6-4 Biological Properties of Soil (Courtesy USDA-NRCS)

Microbial soil crusts play an important role in regulating nutrient cycling, biomass production, soil stability, and water infiltration. More in-depth information on the soil food web is available in the Master Gardener Training Manual.

Virginia Physiographical Provinces and Soil Orders

Numerous geological tectonic plate interactions and climate extending variations from 250 to 540 million years ago resulted in a great variation in geologic resources. Virginia has a very diverse physiographical landscape. Virginia is divided into five main physiographical provinces as a result. Soils have developed from a broad range of parent rock and vegetation materials. Soils are not static and are constantly being moved and changed by gravity, water, wind, and man. "Consequently, the numerous classified soil types that cover the state exhibit great variation in depth, textural and mineral composition, organic matter content, water-holding capacity, pH, fertility, and other characteristics. Drastically different soils may occur within the same landscape. Several soils may occur together within a field of a few acres."[3] This is not necessarily the case with urban soils areas where soils have been variably changed by human interaction.

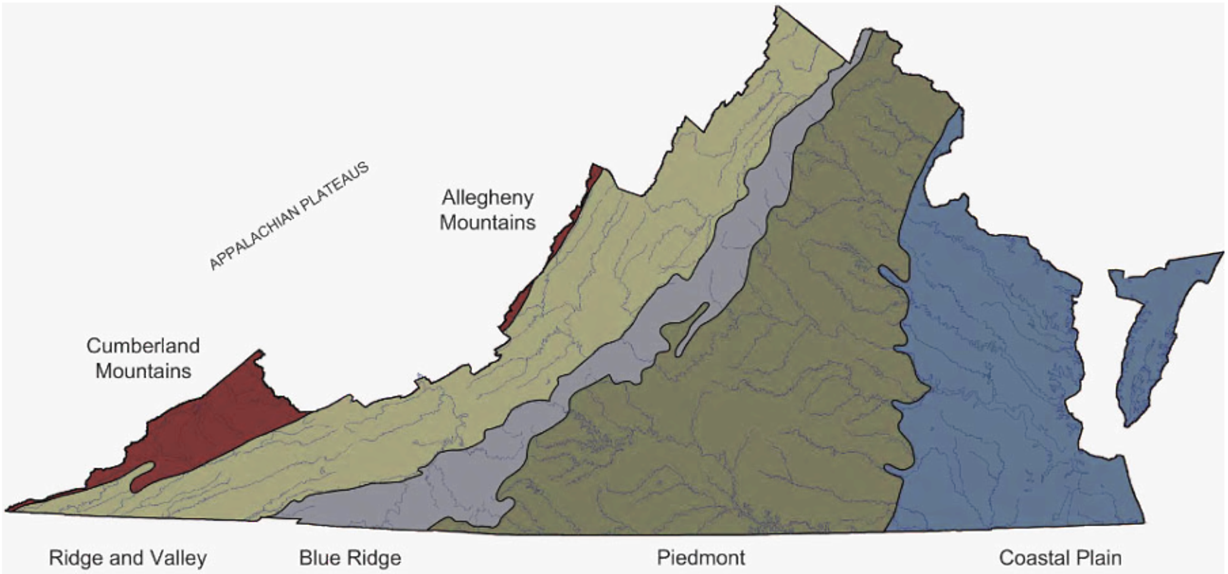

Figure 6-5 Virginia Physiology Map (Courtesy Virginia Department of Conservation and Recreation)

The Cumberland Mountains province (also known as the Allegheny Plateau) covers a portion of Southwest Virginia in Lee, Wise, Dickinson, and Buchanan Counties. Broad summits are deeply dissected by steep, narrow valleys. Level bedrock is dominantly sandstones under the summits and sandstone interbedded with siltstones, shale, and coal below. The area is largely forested with temperate broadleaf and mixed forests. Ultisols dominate on more gentle slopes while Inceptisols occur on steeper areas and along streams. Entisols occur in very gravelly active stream and river floodplains.

The Ridge and Valley province is a series of roughly parallel long narrow ridges and valleys along the western edge of the Commonwealth. The highest ridges are underlain by resistant sandstones and conglomerates, with shales on sideslopes, while the valleys are underlain by more easily weathered limestones, dolomites, and shales. Thick deposits of colluvium occur on mountain footslopes. The Shenandoah Valley is very fertile and has been dominated by agricultural land uses for centuries, while the steeper ridges have often remained in forestland[4]. Soils supporting mixed forest growth, Ultisols and Alfisols occur on gentle slopes and Inceptisols occur on shallow soils near rock outcrops, in and very steep areas and in some floodplains. Mollisols occur in some floodplains with significant limestone in the watershed.

3. Natural Resource Conservation Service. (2017). *Published Soil Surveys for Virginia.* https://www.nrcs.usda.gov/wps/portal/nrcs/surveylist/soils/survey/state?stateId=VA
4. FIsk, S.V. (2015). Farming Lessons from Mother Nature. Soil Science Society of America. https://www.soils.org/discover-soils/story/farming-lessons-mother-nature

The Blue Ridge province consists of a narrow, irregularly weathered series of peaks underlain by a core of resistant granites, gneisses, and greenstone, with resistant metasedimentary rocks (quartzite, metasiltstone, and phyllite) exposed on the western flank.[5] Much of the area is forested and species vary tremendously with elevation, aspect, soil, and disturbance history.[6] The highest elevations such as the Grayson Highlands support Spruce/Fir and the lower regions support temperate broadleaf and mixed forests. Soils found in these areas are usually Inceptisols on the higher peaks and Ultisols on lower slopes and in coves.

The Piedmont province comprises the central one-third of the Commonwealth. It is a rolling to hilly landscape that lies between the Blue Ridge on the west and the Coastal Plain on the east. Most of the province is covered by a thick mantle of soil with soft, highly decomposed former bedrock underneath, often rich in clay and mica. Deep weathering and leaching for millions of years caused loss of many of the original chemical constituents, notably base metals. The Triassic Basins (former rift valleys that occur scattered across the Piedmont) are filled with transported sediments that formed into shales, siltstones, sandstones and conglomerates."[7] The area was extensively cleared and farmed until the Civil War. Many soils are badly eroded from that time. Forests are mixed hardwoods and evergreens, with many loblolly pine plantations. Soils are predominately Ultisols with some Inceptisols near streams. Alfisols and Ultisols occur in the Triassic basins.

The Coastal Plain province covers the eastern one-third of the Commonwealth east of the Piedmont and the Fall Line. The soils formed from transported materials eroded from the other provinces and deposited in rivers or in the ocean. Bedrock is buried very deeply. The terrain is gently sloping except along streams. The forests are mixed hardwoods and evergreens, with many loblolly pine plantations on uplands and swamps along most floodplains. Most older soils are Ultisols and younger soils are Alfisols, with some Histosols in marshes along estuaries, Entisols along ocean shorelines, and Spodosols along sandy river systems such as the Blackwater River.

(**Note:** For a listing of trees that grow naturally in the different physiographical regions of Virginia refer to: Virginia Department of Conservation and Recreation, Division of Natural Heritage. "Overview of the Physiography and Vegetation of Virginia").[8]

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5. Natural Resource Conservation Service. (2017). *Published Soil Surveys for Virginia.* https://www.nrcs.usda.gov/wps/portal/nrcs/surveylist/soils/survey/state?stateId=VA
6. School of Forest Resources & Conservation UF/IFAS. (2017). *Forest Soils and Landscapes.* dendro.cnre.vt.edu/forestbiology/htmltext/chapter7new.htm
7. . Natural Resource Conservation Service. (2017). *Published Soil Surveys for Virginia.* https://www.nrcs.usda.gov/wps/portal/nrcs/surveylist/soils/survey/state?stateId=VA
8. . Natural Resource Conservation Service. (2017). *Published Soil Surveys for Virginia.* https://www.nrcs.usda.gov/wps/portal/nrcs/surveylist/soils/survey/state?stateId=VA

Soil orders are based on 2 or more physical or chemical characteristics that differentiate them from one another. Soil surveys of the state's naturally occurring soils indicate 7 of the 12 USDA, NRCS soil orders are prevalent throughout the state. These are in the order of occurrence in Virginia by percentage:

- **Ultisols** (last formed) are highly weathered and strongly leached, infertile mineral soils with significant subsoil clay accumulation that formed under deciduous, coniferous, or mixed forest and woodland vegetation. Farming, silvopasture, and silviculture requires inputs of lime and fertilizer.
- **Alfisols** are moderately leached soils with significant subsoil clay accumulation and relatively high natural fertility. These soils have mainly formed under forest and have a subsurface horizon in which clays have accumulated. The higher mineral content results in a more productive soil and permits a greater variety of crops than Ultisols.
- **Inceptisols** (beginning) are mineral soils of relatively new in origin and are characterized by having subsoil horizons just beginning to exhibit a moderate degree of soil development. Inceptisols lack significant clay accumulation in the subsoil and may be naturally fertile or infertile.
- **Entisols** (newly formed) exhibit little soil development other than the presence of an identifiable topsoil horizon. These soils occur in unstable environments of recently deposited sediments such as active flood plains, dunes, and landslide areas. They may be naturally fertile or infertile.
- **Mollisols** (soft, deep, fertile) are the soils forming in alluvium eroded from limestone and dolomite bedrock. They are characterized by a thick, dark surface horizon which results from the long-term addition of organic matter. Mollisols are extensively used for forests in Virginia but are among the most productive and fertile soils of the world. They occur in flood plains draining limestone and dolomite such as the Shenandoah, Roanoke, and James River.
- **Spodosols** (sandy, acidic) have a strongly leached surface layer and a subsoil in which an amorphous mixture of organic matter and aluminum, with or without iron, accumulates in a subsoil horizon. Most Spodosols have little silicate clay and have the appearance of white sugar sand. These are soils formed under coniferous forests such as the longleaf pine growing near Zuni.
- **Histosols** (organic, wet) are deep, poorly drained organic soils consisting of muck, peat, or mucky peat. They are usually highly deficient in plant nutrients and often highly acidic. Most of these soils are saturated year-round and occur in marshes and low-energy swamps along some estuaries.

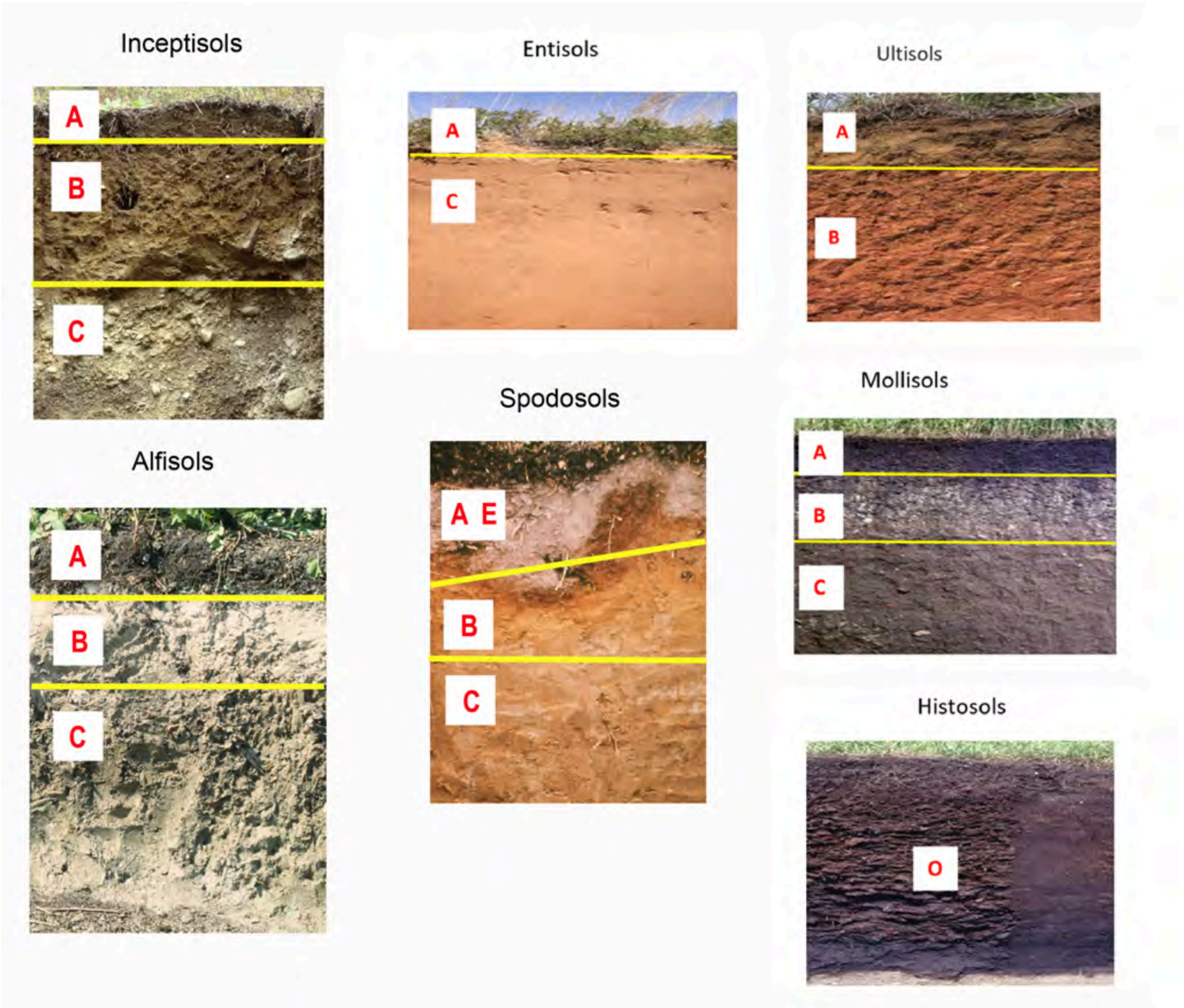


Figure 6-6 Soil Order Pictures (Courtesy USDA-NRCS)

The following diagram shows general degree of weathering and soil development in different soil orders. Also shown are the general climate and vegetative conditions under which soils in each order are formed.[9] Virginia soil orders are indicated with boxes.

9. Brady, N., Wei, R. (2007). *The Nature and Properties of Soils* (14th ed.). Prentice Hall.

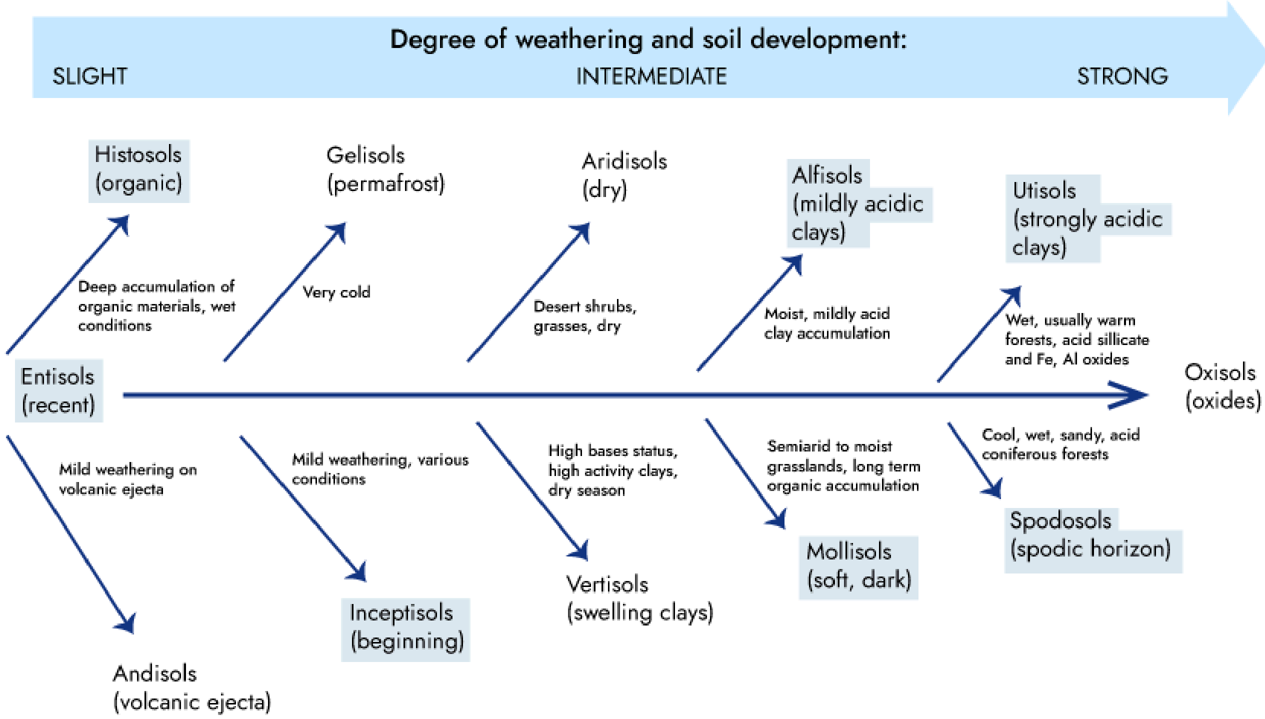
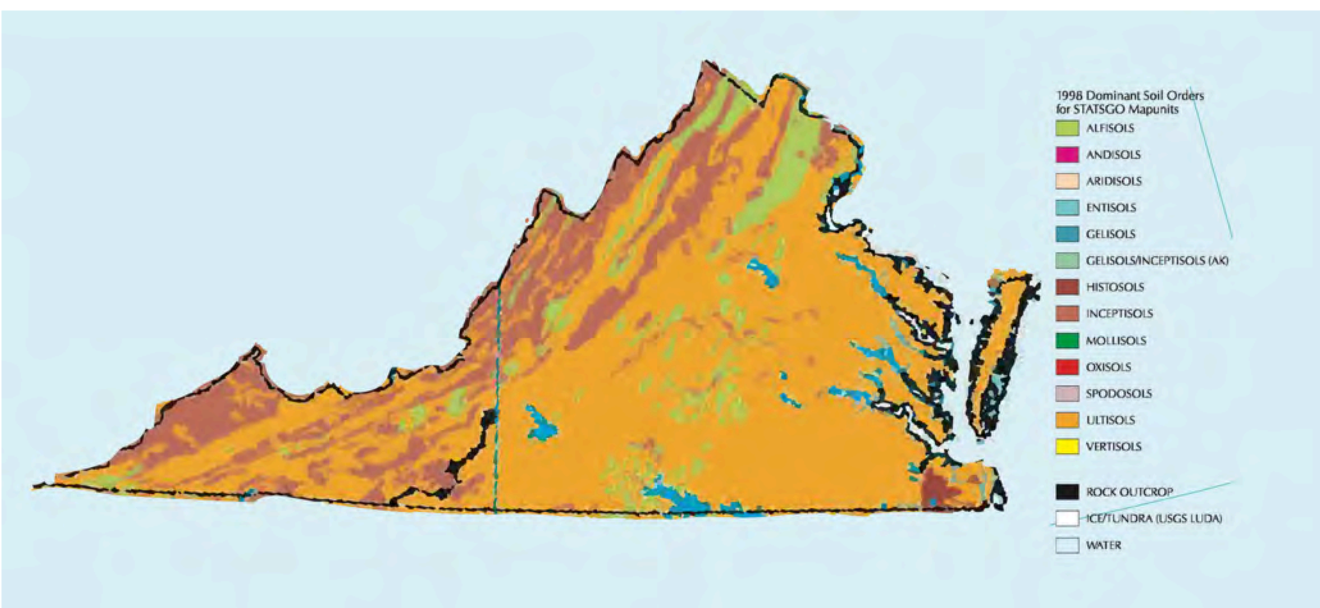


Figure 6-7 Degree of weathering and soil development. Blue shaded boxes indicate presence in Virginia. (Courtesy Gwen Harris)



6-8 Virginia's dominant soil orders

Interactive survey map allowing drilling down to specific addresses: https://casoilresource.lawr.ucdavis.edu/see/

Copy of Table 6-1 Distinguishing Factors of Virginia soils

Soil Order	Characteristics of Horizon and Color	Chemical Composition	Tree Growth Requirements
Ultisols	'A' is leached, pale 'B' has infertile clay accumulation. Red or yellow red due to insoluble iron oxides.	'A' Acidic (H^+, Al^{3+}) 'B' Low in base cations: Ca^{2+}, Mg^{2+}, and K^+ Base Sat. <35% pH ∞5.0	Dominant soil throughout the oak-pine range. Require inputs of lime and fertilizers.
Alfisols	'A' is brown to dark gray 'B' has moderately fertile clay accumulation.	'A' Acidic: Al^{3+}, Fe^{2+} 'B' High in basic cations: Ca^{2+}, Mg^{2+}, K^+, Na^+ Cation sat. >35% pH ∞6.0	Deciduous forest of oak-hickory.
Inceptisols	Weak, brown 'B' horizon development.	Varied pH ∞6.0	Mixed or hardwood forest in the Eastern States.
Entisols	No 'B' horizon development. Light colors, often very sandy or gravelly.	Varied pH ∞7.0	Fertile in flood plains, others must be enhanced.
Mollisols	Thick, dark, fertile, high carbon 'A' horizons.	High in basic cations: Ca^{2+}, Mg^{2+}, Na^+, and K^+ Base sat. >50% Very high in Ca^{2+} pH ∞7.0	Very fertile floodplain soils supporting sycamore, ash, hickory, cedar, and oak.
Spodosols	'A' is light-colored sand. 'B' is very dark, accumulations of humus-Al, with or without Fe.	Acidity: H^+, Al3 Makes Organic Acids 'B' Low in basic cations: Ca^{2+}, Mg^{2+}, and K^+) pH ∞5.0	Limited to acid-tolerant crops and orchards. (Dogwood, Beech Pin oak, Willow oaks Magnolia, Longleaf pine).

Table 6-1 Distinguishing Factors of Virginia soils (continued)

Soil Order	Characteristics of Horizon and Color	Chemical Composition	Tree Growth Requirements
Histosols	Saturated, dark colored organic materials usually more than 20% organic carbon.	High Carbon content pH ∞4.0	(Red maple, black willow aspen, cottonwood, ashes, elms, swamp white oak, pin oak, tupelo and birches).

No discussion is complete without mention of **calcareous soils** which contain an excess of calcium carbonate and have pH typically in the range of 7.2 and 8.5. Calcareous soils are found in dry calcareous forests in the Ridge and Valley area in the mountains of western Virginia. Calcareous fens and spring marshes, small-patch wetlands that developed over limestone or dolomite and are saturated by calcareous groundwater, are limited in Virginia to a few sites in carbonate rock districts of the Ridge and Valley area.[10] Trees are typically dominated by oaks, hickory, ash, and Eastern Red Cedar.

Coastal Plain Dry Calcareous Forests form a group of rare, deciduous (rarely mixed) forests and woodlands of fertile habitats over unconsolidated, calcareous deposits. In Virginia, occurrences are small and highly localized in two environmental situations: 1) steep, convex, south-facing slopes of dissected ravine systems and river-fronting bluffs of the inner Coastal Plain from southeastern Virginia north to Stafford County; and 2) steep cut-slopes bordering estuaries on the outer Coastal Plain. In the first setting, slopes have downcut into Tertiary shell deposits or limesands, producing circumneutral to slightly alkaline soils. In the estuarine settings, shell middens may provide the primary source of substrate calcium. The majority of documented stands are on The Peninsula near Williamsburg (James City and York Counties).[11]

Trees that tolerate calcareous soils include sugar maple (*Acer saccharum*), yellowwood (*Cladrastis kentukea*), Chinkapin oak (*Quercus muelenberghii*), elms (*Ulmus* spp.), American hornbeam (*Carpinus caroliniana*), European hornbeam (*Carpinus betulus*), redbud (*Cercis canadensis*), black walnut

10. Flemin, G.P., Patterson, K.D., Taverna K. (2017). *The Natural Communities of Virginia: a Classification of Ecological Community Groups and Community Types.* Virginia Department of Conservation and Recreation, Division of Natural Heritage, Richmond, VA. http://www.dcr.virginia.gov/natural-heritage/natural-communities/
11. Flemin, G.P., Patterson, K.D., Taverna K. (2017). *The Natural Communities of Virginia: a Classification of Ecological Community Groups and Community Types.* Virginia Department of Conservation and Recreation, Division of Natural Heritage, Richmond, VA. http://www.dcr.virginia.gov/natural-heritage/natural-communities/

(*Juglans nigra*), sycamore (*Platanus occidentalis*), hophornbeam (*Ostrya virginiana*) and lindens (*Tilia* spp.).[12]

Effects of Land Utilization on Soil

Now that the naturally occurring types of soils have been discussed, what happens with the intervention of man: farming, silviculture, and urban and city development activities?

In Virginia there are large tracts of soils highly modified by humans, including soils of urban and suburban developments, landfills, transportation corridors, and mined lands. These soils may contain artifacts such as garbage or brick, concrete, or asphalt. They are typically higher pH than surrounding soils and may exceed pH 7.0. Other modified soils are either deeply excavated or deeply filled, with few to numerous rock fragments. Development is minimal like Entisols and Inceptisols, except where the soils are excavated versions of Ultisols and Alfisols. Trees are typically introduced and many are invasive.

When planting trees, if the soil quality is ignored the chances of growing the long-lived, large, healthy trees are greatly reduced[13]. A soil analysis and site history should be performed prior to plantings in order to provide the most appropriate growing conditions.

Note: For a detail soil analysis of the Virginia counties visit USDA NRCS, Soils.[14]

What has happened to our soil due to human intervention? "In 1630, forest covered 96% of Virginia's land area. Over the first 230 years of European settlement much of the land was cleared for agriculture at one time or another, especially in the Coastal Plain and Piedmont. On poorer soils, attempts at cultivation were usually short-lived, and those areas reverted to forest. Thus, during this initial 230-year period of settlement, an average forest cover of 40–60% was maintained across Virginia (Scirvani 2003). Areas left in forest were cut for domestic uses and commonly subjected to free-ranging cattle and hogs (Woodward and MacDonald 1991; Martin and Boyce 1993). Soil depletion and erosion during this time were severe and led to massive sediment loading in floodplains and bottomlands. During the nineteenth century, accessible oak forests in the Ridge and Valley, Blue Ridge, and northern Piedmont were repeatedly cut for tanbark and processed into

12. Flemin, G.P., Patterson, K.D., Taverna K. (2017). *The Natural Communities of Virginia: a Classification of Ecological Community Groups and Community Types.* Virginia Department of Conservation and Recreation, Division of Natural Heritage, Richmond, VA. http://www.dcr.virginia.gov/natural-heritage/natural-communities/
13. Urban, J. (2008). Up by Roots. ISA.
14. Reiter, E. (2019). *A Multidisciplinary Approach to Conservation.* Virginia Cooperative Extension. https://www.pubs.ext.vt.edu/content/dam/pubs…/2910-1417_pdf.pd

charcoal to fuel the furnaces of an active iron industry (Orwig and Abrams 1994; USDA Forest Service unpublished data). Most of the older forests remaining in the Piedmont and Coastal Plain at the time of the Civil War were destroyed to fill both armies' prodigious needs for construction lumber and firewood. Natural, accidental, and intentionally set fires continued to burn forests and fields at irregular intervals throughout this era, since there were no effective ways of stopping or controlling them once started."[15]

Agricultural activities associated with growing crops and raising livestock affects the physical and chemical composition of soils. Below depicts how plowing changes the soil horizons over time.

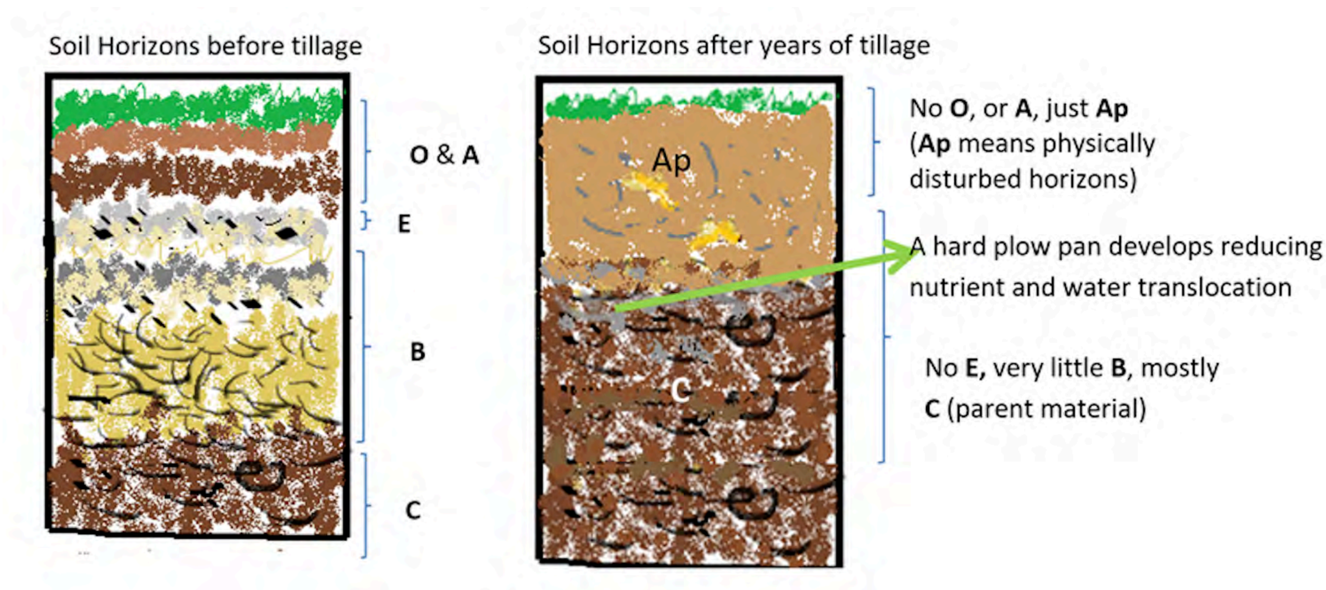


Figure 5-2 Taxonomy of Gymnosperms (Courtesy Patsy McGrady)

Plowing

Grassland soil into crop fields results in a release of nutrients that slowly declines, much like slash-and-burn agriculture. All tillage operations, including aeration and lifting, cause direct damage to soil macrofauna (moles, mice, earthworms…) and potentially expose them to new predators. Increased intensity of tillage is usually linked to disruptions in the habitat space for soil organisms and a decrease in the time the soil is covered by a growing plant (whether trees, crops, or weeds). There is evidence that the food web of soil organisms under farmed fields is less robust than that found under heaths and woodlands.

15. Natural Resource Conservation Service. (2017). *Published Soil Surveys for Virginia.* https://www.nrcs.usda.gov/wps/portal/nrcs/surveylist/soils/survey/state?stateId=VA

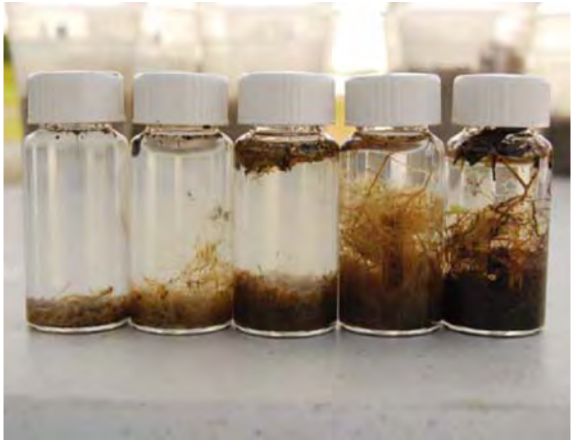


Figure 6-10 Organic Tillage (Courtesy Charles White, Penn State Extension)

"Particulate organic matter such as this contains organic forms of nutrients which can be made available to plants through microbial decomposition processes. Vials to the left of center had increasing levels of tillage in the crop rotation while vials to the right of center were from un-tilled soils under permanent grass sod and forest. The vial in the center is from a continuous no-till field with annual crop rotation." From Penn State "Managing Soil Health: Concepts and Practices", 2012.[16]

Farmland or grasslands that are well managed have an "A" horizon soil with enough organic matter to supply plant nutrients, increases soil aggregation, limits soil erosion, and also increases cation exchange and water holding capacities, all of which are ideal for trees and other plants. Early growth of trees on former farmland may be greatly enhanced by treatments associated with the previous land use, such as fertilization or cultivation of an agricultural crop, and by post planting control of competing vegetation. One of the best known examples of the association of tree growth with previous land use is the "old-field effect" on the growth of loblolly pine (*Pinus taeda*) plantations in the southeastern United States. The effect was named when it was noticed that pine seedlings planted on old fields often grew faster than those planted between 1957 and 1963 on cutover sites. A similar phenomenon known as the "pasture effect", that is, there is better tree growth on land previously in pasture than on sites previously in tree cover.[17]

Farmland used as **pastures** and feedlots where the trampling, pawing, and wallowing by hoofed farm animals disturb the soil and in some cases completely destroy the soil crusts. The most severe effect of trampling is the compaction of soils which damages plant roots. These changes may prevent plants from acquiring sufficient resources for vigorous growth and causes roots to become concentrated near the soil surface. Heavy livestock such as cattle compact soil structure and destroy vegetation on parts of a field that they tread most often. Physically damaged soil can be even more susceptible to the chemical and biological impact of feces and urine. Destruction of soil structure

16. Penn State Extension. (2012). *Managing Soil Health: Concepts and Practices.* https://extension.psu.edu/managing-soil-health-concepts-and-practices
17. Murray, M., Harrington, C. (2017). Y*ield Comparison of Three Douglas-Fir Plantations on Former Farmland in Western Washington.* USDA Forest Service, Forestry Sciences Laboratory. https://www.fs.fed.us/pnw/olympia/silv/publications/opt/341

can be harmful because restoration of vegetation does not always occur spontaneously once the grazing animal is withdrawn.[18]

Forest soils, both natural and silvicultural, provide important functions:

- "Providing water, nutrients, and physical support for the growth of trees and other forest plants.
- Allowing an exchange of carbon dioxide, oxygen, and other gasses that affect root growth and soil organisms.
- Providing a substrate for organisms linked with vital ecosystem processes.
- Harboring root diseases and other pests.
- Affecting water quantity and quality"[19]

In undisturbed forest soils under broadleaf trees, autumn leaf falls provide abundant and rich humus which begins to decay rapidly in spring, just as the growing season begins. Where parent materials are sandy, evergreen vegetation tends to dominate the landscape.

"Healthy forest soils act like a giant sponge, absorbing precipitation, holding water against the force of gravity, and then slowly releasing it. In actively managed (working) forests, road construction, soil compaction, and organic matter removal from harvesting and site preparation can change the amount and timing of water flows and cause excessive soil erosion with the consequence of degrading water quality and fish habitat. Forestry access and timbering roads, particularly those built to older design standards or that are not maintained are regarded as the cause of most of the soil erosion and stream sedimentation coming from managed forests."[20]

Timbering creates forest litter, including slash after logging. The litter ranges greatly in amount, size, nutrient content, and stage of decomposition.[21] Removing tree trunks may have little effect on site productivity, but "cleaning up" branches and foliage (i.e., slash) appears to have greater potential for nutrient removal than leaving them onsite. Decomposition after timber harvest frees

18. Franzluebbers, A., Stuedemann, J. (2017). *Soil Organic Matter Stratification with Depth under Pastures in the Southern Piedmont USA*. USDA. https://www.ars.usda.gov/research/.../publications-at-this-location
19. Helgerson, O., Miller, R. (2008). *Keeping Your Forest Soils Health and Productive.* Washington State University Extension. https://www.fs.usda.gov/treesearch/pubs/30437
20. Helgerson, O., Miller, R. (2008). *Keeping Your Forest Soils Health and Productive.* Washington State University Extension. https://www.fs.usda.gov/treesearch/pubs/30437
21. Helgerson, O., Miller, R. (2008). *Keeping Your Forest Soils Health and Productive.* Washington State University Extension. https://www.fs.usda.gov/treesearch/pubs/30437

mineral nutrients from organic matter, which increases mineral nutrient leaching until the site is revegetated.[22]

Forest fires, either natural or prescribed, heat the soil. Light, moderate, or intense fires affect the soil's physical, chemical, and biological properties and the amount of organic matter destroyed is directly related to the intensity of the fire. Soil nutrients are either lost by volatilization, or are transformed into highly available ions by the burning. Nitrogen, for example, is easily volatilized and lost during burning. The nutrients not volatilized: calcium, magnesium, potassium, sodium, and phosphorus-are released as highly mobile ions which can be metabolized rapidly either by plants or microorganisms on the sites, or can be lost by erosion and runoff. The effect of soil heating on micro-organisms is less well understood but, micro-organisms are affected lethally at much lower temperatures than those necessary to change nonliving organic matter.[23]

Although fires, either natural or prescribed, do change the soil characteristics, bear in mind that many tree species depend on fire for growth (removes competition), maturation (opens canopy), and release of seeds, triggered, in whole or in part, by fire or smoke. Virginia trees that depend on fires are certain pine species such as longleaf pines.

Timbering and burning can also affect the hydrology of cleared forest land, especially sloped areas. When tree roots are left to rot or are burned a "soil pipe" often occurs. This is like the "lost wax effect". Once the wood is gone a "pipe" remains. The presence of soil pipes can affect how water drains or flows through the soil and plays a role in soil erosion and hillslope stability. The presence of soil pipes can cause retained water to drain faster than normal, potentially causing flooding during the wet season and empty streams in the dry season.[24][25]

Soils produced by coal mines tailings, power plants fly ash and household and industrial waste sites are known as mined or **anthropogenic soils**.

"The amount of **coal refuse** in the Appalachian coal fields is difficult to estimate, but active disposal facilities cover thousands of acres, and abandoned refuse piles dot the landscape in almost every major watershed. A vigorous plant community can reduce water and oxygen erosion. Establishment

22. Helgerson, O., Miller, R. (2008). *Keeping Your Forest Soils Health and Productive.* Washington State University Extension. https://www.fs.usda.gov/treesearch/pubs/30437
23. Helgerson, O., Miller, R. (2008). *Keeping Your Forest Soils Health and Productive*. Washington State University Extension. https://www.fs.usda.gov/treesearch/pubs/30437
24. Kumar, S., Anderson, S., Udawatta, R. (2008, December). Agroforestry and Grass Buffer Influence on Macropore Measured by Computed Tomography under Grazed Pasture Systems. *Soil Science Society of America Journal. 74*(1), 203-212. www.soils.org
25. Maderick, R., Gaynon, S., Makuch, J. (2006). *Environmental Effects of Conservation Practices on Grazing Lands.* Agriculture Library ARS-USDA. https://www.ars.usda.gov/ARSUserFiles

and maintenance of permanent vegetation on refuse, however, is complicated by physical, mineralogical, and chemical factors."[26]

"Because of the inherently low fertility of refuse, vegetation establishment requires the addition of nitrogen, phosphorus, and potassium fertilizers. Currently, very little has been documented about the use of woody plants for the reclamation and revegetation of coal refuse. Industry experience indicates that black locust (*Robinia pseudoacacia L.*), white pine (*Pinus strobus*), and red pine (*Pinus resinosa*) can be successfully direct-hydroseeded onto conditioned refuse. "[27]

Reclamation of **chemical (toxic) waste sites** (brownfields) requires time and is costly. The contaminated soils must be removed and new soil brought in. Tree growth can occur and helps absorb the contaminants and heavy metals. Heavy metal residues do not usually affect tree growth but trees sequester and systemically distribute the heavy metals. Animals may be poisoned by eating parts or fruits of the trees. Of course, herbicidal waste will prohibit plant growth and must be neutralized.

Urban soils in "built environments" can be challenging to manage for non-invasive native tree production. The status of urban soil can be natural, anthropogenic, compacted, horizon disturbed, or a combination of all. The challenge is to provide an urban environment that functions like the natural environment. It is important to note that some trees are adaptable to a fairly wide range of environmental conditions while others have a narrow range in which they will grow well. All trees will grow well under near optimal conditions with a pH of 6.8 and consistently moist but well drained soil. However, we rarely find these conditions in the urban environment. Most urban soils have a higher pH (from near neutral to alkaline) than surrounding rural areas due to limestone-containing materials in the street environment.[28]

"The type of soil that a tree or shrub grows in can affect its nutrient needs. Soil texture and soil structure influence the amount of water, air, and nutrients held in the soil for plant use. Clay soils can be nutrient rich, but have a large amount of fine particles that tend to compact and restrict water and air movement. Sandy soils drain well, but contain many coarse particles that have little capacity for storing water, air and nutrients. Organic material can be thoroughly mixed into soils with high clay or sand contents to help improve soil structure. Repeated applications may be needed depending on the amount applied and the stage of decomposition or type of organic matter used.

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26. Daniels, W., Stewart, B., Zipper, C. (2000). *Reclamation of Coal Refuse Disposal Area.* Virginia Cooperative Extension. pubs.ext.vt.edu/460/**460-131**/**460-131**_pdf.pdf
27. Daniels, W., Stewart, B., Zipper, C. (2000). *Reclamation of Coal Refuse Disposal Area.* Virginia Cooperative Extension. pubs.ext.vt.edu/460/**460-131**/**460-131**_pdf.pdf
28. Bassuk, N., Curtis, D., Marranca, B.Z., Neal, B. (n.d.) *Recommended Urban Trees: Site Assessment and Tree Selection for Stress Tolerance.* Urban Horticulture Institute, Department of Horticulture, Cornell University. http://www.hort.cornell.edu

Organic material should be mixed into the soil up to several years before trees are installed to obtain maximum benefit."[29]

"Characteristics of soil in any urban area depend on many things. They depend on how deep the site has been excavated during construction and if new materials were brought in and mixed with the original soil materials. They depend on the properties of the original natural soil and the past uses of the site. Often the topsoil is removed from the site prior to construction and may or may not be returned to the site. After excavation, subsoil may be placed as fill over topsoil. Changing the order of the soil layers or mixing the topsoil and subsoil can alter soil properties. These variables make predicting soil behavior difficult in urban areas."[30] Tree root growth occurs mainly in the 'A' horizon which normally contains the most nutrients. If the horizons have been mingled or removed the planter must restore their beneficial properties.

Examples of the Factors That May Affect the Productivity of Urban Soil

- Little or no addition of organic matter.
- Artifacts that disrupt water movement.
- Elevated salt content.
- Interrupted nutrient cycling and modified activity of micro-organisms.
- High soil temperatures that increase the rate of chemical reactions.
- Generally higher pH values resulting from additions of cement, plaster, and road salts.
- Lateral (sideways) subsurface water flow resulting from compacted layers.

29. Trozzo, K., Munsel, J., Chamberlain, J. (2012). *Native Fruit and Nut Trees and Shrubs of the Virginia Mountain and Piedmont.* Virginia Cooperative Extension. https://pubs.ext.vt.edu/ANR/ANR-23/ANR-23NP.html
30. Schneider, C. (2014). *Encouraging Urban Tree Growth with Organic Soil Amendments.* Soil Science Society of America. www.soils.org

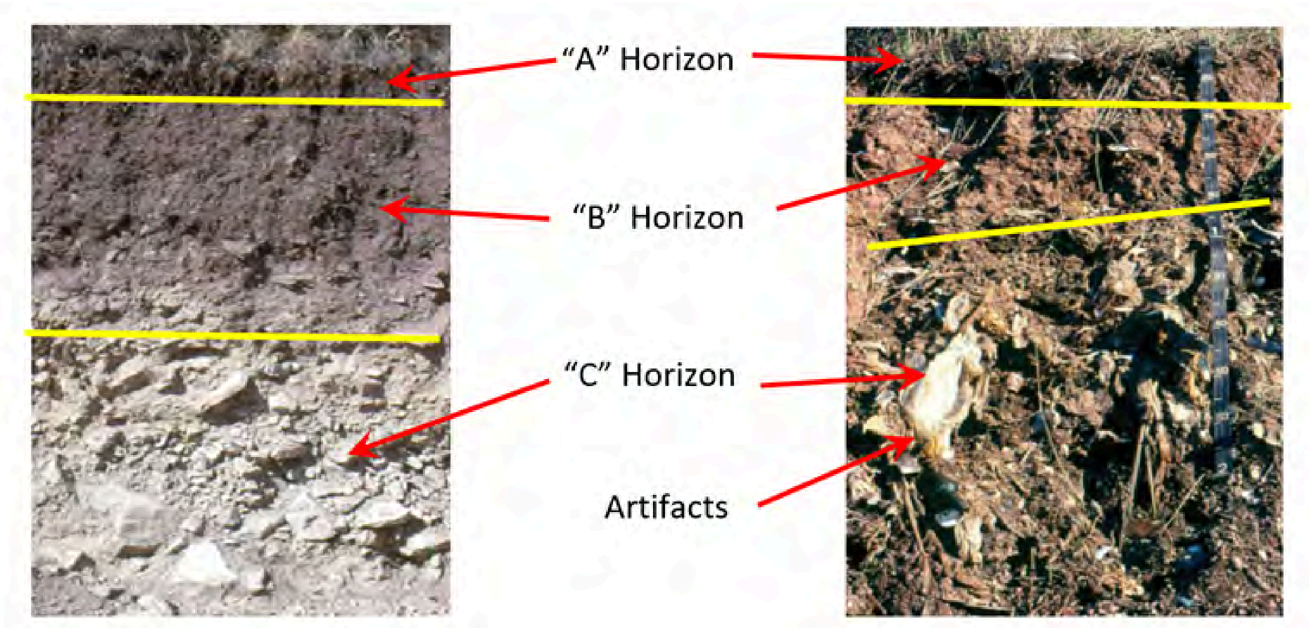

Figure 6-11 Natural vs Urban Soils: Natural Soil Sample (left), Urban Soil Sample (right) (Courtesy USDA-NRCS)

Urban or city soils containing artifacts are called **"Human-altered and human-transported"** soils . "They are characteristically heterogeneous and often suffer from [reduced organic carbon], excessive compaction, excessive artifact content, diminished biological activity, and increased run off [reduced infiltration rate]due to surface crusting or water repellency. They generally have elevated pH, exchangeable bases, and carbonate content. Levels of organic C^{+4}, N^{-3} and P^{-3} tend to be very low in recently deposited human transported material. Unaided, urban soils may take 30-100 years to reestablish properties similar to those of natural soils."[31]

The pictures below show disturbed urban soils in eastern Virginia.

31. Howard, J. (2017). *Anthropogenic Soils*. Springer International Publishing.

Figure 6-12 (Courtesy Chad Peevy)

Figure 6-13 (Courtesy Chad Peevy)

Artifacts often occur in soil altered or transported by humans.

Here are some artifacts in Virginia soil:

- Asphalt
- Concrete
- Metal
- Mechanically abraded rock fragments
- Brick
- Fertilizers
- Paper
- Mining and milling waste
- Cardboard
- Glass
- Plastic
- Combusted coal by products
- Carpet
- Heavy metals
- Pesticides
- Wood products
- Cloth
- Midden
- Rubber
- Salts

Horizon disturbance refers to the change of the natural soil horizon arrangement in the soil profile. Most of the changes occur by the removal of the top soil, dumping of construction waste, or compaction of site prior to tree planting. "Poor quality subsoil with fine texture or high clay content is often brought to the surface or used as fill soil."[32]"Tree growth enhancements may include overcoming physical and chemical root restrictions, water supply, and drainage to allow tree growth. The soil may require amendment to provide the nutrients to balance soil fertility and acidity (pH), and reduce the likelihood of contamination or disease problems."[33]

Compaction refers to the change in soil bulk density which is dependent on soil particulate matter size, moisture content of the soil, and the type or weight applying the pressure (human or vehicular traffic, construction equipment, and vibrations). Soil crusting occurs. "As soil particles are pressed together, root penetration, water infiltration, and drainage rates are reduced."[34]Compaction can be

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32. Gilman, E. (1997). *Trees for Urban and Suburban Landscapes.* Delmar Publishers.
33. Schneider, C. (2014). *Encouraging Urban Tree Growth with Organic Soil Amendments.* Soil Science Society of America. www.soils.org
34. Vawter, J., *et. al.*. (2009) *A Training Manual for Virginia Tree Stewards Volunteers for the Community Forest* (3rd ed.). Virginia Urban Forest Council. mcleantreesfoundation.org/documents/Tree%20Steward%20Training%20Manual.pd

reduced by mechanically deep tilling, vertical aeration (coring), or vertical mulching (digging trenches and backfilling with amended or original soil).[35] Care must be taken not to till the soil when wet or moist.

"Soil Profile Rebuilding is an appropriate soil restoration technique for sites where topsoil has been completely or partially removed and subsoil layers have been compacted (graded and/or trafficked by equipment) such as the staging areas near building or road construction sites. It may also be used with some modifications if topsoil is present. This is not an appropriate technique in sites with surface compaction only (6 inches or less), although this situation is rare on construction sites. This technique is not appropriate within the root zones of trees that are to be protected since it will break apart existing tree roots. Soil Profile Rebuilding can improve physical and biological characteristics of soil to allow for revegetation. It does not address soil chemical problems, soil contamination from heavy metals, pathogens, excessive debris or gravel."[36]

"One new tool for urban tree establishment is the redesign of the entire pavement profile to meet the load-bearing requirement for structurally sound pavement installation while encouraging deep root growth away from the pavement surface. The new pavement substrate, called 'structural soil', has been developed and tested so that it can be compacted to meet engineering requirements for paved surfaces, yet possess qualities that allow roots to grow freely, under and away from the pavement, thereby reducing sidewalk heaving from tree roots."[37]

Manmade Climate Change, Saltwater Intrusion, and Ghost Forests

At the beginning of the chapter the effects of climate and geologic factors were presented as the elements producing soil over millions of years. For centuries, man has made composition changes through agricultural and industrial activities. In the last 200 years there has been a rapid decline in coastal forests due to manmade climate change. Obvious change agents are sea level rise and saltwater intrusion into the eastern part of the state, resulting in increased soil salinity that kills trees, increases marshland, and creates ghost forests.

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35. Vawter, J., *et. al.*. (2009) *A Training Manual for Virginia Tree Stewards Volunteers for the Community Forest* (3rd ed.). Virginia Urban Forest Council. mcleantreesfoundation.org/documents/Tree%20Steward%20Training%20Manual.pd
36. Day, S., Wiseman, E., Dickerson, P., Sarah, B., Harris, R. (2010). Tree Root Ecology in the Urban Environment and Implications for a Sustainable Rhizosphere. *Arboriculture and Urban Forestry, 23*(5), 193-205. http://wiww.isa-arbor.com.
37. Bassuk, N., Curtis, D., Marranca, B.Z., Neal, B. (n.d.) *Recommended Urban Trees: Site Assessment and Tree Selection for Stress Tolerance.* Urban Horticulture Institute, Department of Horticulture, Cornell University. http://www.hort.cornell.edu

The pumping of fresh water from underground aquifers for agriculture and urban needs leads to saltwater intrusion. The inland water aquifers are gradually being affected all the way up to the natural fall zone between the piedmont and the coast. If water is pumped out faster than nature replenishes it, the water table levels decrease allowing salt water to fill the vacancy as shown in Figure 6-13.

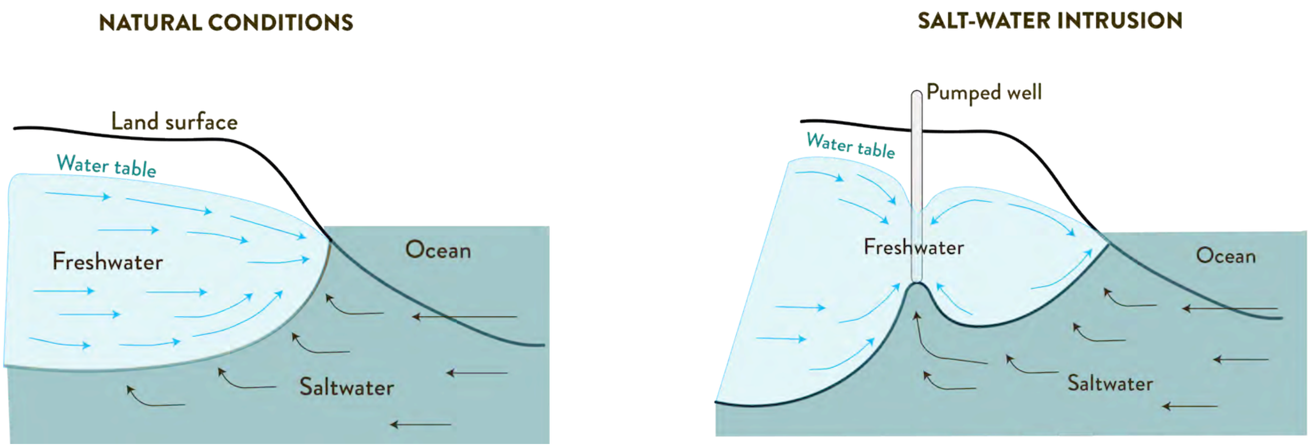

Figure 6-13 Saltwater Intrusion

The increasing salinity on the Atlantic Coast is due to multiple factors. The melting of the ice caps, the change in the gulf stream flow, increasing frequency of storms pushing sea water inland, gradual sinking of the shoreline due to geologic movements, the reduction of the underground aquifer water supplies, and inland droughts reducing the amount of fresh water flowing to the ocean all affect water salinity levels.

As salinity increases, the most sensitive trees succumb. The leaves and needles dehydrate, turn brown, and die. The foliar damage decreases the tree's ability to photosynthesize which gradually reduces root energy storage and results in death. Oak, hickory, and other hardwoods die first, then cedars, and finally loblolly pines. When the older trees die there are no replacements. Seeds and seedlings are more sensitive than older trees to the salinity increase; therefore, there are no undergrowth replacement trees.

Currently there are no mechanical means to prevent sea level rise or saltwater intrusion. Active reforestation research using more salt tolerant hybrids of coastal forest trees offers hope. Chapters Seven and Eight offer some more discussion.

6-14 Ghost forest (Courtesy Wing-Chi Poon, Wikimedia Commons)

Tree and Shrub Fertilization

Woodland trees, with their duff cover and canopy coverage, rarely need fertilizing if their environment has remained the same for an extended time, but trees in urban areas do not have the environmental advantages of woodland trees. Topsoil and the vegetative cover have often been removed while various mechanical injuries have resulted from digging for irrigation and utility lines or for buildings and pavement. There are many questions to consider when assessing the ability of a soil to grow trees. What amount of compaction is restricting root growth? Are tree roots in sites of limited soil volume? What contaminants are in the soil? Is the tree sharing root space with other trees? What is its nutrient content?

Sometimes fertilization can also stress a tree, so determining an urban tree's need for fertilization is not a lightly-made decision.[38] All fertilizers are salts which can increase the salinity of the soil. Fertilization may also decrease a tree's resistance to sucking and chewing insects because it's

38. Scharenbroch, B.C., Smiley, E.T., Kocher, W. (2014). *Best Management Practices Soil Management for Urban Trees*. International Society of Arboriculture.

energy is spent in growth at the expense of defensive chemicals.[39] Overfertilizing a soil can also lead to excessive vegetative growth on a tree at the expense of flower and fruit production, or release of excess nutrients to deep percolation or surface waters. Misuse of fertilizers may also add to other environmental issues which may need remediation to clean up subsequent problems.

Tree care professionals research a tree species and know how it is supposed to look when it is healthy and vigorous in order to recognize symptoms that indicate when something is not normal for that species. Visual inspections of a leaf's symptoms can lead to multiple suggestible causes including insect damage, environmental stress, pathogen issues or a combination of stressors, but soil and foliar analyses can definitively determine a nutrient deficiency either in the soil or in the leaves. Soil test kits are readily available from Virginia Tech and give essential nutrient amounts, except nitrogen, in the soil, along with the soil sample's pH.

Once a nutrient deficiency has been corrected, maintenance fertilization can replace nutrients lost to natural nutrient cycling or to restore balance when nutrients are lost to tree litter removal. Growth promoting fertilizer[40][41] may be needed for container trees or young trees in rapid growth stages to encourage vegetative growth, flowering, and/or fruit production depending upon the nutrients been applied. Also keep in mind that young trees use more N than more mature trees.

Soil Tests

In addition to the availability of the essential nutrients in the soil, soil tests also determine **pH** which measures the number of free hydrogen ions (H+) in the soil solution. pH is measured on a scale of 1 – 14 with 7 being neutral. Readings less than 7 indicate **acid soils** and readings greater than 7 indicate **basic or alkaline soils**. Areas of high rainfall, as befits Virginia, tend to have acid soils due to basic elements such as Ca, Mg, K, and Na being washed away. If pH is too low for the tree species being considered for an urban landscape, apply lime (calcium carbonate) according to soil test recommendations to raise the pH. If the pH is less than 5.0, use a non-ammoniacal source of nitrogen to raise the pH. If pH reading falls between 5.0 and 7.2, most other fertilizers can be used. The pH range most conducive to temperate trees and shrubs is 5.5 – 6.5.[42] Refer to "Virginia Tech

39. Herms, D.A. (2016, December). Understanding Tree Responses to Abiotic and Biotic Stress Complexes. *Arborist News.*
40. Werner, L.P. (2010, August). *Tree Nutrition and Fertilization Practical Considerations (Part II).* Arborist News.
41. Whitmore, A. (2000). *Impact of Livestock on Soil* [Address]. Livestock Farming and the Environment: Proceedings of Workshop 4 on Sustainable Animal Production, Hannover, Germany. http://literatur.vti.bund.de/digbib_extern/zi025653.pdf#page=46
42. Scharenbroch, B.C., Smiley, E.T., Kocher, W. (2015, August). *Managing Urban Soils That Support Urban Trees (Part two).* Arborist News.

Publication 430-027 Trees and Shrubs for Acid Soils" for recommended trees and shrubs for various acid soils.[43]

Areas with poor rainfall have **basic soils**. If pH is greater than 7.2 or is too basic for the tree species being considered, then apply elemental sulfur or fertilizers containing ammonium (NH^{4+}). Aluminum sulfate can also acidify soil but it is generally not recommended because it adds Aluminum cations to the soil. Aluminum, a nonessential element which tends to be available in soils, is toxic to trees and becomes more readily uptaken by trees as pH decreases.

Reducing pH significantly in **calcareous soils** is unrealistic.[44] These soils inhibit nutrient uptake of many of the essential nutrients especially iron, zinc, manganese, and boron; however, they have high levels of magnesium and calcium carbonates which are readily available for uptake by trees.[45]Fertilizers with ammonia volatize easily in high pH soils.

Saline soils have excessive sodium content and can hinder growth and development of trees than are not salt-tolerant. In areas with 20 inches or more rainfall annually, saline soils typically are not a problem. Saline soils can be caused when areas are irrigated with water containing dissolved salts, use of de-icing salts, encroachment of seawater, over fertilization, and brackish water encroachment.

Salt-tolerant plants or shrubs, which divert sodium ions away from a tree's absorbing roots, may be planted within a tree's dripline. The soil can also be flushed with large amounts of quality water. Refer to "Virginia Tech Publication 430-031 Trees and Shrubs That Tolerate Saline Soils and Salt Spray Drift" for a list of salt-tolerant trees and shrubs.[46]

"Soil pH also influences the composition/activity of **microorganisms**. Generally, the activity of fungi increases at lower pH and the activity of bacteria increase with rising pH."[47]

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43. Appleton, B., et.al. (2015). *Trees and Shrubs for Acid Soils.* Virginia Cooperative Extension Publication 430-027, Virginia Polytechnic Institute and State University.
44. Sam Houston University. (n.d.). *Soil Properties* [PowerPoint]. https://www.shsu.edu/~agr_www/documents/SoilProperties.ppt
45. Flemin, G.P., Patterson, K.D., Taverna, K. (2017). *The Natural Communities of Virginia: a Classification of Ecological Community Groups and Community Types, Third approximation (Version 3.0).* Virginia Department of Conservation and Recreation. http://www.dcr.virginia.gov/natural-heritage/natural-communities/
46. Appleton B, et.al. (2015). *Trees and Shrubs That Tolerate Saline Soils and Salt Spray Drift.* Virginia Cooperative Extension Publication 430-031, Virginia Polytechnic and State University. https://ext.vt.edu/
47. Werner, L.P. (2010, August). *Tree Nutrition and Fertilization Practical Considerations (Part II).* Arborist News.

Fertilizer Types

Recall that a fertilizer's **analysis** is always written in the form N – P – K which gives the rate of nitrogenous fertilizer, the amount of phosphate (P_2O_5), and the amount of potash (K_2O). While all of the nitrogenous form is available to the plant, only 43% of phosphate is actual phosphorus content, and 83% of potash is actual potassium.[48]While a complete fertilizer contains all three of these essential elements, an incomplete fertilizer is missing one or two of these elements.

Fertilizers may also be categorized by their **mode of action**, either fast- or quick-release and slow- or controlled-release. Although fast-release fertilizers are soluble immediately, they also tend to be more prone to leaching and have a higher potential for phytotoxicity. Because of these negative characteristics, they are usually not recommended.[49] Slow- or controlled-release fertilizers are more soluble over time, have few phytotoxicity effects, and can be applied at higher rates with fewer applications or at lower rates over multiple applications. The coatings of slow-release fertilizers slow down the rate of nutrients released to plants. Water, heat, and microbial activity decompose various slow-release forms. Of slow-release and controlled-release forms, controlled-release forms actually control the rate at which nutrients become available to the plants whereas slow-release forms slow the process of nutrient availability from that of quick-release forms.

Fertilizer forms may be either **organic or inorganic**. While the chemistry definition of organic refers to a compound containing carbon, another definition says that organic forms come from once-living organisms,[50]which is the definition followed here. Keep in mind that trees uptake inorganic ions regardless of the source of nutrition being organic or inorganic. The applicator is the determinant of the form being used.

Organic forms may be composted manure, treated sewage sludge, fish emulsion, bat guano, or compost. These may be applied either in liquid or dry formulations and may be available in the industry in either natural or synthetic forms. Organic forms are slow-release fertilizers that do not leach readily from soil due to their slow conversion to inorganic ions that are subsequently taken up by plants.

Inorganic forms have higher concentrations of essential elements, are water soluble, and are less affected by soil temperature than organic forms. Inorganic formulations may be either liquid or dry.

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48. Virginia Department of Forestry. (2014). *Riparian Buffer Zones: Common Plants*. www.dcr.virginia.gov/natural-heritage/document/riparian-nat-plants.pd
49. Sam Houston University. (n.d.). *Soil Properties* [PowerPoint]. https://www.shsu.edu/~agr_www/documents/SoilProperties.ppt
50. Scheyer, J., Hipple, K. (2005). *Urban Soil Primer*. Natural Resource Conservation Service. http://soils.usda.gov/use.

Inorganic sources of iron, zinc and manganese may be applied in chelated forms, which are highly soluble yet hold metal ions in solution, to either the soil or the foliage.[51]

Fertilizer Application Methods[52]

Whether fertilizers are liquid or dry formulations, they may be effectively **broadcas**t as long as they are applied over the rooting zone as a surface application. Some issues may arise with the broadcast method. If the soil surface is covered with turf or an organic mulch, the essential nutrients, especially phosphorus, in the fertilizer may not work their way into the root zone without being taken up by turf or fixed in the mulch. Due to runoff potential, broadcasting fertilizers is not recommended on slopes. Broadcasting is a good method for open grown trees with little or no understory vegetation.

The most common method used by commercial arborists is **sub-surface**, which works well with liquid or dry formulations also. This is the best method to use for trees with competing understory vegetation. Typically, a grid of holes, 4 – 8 inches deep and 12 – 36 inches apart, is dug between the trunk and the dripline and the same amount of fertilizer is applied to each hole. This is a standard method for application of amendments also. Soil injection is another form of sub-surface application but is costly and needs specialized equipment.

Before you dig, contact Miss Utility at va811.com or dial 8-1-1 for utility lines. Homeowners are responsible for irrigation lines, which are not located by Miss Utility.

Trunk injection is used to correct a micronutrient deficiency such as iron. The preferred time of year is during spring or early summer after leaves have fully expanded, with one application annually. Shallow holes are made with drill bits into the flare of the tree, which presents the dilemma of wounding the trunk; however, annual applications via trunk injection are discouraged. Injection is not efficient with macronutrients. Trunk injections for fertilizers are considered to be a controversial practice among many professionals in the industry because it treats the symptoms and not the underlying cause.

When soil applications have limited success with nitrogen, iron or zinc, **foliar** application of fertilizers may be considered. A liquid formulation of fast-release fertilizer is sprayed onto young leaf surfaces where uptake is the highest. Entry into the leaves is via stomata but a leaf's waxy or oily surface will impede entry.

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51. Sam Houston University. (n.d.). *Soil Properties* [PowerPoint]. https://www.shsu.edu/~agr_www/documents/SoilProperties.ppt
52. Whitmore, A. (2000). *Impact of Livestock on Soil* [Address]. Livestock Farming and the Environment: Proceedings of Workshop 4 on Sustainable Animal Production, Hannover, Germany. http://literatur.vti.bund.de/digbib_extern/zi025653.pdf#page=46

Rate of Application

Because ANSI standards change periodically, it is best to access both the standards and related Best Management Practices for Tree and Shrub Fertilization. Currently the 3rd edition 2013[53] is available. For **annual maintenance** fertilizer, 2 – 3 pounds of slow release N per 1000 ft^2 in the temperate zone are recommended. While fast release fertilizers are not recommended, 1 – 2 pounds of fast release N per 1000 ft^2 may be used for maintenance when slow release fertilizers do not meet objectives.

For **corrective fertilization** of nitrogen deficiency or when growth promotion is encouraged, the typical rate is 3 – 6 pounds of slow release N per 1000 $ft.^2$

Timing of Application

Early in the growing season, plants are using stored reserves of essential nutrients. The reservoir peaks at bud break and diminishes as the leaves mature; however, the time of maximum nutrient uptake is throughout the growing season from after bud break in the spring until leaf color change in the fall.[54]Adequate soil moisture is necessary for nutrient uptake.

Fall application typically does not predispose a healthy tree to winter injury. Stressors such as topping or shearing, excessive nitrogen levels that promote vegetative growth late in the season, non-native tree species, and an indeterminate growth habit may cause injury with autumn fertilizer applications.[55]

Environmental issues can dictate timing of application. Avoid application before or during heavy rains to avoid run-off. Application during drought is not recommended because absorption by plants is minimal and fertilizer salts may build excessively.

It is not recommended to apply fertilizer during **transplanting** when a transplant's root system is compromised unless the soil is proven to be nutrient-deficient. In that case, incorporate the fertilizer into the backfill soil or beyond the root ball. Although phosphorus is usually available in sufficient quantities in soils, urban soils may lack this nutrient and need to be supplemented.[56]

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53. Sam Houston University. (n.d.). *Soil Properties* [PowerPoint]. https://www.shsu.edu/~agr_www/documents/SoilProperties.ppt
54. Scharenbroch, B.C., Smiley, E.T., Kocher, W. (2015, August). *Managing Urban Soils That Support Urban Trees (Part two).* Arborist News.
55. Scharenbroch, B.C., Smiley, E.T., Kocher, W. (2015, August). *Managing Urban Soils That Support Urban Trees (Part two).* Arborist News.
56. Sam Houston University. (n.d.). *Soil Properties* [PowerPoint]. https://www.shsu.edu/~agr_www/documents/SoilProperties.ppt

Table 6-3 Organic Soil Amendments

Common Name	Analysis/Composition	Notes
Bat guano	10--3--1; 3--10--1 (variable)	Decomposed/dry guano; bioremediation of toxic soils
Blood meal	12.5--1.3--0.7	Expensive; quick-acting N; can burn plants; lasts 4 months
Bone meal	3--20--0 + 20%-30% Ca	Quick P; Lasts 12 months or longer
Clodbuster or Leonardite	15% humic materials; 15% humic acid	Helps make nutrients available to plants; lasts 12 months
Composted manure	Variable; 1-2--0.5-1.5--1-1	Slow-release
Cottonseed meal	3-6--2--1-2	Lasts 4-6 months; may contain pesticide residues
Fish emulsion	4--4--1	Boosts seedlings
Fish meal	10.5--6--0	Lasts 6-8 months
Greensand	0--1.5--6-7	Glauconite (iron potassium silicate); slow-release; insoluble; loosens heavy clay soils
Kelp meal & liquid seaweed	1--0--1.2	Concern about contamination from Increasing sea pollution; lasts 6-12 months
Soybean meal	6--2--2	From soybean oil processing
Treated sewage sludge	4-5--2--0.32; Milorganite	Biosolids; slow-release; promotes rapid timber growth
Wood ashes	0-10% K2O + 5% Mg + 50% CaCO3-	Increases pH; water soluble; lasts 12 months or longer

Fertilization of trees and shrubs has its place in a well-managed tree care program. People in the tree care industry, such as certified arborists and tree stewards, realize that a need for fertilization must exist before application to avoid instances of misapplication. Once the need is established and a specific fertilizer area is determined, consider the tree species, its growth phase, the health of the tree, and soil conditions. In addition to attaining a certified arborist designation through International Society of Arboriculture, an applicator can also attain the Nutrient Management Certification which is offered by Virginia Department of Conservation and Recreation.[57]

Contracts must clearly state the objective(s) wanted to achieve an established goal. Then a soil analysis is needed to determine nutrient needs along with the fertilizer application. The exact application area and the method of application are also stated.

57. Watson, G., Hewit, A., Custic, M., Lo, M. (2014). The Management of Tree Root Systems in Urban and Suburban Settings: A Review of Soil Influence on Root Growth. *Arboriculture & Urban Forestry, 40*(4), 93-217. www.isa-arbor.com/quizbank/352/193_217_AUFJuly2014.pdf

Table 6.4 Fertilizers

Chemical Name	Common Name	Composition	Notes
Ammonia gas		NH3	82-0-0; pH 11-12
Ammonium		NH4+	Decreases pH
Ammonium nitrate		(NH4)NO3	33.5-0-0; decreases pH; explosive
Ammonium phosphate		NH4P2O5	16-20-0; often with 13% S
Ammonium sulfate		(NH4+)2SO4	21-0-0; decreases pH; 24% S
Calcium carbonate	Limestone; calcite	CaCO2	Increases pH; 40% Ca
Calcium carbonate w/ magnesium	Dolomitic limestone	CaCO2MgCO2	Increases pH; 2-13% Mg
Calcium chloride		CaCl2	Deicer
Calcium hydroxide	Hydrated lime; slaked lime	Ca(OH)2	Increases pH; expensive; caustic; pH>12
Calcium nitrate		Ca(NO3)2	15.5-0-0; increases pH; 19-22% Ca; pH 5-7
Calcium oxide	Quicklime; burned lime	CaO	Increases pH; expensive; difficult to handle; releases heat when added to water
Calcium sulfate	Gypsum	CaSO4	No pH change; 29% Ca, 23% S
Hydrogen carbonate	Bicarbonate–historical name; not bicarbonate of soda	HCO3-	Increases pH
Hydrogen ion		H+	When free in soil solution, then pH decreases

Table 6.4 Fertilizers (continued)

Chemical Name	Common Name	Composition	Notes
Hydroxide ion		OH^-	When free in soil solution, then pH increases
Iron sulfate	Ferrous sulfate	$FeSO_4$	No NPK source; 20% Fe, 11% S
Magnesium sulfate	Epsom salts	$MgSO_4$	No pH change; 10% Mg, 13% S
Nitrate		NO_3^-	Preferred form of N uptake by plants
Phosphate		P_2O_5	Form found in fertilizers
Phosphoric acid		H_3PO_4	Decreases pH in water
Potash		K_2O	Form found in fertilizers; mined product; any K compound
Potassium chloride	Muriate of potash	KCl	0-0-60; no pH change
Potassium nitrate	Salt peter	KNO_3	13-0-44: increases pH 7-10
Potassium sulfate	Sulfate of potash (SOP)	K_2SO_4	0–0–48-53; no pH change; 17-18% S
Sodium nitrate		$NaNO_3$	16-0-0: increases pH; 26% Na
Sulfur, elemental		S	Lowers pH; nonsoluble; use gypsum
Triple superphosphate	TSP	$Ca(H_2PO_4)_2$	0-45-0; contains no gypsum; 15% Ca
Urea		$CO(NH_2)_2$	45-0-0, 46-0-0, decreases pH; not considered an organic fertilizer

Review Questions

1. What are 3 physiographic reasons tree species populations of the Appalachian slopes are usually different from the Coastal plains?
2. Moisture retention contributes to successful tree establishment. What 2 soil elements affect retention?
3. Soil Orders are usually differentiated by two or more ____________ & ____________ characteristics.
4. In what horizons do most tree roots grow?
5. Once disturbed, how does horizon displacement affect root growth and how long does it take to equilibrate the physical and chemical properties of soil?

6. Microflora is essential to root nutrient adsorption. Explain this mycorrhizal symbiotic relationship.
7. When planting trees, it is important to know prior land utilization. How do silviculture, farming, and industrial waste affect soil properties?
8. Urban soils pose many problems to overcome when planting trees. Name 3 common obstacles.
9. Name the primary limiting nutrient for woody plant growth and development.
10. Name three situations when saline soils exist.
11. True or False: Slow-release fertilizers actually control the rate at which nutrients become available to plants.
12. True or False: Trunk injection of nutrients is the best way for trees to quickly receive the nutrients they need.
13. The time for maximum nutrient uptake in trees is throughout the growing season between __________________ in the spring and __________________ change in the fall.
14. True or False: Applying fertilizer to trees during transplant is a recommended practice.
15. What must be true before a fertilizer program is recommended?
16. True or False: Fall application of fertilizer typically does not predispose a healthy tree to winter injury.

CHAPTER 7: TREES AND ECOLOGY

"The Earth may not be a spaceship but an organism, and the trees may be its lungs." – Michael Pollan

Chapter Contents:

Introduction

Ecology is the study of interrelated patterns, processes, interactions, and relations of flora, fauna, and ecosystems/habitats, including biotic and abiotic factors. Ecology is all plants, animals, and micro-organisms functioning together with the environment in complex and dynamic ways to create system balance. Forests and woodlands support the most biodiversity of plants and animals of all land-based habitats. Above and below ground, trees create micro-environments and microclimates. This is fairly obvious for tree communities but also true for individual trees, though the effects may be smaller and harder to see.

Historically, people have treated trees as individuals, especially in human built environments. A shift is needed to think about and treat trees as communities instead. Research in many disciplines supports this assertion and continues to provide new evidence of the interconnectedness of trees to each other and to other life forms in the community (plant, animal, insect, and fungi).[1] In many cases there is reliance or symbiosis occurring where one species cannot live or function without another. Thus, removal, treatment, or impact on one species affects other(s), and the effects ripple through the entire community. Species diversity within a community supports a web of complex relationships and creates checks and balances leading to resiliency and sustainability of the community.

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1. Reece, J.B., Urry, L.A., Cain, M.L., Wasserman, S.A., Minorsky, P.V. & Jackson, R.B. (2011). *Biology* (9th ed.). Benjamin Cummings.

Community balance is not, however, static over time. In the long historical view, ecosystems change gradually, interrupted by occasional events such as earthquakes or hurricanes. However, today's reality is one of increasing urbanization and rapid climate change, requiring a new level of understanding of and management help for the trees in our cities and forests.

This chapter considers the significance of trees to the ecological balance in Virginia. The discussion of ecology is expanded beyond just interactions between naturally occurring organisms. It also considers the broader picture of biological, physical, social, and economic factors which together describe the reality for those organisms (including people and trees). The goal is to equip the tree steward with conceptual and resource tools to understand the context within which trees grow, including the regional differences across the state.

Learning Objectives

1. Understand the definitions of key words in the fields of ecology and sustainability study.
2. Understand the concept of Healthy Tree Cover.
3. Understand the roles of the forester, the urban forester and the arborist.
4. Be able to discuss factors which influence Healthy Tree Cover.
5. Be aware of methods to improve Healthy Tree Cover.
6. Be aware of regional differences within Virginia.
7. Be aware of climate change dynamics as they affect the trees and tree cover in forests and urban areas.
8. Understand the ecological situation in the student's home region in enough depth to help improve Healthy Tree Cover through VCE outreach.

REVIEW: VCE Master Gardener Handbook 2015 (9/18 update)

- Chapter 19: Water Quality and Conservation
- Chapter 20: Habitat Gardening for Wildlife

Definitions and Discussion

This section lays out the significant terms tree stewards should understand when considering trees as a part of ecological programs and activities. The terms and definitions are interrelated and build upon each other in many ways. The diagram below is one way to organize these different elements. The root zone reflects how important it is for each of these concepts that activity be based upon proper research, well-designed education, and consistent communication.

Figure 7-1 Ecological Terminology Tree. (Courtesy Carol King)

Ecology is the study of the interrelationships between individual organisms and groups of organisms and between living organisms and the abiotic features of their environment.[2] It is important to note that relationships of many sorts, among many organisms and factors, influence **ecological systems (ecosystems for short)**. Often, we think of the natural environment as a peaceful, serene coexistence: a poetic, romantic view. The reality is that the balance in a healthy ecosystem is achieved as an equilibrium among constant pushing and pulling by all the inhabitants. Dr. Doug Tallamy talks about a healthy garden as "a dynamic community of interacting organisms."[3]

Biome is defined as any of the world's major ecosystem types (terrestrial or aquatic), typically described in terms of dominant life forms and physical characteristics. Biomes are especially useful to look at for the adaptations the life forms make to survive in their surroundings.[4] The US Temperate Deciduous Forest Biome is a descriptor for the forest coverage of most of the eastern part of the United States. Broadly speaking, precipitation varies from 28 to 60 inches, evenly throughout the year. Freezing or near-freezing temperatures occur annually, and there are four distinct seasons.[5]

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2. Allaby, M. (2015). *The Dictionary of Science for Gardeners*. Timber Press.
3. Tallamy, D. (2007). *Bringing Nature Home.* Timber Press.
4. Reece, J.B., Urry, L.A., Cain, M.L., Wasserman, S.A., Minorsky, P.V. & Jackson, R.B. (2011). *Biology* (9th ed.) Benjamin Cummings.
5. Virginia Tech College of Natural Resources and Environment, Forest Outreach (2021, February 16). *Temperate Deciduous Forest Biome.* https://dendro.cnre.vt.edu/forsite/tdfbiome.htm.

Forest regions in the Eastern US are shown in the map available below, from an expert analysis in 2006. The cited paper notes that "continuing environmental change will be an issue for future research." Virginia is in the Mesophytic and Southern Mixed regions, which include oaks and pines as significant species in a large and diverse list of tree species. More detailed descriptions of these regions can be found at Virginia Tech's CNRE Forest Outreach (FORSite).[6]

For a map of **forest regions**, please see the National Park Service Eastern Deciduous Forest page: https://www.nps.gov/im/ncrn/eastern-deciduous-forest.htm

Phenology is the "study of seasonal events, such as when plants produce leaves, flowers and fruit, when leaves fall, the arrival and departure of migrant species, nest-building, hibernation, etc."[7] The significance of this field of study comes in the inter-relationships between different organisms within a biome: many plants depend on pollinators that hatch or arrive when the flowers are in bloom. Similarly, insect life cycle dates may be significant for birds who depend on them to feed their young. When timing changes occur to some parts of a phenological chain but not to all, then species disruption is likely. Logically, phenological disruption effects will be seen with annual and perennial plants (and their associated animals) before longer-lived species such as trees, but this is a concern for all species considering the rate of urbanization and climate change.

Disturbances in nature are more the norm than the exception, with frequency and destructiveness on the rise. Storms cause flooding, mudslides and erosion which kill trees. Winds make trees grow strong trunks but can also damage them. Forest fires cause detrimental cascading effects on soils and wildlife. Yet the absence of smaller, regular fires can also be a disturbance. For example, such fires allow the longleaf pine to sprout its seeds and to outcompete plants which are not fire resistant.[8] Human intervention is definitely a form of disturbance, such as concrete infrastructure projects that cause ecosystem fragmentation and degradation, with severe impact on trees. Sometimes the disruption can be in seemingly 'green' realms of activity: trees get harvested, in some cases almost to extinction, while others are shipped and grown around the world, well out of their original ecosystems. Multiple disturbances can compound the ecosystem impact and start destructive cycles that are hard to stop.

6. Virginia Tech College of Natural Resources and Environment, Forest Outreach (2021, February 16). *Temperate Deciduous Forest Biome.* https://dendro.cnre.vt.edu/forsite/tdfbiome.htm.
7. Allaby, M. (2015). *The Dictionary of Science for Gardeners*. Timber Press.
8. Vose, J.M. & Elliott, K.J. (2016). Oak, Fire, and Global Change in the Eastern USA: What Might the Future Hold? *Fire Ecology, 12(2).*

Along with disturbances, ecological systems are distinguished by the pervasiveness of **change**: not just a busy hum of constant tedium, but also an unending drama of skirmishes between creatures large and small struggling to stay alive and prosper in the face of shifting circumstances. One of the more important aspects of an ecological system is its **resilience**, or ability to handle the changes and recover/move on from disturbances. While the foregoing has always been true, data trends indicate more severe and frequent disruptive weather events; which may mean the acceleration of change patterns over the past or the decline of species and ecosystems that cannot adapt and thus are not resilient.

Climate is defined as the weather conditions experienced in a particular location averaged over a long period of time. In the United States, this is generally 30 years, adjusted every 10 years.[9] Trees are major components in soil, air and water cycles, and thus are important for overall climate stability.

Climate Change, according to the National Oceanic and Atmospheric Administration (NOAA), is "a significant and persistent change in an area's average climate conditions or their extremes."[10] The primary components of climate change are temperature, precipitation and sea level rise.[11] Looking deeper, the combination of these effects means both drought and floods; erosion and other soil detriments; increasing wildfires and invasive pest issues; and challenges to the natural adjustments by trees in terms of genetic pools, reproduction patterns and migration.[12]

Mesoclimate is the weather of a neighborhood or a city as modified by local influences of buildings, terrain, bodies of water, wind, and cloud cover.[13] This can lead to significant differences in the survivability of plants on the margins of their hardiness zones, water tolerances, etc. Many of the benefits/ecosystem services which trees provide, especially in the built environment, are actually improvements to the local mesoclimate or mitigation of its extremes (i.e. cooling of heat islands or moderating flooding). As climate changes continue to pose unprecedented challenges, management strategies at the mesoclimate level will have increased significance.

Microclimate is the same thing as mesoclimate but in a very small space. For example, a cold-sensitive tree can survive in a colder climate when it is planted against a sunny wall and screened from cold winter winds. Every site (home landscape, school yard, city park, etc.) has microclimates created by sun/shade exposure, wind, soils, water, buildings or other factors.

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9. Allaby, M. (2015). *The Dictionary of Science for Gardeners.* Timber Press.
10. National Oceanographic and Atmospheric Administration. (2021, February 9). *National Centers for Environmental Information.* www.climate.gov/taxonomy/term/3446
11. Easton, Z.M. & Faulkner, J.W. (2016). *Communicating Climate Change to Agricultural Audiences.* Virginia Cooperative Extension.
12. Rogers, B.M., Jantz, P., & Goetz, S.J. (2017) Vulnerability of Eastern US Tree Species to Climate Change. *Global Change Biology, 23.*
13. Harris, R., Clark, J.R., & Matheny, N.P. (2004). *Arboriculture (4th ed.).* Prentice Hall.

Natural Community is a usually recurring grouping of live organisms which co-exist and interact, taken together with their physical environment and ecological processes.

- The Natural Communities of Virginia Classification of Ecological Groups and Community Types, from the Virginia Department of Conservation and Recreation is a catalog of the significant naturally-occurring ecological communities across the state. This resource gives tremendous insight into what lives together and where.[14]
- The **Digital Atlas of Virginia Flora** is a searchable database which lists the vascular plants in Virginia and displays where they are found in the state.[15] For example, the maps below show each county where the white oak, *Quercus alba* is found (figure 7-2) and where the Bald Cypress, *Taxodium distichum* is found (figure 7-3). The database will also give a listing of plant species found within a specific county or city.
- **Flora of Virginia** is a 2012 publication that documents and contains detailed descriptions of all 3,164 species of plants found in Virginia.[16] The last such catalog for Virginia was published in 1762!

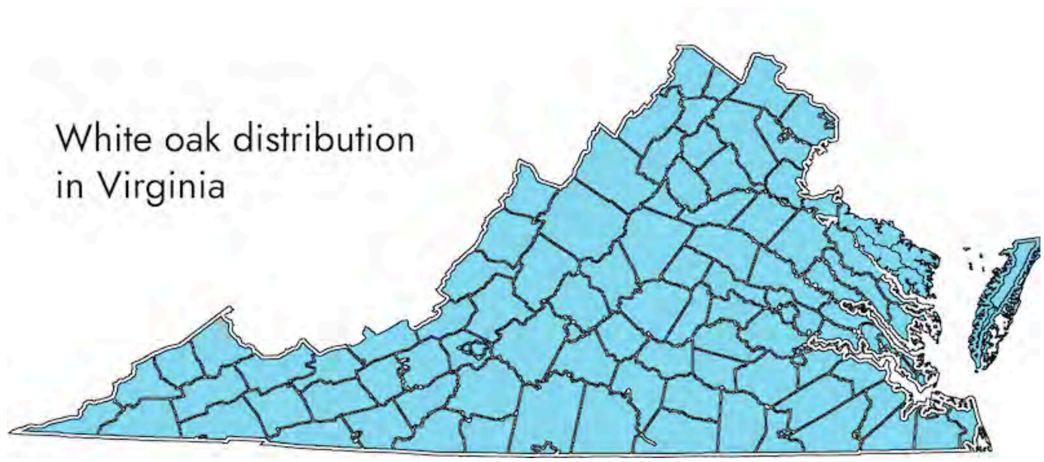

Figure 7-2 White Oak Distribution (shown in blue). White oaks are distributed throughout the whole state.

14. Fleming, G.P., Patterson, K.D., & Taverna, K. (2017, November 9). *The Natural Communities of Virginia: a Classification of Ecological Community Groups and Community Types*. Virginia Department of Conservation and Recreation, Division of Natural Heritage. http://www.dcr.virginia.gov/natural-heritage/natural-communities/
15. Virginia Botanical Associates. (2017, November 8). *Digital Atlas of the Virginia Flora 2017.* Accessed at http://vaplantatlas.org/
16. Weakley, A.S., Ludwig, J.C., & Townsend, J.F. (2012) *Flora of Virginia, Foundation of the Flora of Virginia Project Inc., Richmond.* Botanical Research Institute of Texas Press.

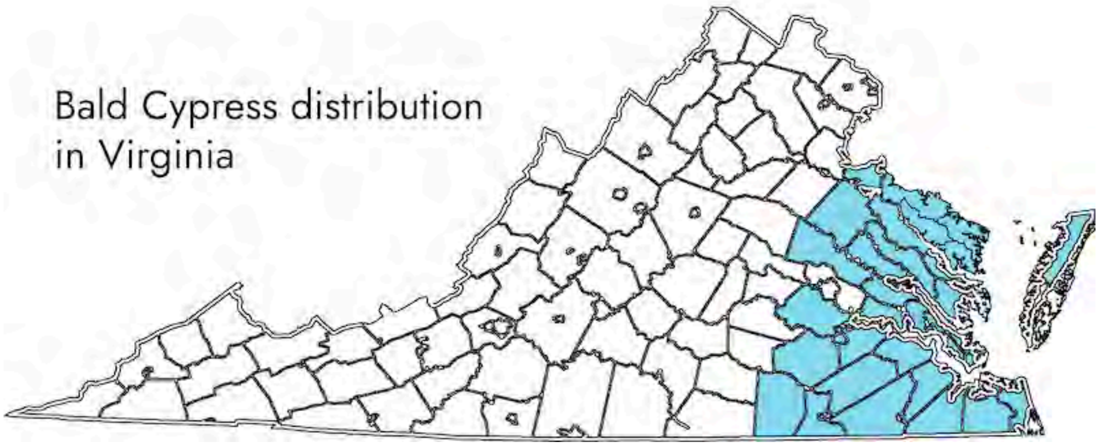

Figure 7-3 Bald Cypress Distribution (shown in blue). Bald Cypress distribution covers only the lower East coast, extending as far to the interior as Brunswick county.

Human Changes alter the natural communities in many ways. It is critical that we understand both the natural ecosystems and how human development has altered them. As an example (referring back to Chapter Six), urban soils are unlike any naturally developed soil, yet city-dwellers and planners must deal with their ecological consequences.

Ecosystem Services is a term describing services (also called benefits) provided by the environment, especially trees and tree communities. These services are grouped into four broad categories:[17]

- Provisioning – products from ecosystems including food, drinking water, medicinal products, fuel wood, jobs, timber and drinking water.
- Regulating – such as climate regulation, disease regulation, pollination, migratory wildlife, water quality, and water supply, soil health and stabilization.
- Supporting – carbon dioxide and oxygen cycles, cycling of nutrients (N & C), genetics, pollinators & beneficial insects, energy transformation, formation of soil, beneficial insect and migratory species habitat, primary production/connection of ecosystems and resiliency/sustainability.
- Cultural – nonmaterial benefits people gain from ecosystems including: recreation, spiritual benefits, aesthetic enjoyment, education, reduced violence, seasons, memorials, mental and physical health, community engagement, and historical and cultural benefits.

17. University of Maryland, College of Agriculture and Natural Resources, Department of Environmental Science and Technology. (2021, March 30). *Ecosystem services.* https://extension.umd.edu/woodland/your-woodland/ecosystem-services

Sometimes these services are assessed in dollar terms. Examples include: when coastal communities apply for grants to plant riparian buffer zones to reduce the impacts of erosion and flooding, when cities assess the value of tree canopy for stormwater management and heat island moderation, or when trees increase property value and reduce crime. Often, though, people do not understand or value these services, especially when making cost/benefit planning decisions.[18] Some developing fields of study, such as the role the amount of tree canopy or specific tree species play in urban stormwater management, show where more scientific research and modeling are needed to refine urban tree policies.[19]

Sustainable Ecology is a term describing a state in which the interrelationships between living organisms and their environments are so balanced that long term stability is not sacrificed for present productivity and vice versa. In other words, it means using natural resources wisely in the short term so that the resources continue to be available in the long term. Trees are among the most significant contributors to sustainable ecology, in urban, suburban and rural settings. As an example, the Digital Atlas of Virginia Flora lists nine life support processes essential for the continuation of life on Earth, of which two are inextricably tied to trees: Land-System Change and Biosphere Integrity.[20]

Silviculture and Forestry are terms used to describe the science of developing, caring for and cultivating forests, as well as managing trees for timber production. The two terms are not synonymous, but the differences are a subject of another book. There is considerable discussion among foresters about **ecological forestry** (among a number of similar phrases), meaning practices which:

- Recognize the intrinsic value of forests in balance with larger ecosystems
- Understand that forests must provide for human social and economic needs
- Plan for the long term with scientific data and location-specific experience[21]

Arboriculture is the study and practice of caring for trees and other woody plants in the human built landscape.[22][23] This usually means a focus on individual trees or those in settings without natural forest surroundings. Examples are home landscapes, city street trees and trees in school yards, cemeteries and public venues. Arborists specialize in helping trees adapt to and survive in the built

18. Schwab, J.C., Ed. (2009). *Planning the Urban Forest: Ecology, Economy and Community Development.* American Planning Association.
19. Berland, A., Shiflett. S.A., Shuster, W.D., Garmestani, A.S., Goddard, H.C., Herrmann, D.L., & Hopton, M.E. (2017) The Role of Trees in Urban Stormwater Management. *Landscape and Urban Planning 162,* 167-177.
20. Digital Atlas of the Virginia Flora. (2017). Virginia Botanical Associates. http://vaplantatlas.org/
21. Evans, Z. (2017, May 21). *What is Ecological Forestry?* www.forestguild.org
22. Harris, R., Clark, J.R., & Matheny, N.P. (2004). *Arboriculture (4th ed.)*. Prentice Hall.
23. Lilly, S. (2010) *Arborists' Certification Study Guide.* International Society of Arboriculture.

environment, including extensive research into best selection, planting and establishment practices, soil analysis and mitigation, long-term maintenance and risk assessment.

Urban Forestry is the management of trees and associated plants in urban and suburban areas, including both naturally occurring and planted trees. The focus is on the larger populations of trees rather than individual specimens. Examples include the tree canopies in public parks, green spaces and natural areas. Municipal tree managers, tree officers and city/county arborists engage in urban forestry as they work with civil engineers, public works departments, government agencies, educational institutions and the public to improve the built environment by preserving or planting trees and other woody plants.[24][25] Urban forestry involves maximizing the value of tree-related ecosystem services.

Healthy tree cover is an informal concept proposed for the purposes of this manual. In the terminology tree graphic at the beginning of this section, the entire canopy of the tree represents healthy tree cover. The concept can be applied for individual city trees, a grove in a park, a forest stand or any density of trees in between, and it is an integral part of a region's sustainable ecology. What is the human footprint, and are enough trees there to moderate that footprint, provide services, and maintain the system balance? This concept does not intend to promote a goal of full tree cover everywhere, since not all soils, mesoclimates, biomes, plant communities, etc., are appropriate for a full forest of trees. What it does mean is that any situation under discussion should be considered dynamic, and that the tree cover shares in its overall health and sustainable balance. For example, it could mean planning management schemes which value slower growth and lower maintenance of trees and other plantings.[26][27] Pursuing a goal of healthy tree cover will help localities react to challenges such as extreme weather, sea level rise/land subsidence, pest threats, soil/air/water pollution , heat island, and other physical, economic and social factors.

Ecological Factors of Significance to Healthy Tree Cover

> "And yet trees, nature's largest and longest-lived creations, play an extraordinarily important role in our cityscapes. They are not only critical to public and individual health but are also the dominant component of what is now called green infrastructure, defining space, mitigating storm water, cooling the air, soothing

24. Harris, R., Clark, J.R., & Matheny, N.P. (2004). *Arboriculture (4th ed.)*. Prentice Hall.
25. Lilly, S. (2010) *Arborists' Certification Study Guide.* International Society of Arboriculture.
26. Herms, D,A. (2016). Understanding Tree Responses to Abiotic and Biotic Stress Complexes. *International Society of Arboriculture 25(6)*, 12-18.
27. Rainer, T., & West, C. (2015). *Planting in a Post-Wild World.* Timber Press.

our psyches, and connecting us to nature and to our past." Jill Jonnes, Urban Trees[28]

This section is meant to encourage discussion. It does not reflect any one research source or discipline among the many to be found under the search topic Ecology. The focus is on arboriculture, urban forestry and forest management, but crossovers of topics into storm water management, air quality, carbon sequestration, etc., are inevitable as everything is connected as part of an ecosystem/community. A salient point here is that trees influence, as well as are influenced by, these ecological factors such that there is interdependency, with consequences for urban ecosystem function and the well-being of people.

Tree Stewards are encouraged to perform outside research into the ecological factors which have the greatest relevance to their own local needs and priorities. As a means of identifying problems which EMG Tree Stewards can usefully try to address, this section considers factors grouped by their causal origins: natural biotic and abiotic, plus human-connected, as part of the overall environment in which the trees live.

Natural Biotic Factors

Biotic agents and factors in tree success or failure are discussed from a variety of perspectives in Chapters Six, Eight, Ten and Eleven. Among the important considerations for ecological sustainability are **species site suitability**, mature size, and maintenance needs; also **diversity** of species and urban forest pressures/issues.[29][30]

Endangered species are generally considered as part of the larger ecology, though any one species (plant or animal) may occupy a small specialized niche in its ecosystem. Species become endangered when they do not survive ecosystem changes or when part of the ecosystem they depend on is changed or removed. The world is seeing an increase in the number of plant and animal species experiencing extinction threats, both as individual species and as part of larger ecosystems. Recognition of the interconnectedness of ecosystems (thinking of plants as communities versus individuals), informed higher-level planning and policies, and support for and

28. Jonnes, J. (2016). *Urban Forests.* Viking Press.
29. Reece, J.B., Urry, L.A., Cain, M.L., Wasserman, S.A., Minorsky, P.V. & Jackson, R.B. (2011). *Biology (9th ed.)* Benjamin Cummings.
30. Morgenroth, J., & Livesly. S. (2016). Right Species, Right Place: A perspective on the second International Conference on Urban Tree Diveristy. *Arborist News 26(2),* 56-57.

encouragement of good plant choices and habitat care, can keep these situations from becoming worse.

Invasive species is a huge and serious topic in the world of trees and ecology.

- Invasive trees (for example, tree of heaven, mimosa, chinaberry, and Bradford pear) and invasive plants like bamboo, kudzu, and Chinese wisteria, threaten the balance of ecosystems.
- Invasive pests (insects and diseases) threaten valuable tree species (for example emerald ash borer, *Lymantria dispar*, Asian ambrosia beetle, crape myrtle bark scale, Dutch elm disease, chestnut blight).

The US Department of Agriculture maintains a National Invasive Species Information Center, and the USDA Natural Resources Conservation Service has a website dedicated to Introduced, Invasive and Noxious Plants. In Virginia, the Department of Conservation and Recreation (DCR) maintains an Invasive Species List which indicates (for plants) the degree of threat in different parts of the state. It's recommended that students become familiar with at least the DCR website to get the most recent information for Virginia. (http://www.dcr.virginia.gov/natural-heritage/invsppdlist)

Natural Abiotic Factors

Abiotic factors are the non-living parts of the environment that can influence trees and ecosystems. Abiotic factors include sunlight, soil, temperature, water and people's actions and practices. Extreme weather events and disturbances such as tornados, floods, snowstorms, and droughts may act as super-abiotic factors which require larger-scale reactions. As an example, there are fairly recent tree-planting campaigns or incentive programs for towns in which large storms have removed a significant number of trees all at once.

Sunlight is necessary for photosynthesis, which is the process plants use to convert carbon dioxide and water to oxygen and sugar. We breathe the oxygen and the sugar then becomes food for the plants and ultimately food for people and animals. Simply put, without the sun and photosynthesizing plants we could not live. Tree ecosystems accumulate large amounts of biomass, which correlates to large stores of energy, rapid growth, resilience, sustainability.

Soil is one of the fundamental factors in defining the biological components of any ecological system. This is most evident in forested or other natural lands. The **parent material**, or underlying rock, determines the soil order. When it comes to urban and suburban lands, though, the soil can be seriously compromised through cutting/filling, mixing, compaction, pollutants and nutrient issues. Chapter Six discusses soils in detail.

Temperature can be influenced by building reflection and heat radiation, sunlight, elevation, prevailing winds, nearby water, and season. Consult the USDA's Plant Hardiness Zone Map and the American Horticultural Society's Plant Heat Zone Map to see the temperature parameters for your location. These zones have shifted over the last several decades, generally trending warmer. EMGs should be alert to further changes.

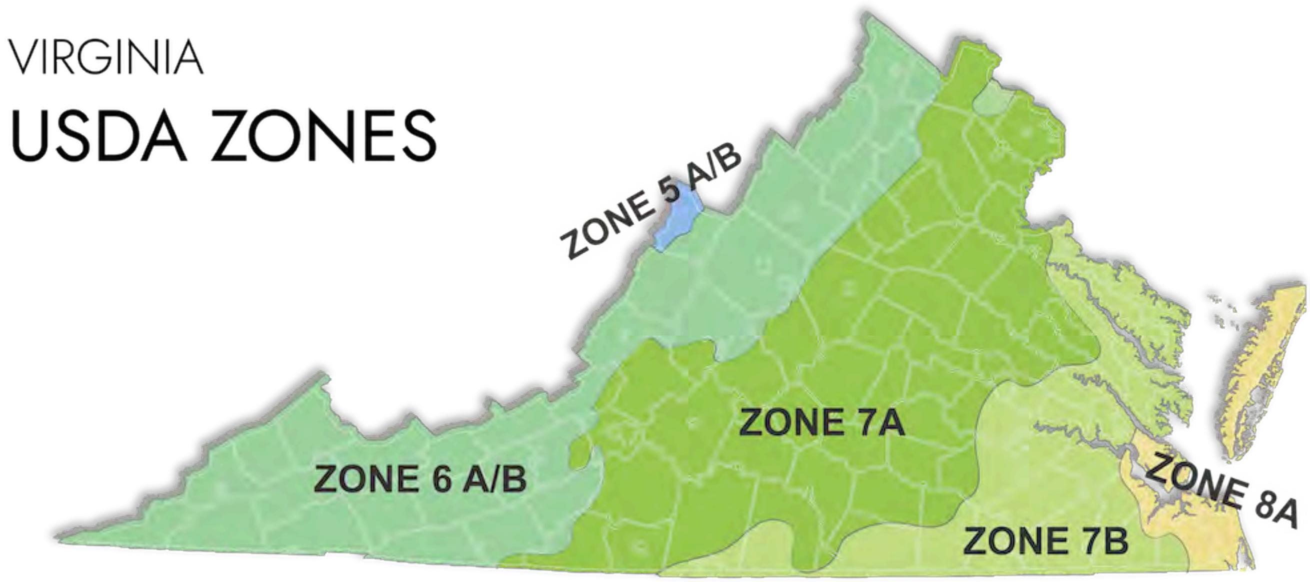

Figure 7-5 Virginia USDA Hardiness Zones.

To look up a USDA plant zone by zip code, see: https://planthardiness.ars.usda.gov/PHZMWeb/

Cold hardiness zones are commonly listed on plant tags and in plant descriptions. Some regions of Virginia are more prone to certain kinds of extreme seasonal weather, especially hurricanes near the coast and blizzards in the mountains. Chapter Eleven discusses these as well as other storm-related phenomena. It is worth noting that prevailing winds affect ambient temperature and can result in plant shapes that are one-sided or 'sheared' near a coastline, on a mountain ridge, or in wind tunnels created by buildings. Trees that grow at higher altitudes and colder climates can be adversely affected by rising annual temperatures, particularly if they have limited migration options. The balsam fir, found now at higher elevations in Virginia, is a case in point.[31]

"Water is life." All living organisms need water. Plants must have water to grow. Water form, amount, and quality are considerations. Is water in the form of floods, tidal currents, or precipitation (rain, snow, hail)? Obviously, some forms are more damaging than others. Is the amount average, extreme, or seasonal? Virginia receives fairly consistent precipitation in the form of rain spread throughout the year, averaging about 45 inches per year, in addition to occasional extreme water events like hurricanes, nor'easters, and flooding. When considering annual rainfall and frequency of storms,

31. *Climate Change Trees Atlas.* (2021, March 1). https://www.fs.fed.us/nrs/atlas/tree/12.

it is important to be aware of historic data. Scientific research and modeling will also help inform decision-making and planning.

Water quality also impacts trees. Whether water is fresh, salty/brackish, or polluted runoff influences which species grow, where and how well. Trees are water regulators, intercepting and absorbing rainfall, removing particulates from rainfall, transpiring water back into the atmosphere, softening the impact of rainfall on the ground, storing large amounts of water, reducing runoff, recharging ground water sources, preventing erosion, and moderating flooding. Thanks to Chesapeake Bay publicity, there is increasing recognition of the relationship between watershed activities (especially activities that affect tree canopy amount) and water quality. So, this manual reminds tree stewards about Virginia's watersheds as shown below.

For a map of Virginia's **watershed regions**, see DCR: https://www.dcr.virginia.gov/soil-and-water/hu

Factors from Humans in Aggregate and Over Time

> "Humans are the only creatures in this world who cut the trees, make paper out of them, then write SAVE THE TREES on it." Anonymous

Land Use is usually categorized as urban, agricultural, industrial, forest or natural grassland. Further refinements may split out city center or suburban from urban, heavy or light industry, managed forest (multiple species) from timber crops (monocultures) or highly productive agricultural regions. These categories are useful at high level planning.

When forming and executing tree cover plans, the focus is more at the level of watersheds, cities, counties, and neighborhoods. Considerations include: **percent of impervious surfaces** (pavement, buildings), open space with pervious surface (lawn, park, sports field), or space with some amount of tree and shrub cover. This level of information is most valuable to government and citizen planning groups. EMGs often assist with city tree inventories to help officials make informed decisions.

One consideration which is frequently overlooked is the importance of **green corridors** between areas of vegetative cover for the preservation of biological diversity.[32]The idea is to use small amounts of vegetated land to connect larger vegetated areas. For example, a riparian buffer corridor through residential properties that connects two larger city park areas, or an old railroad right of way that's been vegetated and also has a walking and biking trail that connects a park to a wildlife refuge.

32. Schwab, J.C., Ed. (2009). *Planning the Urban Forest: Ecology, Economy and Community Development.* American Planning Association.

These small connecting green corridors can have a significant positive impact on tree canopy cover and animal species movement and habitat if properly planned. On the scale of forests, the principle of contiguity is even more important for tree survival, as fragmented landscapes complicate species migration and reproduction.[33]

At the even more focused level of neighborhoods and individual properties, canopy cover impacts the **variety of habitat types** available to different plant and animal species. In nature, there are gradual shifts from forest to grassland to rock or shore, creating a variety of habitats. In the built environment, the transition zones are more numerous and usually more abrupt. Individual homeowners can positively affect the ecological balance by planting canopy layers to create transition zones.[34] If the patchwork of individual landscapes and gardens becomes connected, the total amount of edge habitat increases and benefits many plant, animal, and insect species which may be stressed or struggling.[35] Land use areas, connecting corridors, and transition zones often cross individual property, city/county and even state lines and should be considered carefully when planning at any level.

Pollution is everywhere: air, water, and soil. Point source pollution has mostly been addressed through regulations. Non-point source pollution consists of all the little actions that everyone does that collectively cause problems over time. Non-point source pollution is much harder to regulate and is often addressed through educational and incentive programs, since the end goal is behavior change.

Healthy tree cover is an integral part of pollution prevention and air, land, and water reclamation and remediation efforts. Some examples:

- Tree canopies intercept particulates in the air
- Tree canopies absorb carbon dioxide and release oxygen
- Tree roots absorb pollutants in runoff or in the soil and internal tree systems break pollutants down into harmless components
- Tree roots in conjunction with soil and soil microbes adsorb pollutants or break them down through chemical reactions into usable or harmless components.

Population is an obvious factor in considering healthy tree cover in the human built environment. This includes humans, domesticated animals (cats and dogs) and wildlife (geese and deer most notably). Human population directly impacts the amount of impervious surface which reduces the amount of space for trees; yet at the same time increases the need for more canopy cover.

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33. Rogers, B.M., Jantz, P., & Goetz, S.J. (2017). Vulnerability of Eastern US Tree Species to Climate Change. *Global Change Biology, 23*..
34. Tallamy, D. (2007). *Bringing Nature Home.* Timber Press.
35. Marzluff, J., (2014). *Subirdia*. Yale University Press.

Population density influences other factors that impact trees and ecology, depending on location and history. Some examples include:

- Industrial activity causing heavy logging for fuel, export or development
- Income distribution reflected in more trees in the more affluent neighborhoods
- Educational achievement levels which hopefully lead to informed decisions
- Political movements which understand and support the value of trees
- Communication networks which can enable action to increase healthy tree canopy

Looking at secondary effects of human population concentrations due to domesticated animals, cats prey on song birds whose populations are already stressed because of insufficient or inappropriate plants to support the insects and caterpillars they feed on. Dogs, along with geese, especially overpopulations of non-migrating wild geese, contribute greatly to the bacterial and nutrient pollution found in runoff. These effects are intensified when there is no tree canopy to slow the rainfall and people don't scoop the poop. Overpopulations of deer, especially at the suburban/rural interface, stress the ecosystem. Deer over browse vegetation which can shift species diversity and distribution in an ecosystem. They rub new antlers damaging young trees and eat young tree seedlings, which can significantly reduce the overall number of trees that grow in an area.

Transportation networks (rail, road and river) are essential for the movement of people and goods. They are influenced by trade routes, topography, military and industrial activity, political boundaries, and population centers. These networks physically disrupt the land. They cut open swaths through forested areas and sever green corridors isolating forested areas. If the transport grid is dense enough, the green space may disappear altogether.

Other human factors include: **history, economics, technical knowledge, academic research, commercial practices, governmental policies, and professional development**.

One of the great challenges in ecological planning is to bridge the gap between local experience and a larger reality. This bridging works both ways, so national and international scientific studies may inform and influence local efforts, if those studies adequately reflect specific local conditions. **The availability and applicability of knowledge** is an important human factor. It does no good to make a scientific discovery or prove an ecological concept if no one knows about it or is able or willing to apply it.

The state of a community's tree cover is dependent on the actions of city/county planners, project engineers and designers, builders, landscapers and other professionals who are often motivated by economics rather than science. The reality of contracts, labor, and cost often dictate tree management. Some cities have departments and crews that manage the city's trees, some cities hire private contractors to do the work, while other cities have no budget for tree management at all. In general, people do not like change and, therefore, resist it. This attitude makes it challenging when it comes to changing how people see the value of trees, how trees have been managed historically, the practices that have been or are being used, and the policies governing trees. Climate change concerns should raise awareness of the value of trees and increase public support for trees. Climate change should also bring more aspects of urban trees into development discussions and planning.

Professionals impact trees. The term professional indicates some level of expertise. Some who call themselves "professional" are not. They sell and perform tree "services" that are uninformed, unnecessary, incorrect, and detrimental to trees. Everyone knows that topping trees is wrong, yet the practice persists because of so-called "professionals" promoting it to make a dollar. Real tree and landscape professionals are up to date on research and appropriate practices. They are generally certified or licensed and attend regular training to maintain their certifications and licenses.

Examples of professional organizations, certifications and licenses related to trees include:

- Trees Virginia (Virginia Urban Forest Council) and the regional Northern Virginia (NOVA) and Southeast Virginia (SEVA) Urban Forest Roundtables,
- Mid Atlantic Chapter of the International Society of Arboriculture's (MAC-ISA) Certified Arborist,
- Virginia Nursery & Landscape Association's Virginia Certified Horticulturist (VCH),
- Chesapeake Bay Landscape Professional (CBLP) Certified Professional.
- Virginia Pesticide Applicator through the Virginia Department of Agriculture and Consumer Services

Improving Healthy Tree Cover

Healthy tree cover is in jeopardy because of:

- Development/urban sprawl/transportation routes/pollution
- Undervaluation as a resource with multiple benefits
- Inadequate protection policies and failure to anticipate problems
- Uninformed plant selection and placement
- Inappropriate maintenance practices
- Insufficient replanting policies/efforts
- Neglected forest without active management
- Lack of invasive species management

Examples of ripple impacts on healthy tree cover:

- Removing an "undesirable" tree from a stand of trees leaves a hole in the overall canopy cover. This can stress the surrounding trees, leaving them vulnerable to pests or storm damage, especially wind damage. Note that removing invasive trees means preserving the desirable trees around it, regardless of shorter term holes in the stand.
- When ecosystem-appropriate undergrowth is removed, habitat is destroyed. The insects, birds,

and other animals that pollinate trees or disburse tree seeds no longer do so.

- When there is no leaf litter or mulch over tree roots, soil conditions are not as favorable for fungi communities which help tree roots absorb nutrients and water. Un-mulched soil is dryer and hotter which stresses tree roots.
- Removing standing dead trees which are not posing threats removes habitat for many cavity nesting birds and animals.
- Removing fallen trees prevents them from decaying and providing the rich organic matter where replacement tree seeds germinate.
- Fertilizer applications that are excessive or at the wrong time promote lush new growth which may attract pests or be susceptible to heat, cold or drought.
- Chemically treating one insect pest on a tree may kill numerous other beneficial insects leaving the tree and other plants in the community susceptible to other insect pests which normally would have been kept in check naturally.
- An herbicide sprayed for broadleaf weeds can be absorbed by tree roots close to the soil surface or through thin bark on the tree trunk causing tree damage or even death.

It takes a long time for a tree to mature and reach capacity for the benefits it can provide. If you lose one mature tree, how long will it take before one or even several smaller trees provide same/equal services/benefits? Chapter Three introduced the National Tree Benefits Calculator, which is a very easy online tool to express the dollar value of a tree's ecosystem services: http://www.treebenefits.com/calculator/.

The first step in improving healthy tree cover is to **know what is there** in whatever space you are dealing with. Chapter Three also discusses the iTree tool, which has made a huge difference in cities' abilities to assess their current tree inventory and canopy condition.[36] Chapters Four and Five cover identifying trees, which comes with experience and practice. Knowing what is there includes who as well: It's equally important to know all the stakeholders involved in any tree inventory or survey, how trees connect to them, and what the goals are.

Planning needs to: include private and civic partners, seek investment in trees, and ensure that projects are financially and physically sustainable.[37] As discussed in the previous section, it is important to take as wide a view as possible of the factors which will influence the outcome of a project. All parts of a plan need to consider and strive for **interconnectedness** and **resilience**. This means making plant choices with context and understanding of which plants belong together, the location conditions, the user goals and capabilities and potential future changes in local conditions. Plants, especially trees, can no longer be thought of as landscape decoration. Think community! Promote, plan, and plant more communities of trees with appropriate layers of shrubs and

36. Jonnes, J. (2016). *Urban Forests*. Viking Press.
37. Schwab, J.C., Ed. (2009). *Planning the Urban Forest: Ecology, Economy and Community Development.* American Planning Association.

groundcovers.[38][39] This may mean educating people on the benefits of plant communities versus individual trees. It may also mean helping people understand that plant communities look, act, and feel different than what they may be used to. For example, a buffer area looks very different than mowed grass to the water's edge. A plant community looks very different than individual plants surrounded by large beds of sterile mulch.

Reforestation or restoration opportunities can be coordinated at the city, county, or state levels. Are there any projects in progress or planned for your area? Who is coordinating it and how can you support or participate? Reforestation/restoration is a long process with many stages before a healthy ecosystem is formed. Are there specific times in the process or specific activities (planting, monitoring, invasive species control, pest scouting) you can assist with? An example is: a local waterworks department purchased an 11 acre abandoned home site near the headwaters of a river draining into a reservoir. The plan was to demolish the structures, remove the septic tanks and debris (recycling the metal and tires), eradicate the invasive plants, and replant with 4500 native tree seedlings. The end result, from waterworks' view, is a cleaner reservoir; but the benefits to the whole ecosystem will go well beyond that.[40]

Tree preservation is important during planning of any construction project and as part of a larger resource conservation program. Successful tree preservation requires knowledge of the species, individual tree and site conditions, stakeholders involved, and construction practices and policies. Inspection and enforcement during the construction period is essential. The end result can definitely be worthwhile if there is enough space and public support.[9] Unfortunately, it is often "easier" to remove a tree and replant if possible after the construction. A cost analysis could be performed comparing the value of the existing tree's ecosystem services versus the time it would take a newly planted tree to provide the same value and services.

Everyone (governments, institutions, companies, organizations and individuals) can do a better job of **tree selection, planting and long term care** on both private and public lands. Distribute science-based information. Teach. Conduct demonstrations. Become active in homeowner's associations, civic leagues, and planning and review boards that impact your community. Support improved communication and better coordination between homeowner groups, environmental groups, private companies, and city planners, engineers and urban foresters/arborists.

One example is an initiative from the California-based Urban Tree Foundation (UTF) that created a series of Planting Details and Specifications based on best science. These include specifications on planting, mulching, and irrigation systems, as well as inspection criteria, in an effort to insure that trees are in good condition before planting and during establishment. The documents are available in

38. Marzluff, J., (2014). *Subirdia*. Yale University Press
39. Rainer, T., & West, C. (2015). *Planting in a Post-Wild World.* Timber Press.
40. *Customer News.* (2017). Newport News Waterworks Department.

PDF format and also in a format ready to use in engineers' and contractors' Computer-Aided Design (CAD) programs. They are free and may be obtained from the International Society of Arboriculture: https://www.isa-arbor.com/education/onlineresources/cadplanningspecifications.

Nursery production and availability is another area that can be improved. Tree growers and sellers respond to market demands, but often the public doesn't know what it wants or what is appropriate for their planting sites. This has meant a fairly limited range of tree species available to the public. Also, counties and cities can establish lists of trees approved for planting (including natives), but the supply has to be available or people will get discouraged and not plant them. The Arbor Day Foundation and a number of forward-thinking nurseries are broadening the choices beyond the standard red maples, dogwoods, and Leyland cypress trees. Remember, though, it can take 5 to7 years to produce a "saleable" size tree. Consider the Virginia Department of Forestry's state nurseries as a resource for tree seedlings: https://dof.virginia.gov/nursery/index.htm.

Opportunities for engagement to improve healthy tree cover through VCE activities:

- Develop a list of nurseries and garden centers in your area that sell trees, especially those that sell native or hard to find species. Provide the list when people ask "Where to find…"
- Insert one "tree fact" into the handouts or onto the agenda for each city council meeting. It might be best to focus on facts that have a dollar value or direct impact on the specific community. TREEmendous tree facts!
- Make a point to introduce yourself to your local city/county arborist/forester. Ask about their background, programs, plans, and opportunities for partnerships or support. Go prepared to BRIEFLY discuss VCE & Tree Stewards. Take small VCE "gifts" (pencil, mug, set of VCE tree pubs, agent and tree steward contact information, etc.) when you go. People remember these things.
- Offer a short program on trees to your civic league, Ruritans, book club, church, etc. Find a way to make the presentation connect to them. For example, trees on the church grounds which are in the Bible, or statistics on trees in the neighborhood preventing crime and raising property values.
- Ask to assist in tree inventories for the city, military installations, the neighborhood, cemeteries, etc.
- Demonstrate pruning, planting, pest ID at garden centers, garden club meetings, etc.
- Offer to conduct the tree sections of the scouting curriculum.
- Lead "lunch and learn" tree tours at city offices (during lunch breaks), parks, cemeteries, etc.
- Install tree trails at local parks, businesses, schools, retirement communities, community centers, etc.
- Develop short presentations for the local MG speaker's bureau.
- Find out what other organizations are doing tree related activities and see where MGTS can fit in and support them (Master naturalists, native plant societies, wildlife groups).
- Have a VCE TS educational display at Earth Day or Arbor Day.

- Order tree seedlings from the Virginia Department of Forestry nursery and coordinate giveaways.
- Make large tree price tags that list the species, dollar value, and services provided and hang these on trees at various activities (i.e. how many birds supported, how much runoff prevented, how much shade provided, how much trees speed up recovery from illness or positively impact people with ADHD).
- Set up a "good mulch bad mulch" demonstration.
- Work with elementary school teachers (appropriate grade and SOL) to do leaf morphology, identification, and a collection, explain why some leaves change color and fall off while others don't.
- Volunteer to make a "Value of Trees" or "How Do Trees Benefit Our City" brochure.
- Make a traveling "Tree ID" or "Tree Insect ID" display.
- Distribute the VCE pub on recommended trees for under utility lines to city planners.
- Write a grant proposal for tree related community projects.
- Research information about trees improving downtown/shopping areas and distribute to businesses.
- Find out what the city policy on street tree replacement is and work to make replacements happen if they are not.
- Become familiar with local tree ordinances, who they apply to, and who enforces them. Work to educate citizens on them or to make changes if necessary.
- Work with a youth group to make tree art (rubbings, drawings, sculptures, etc.) and get it displayed at the local community center or library.
- Organize a canoe/kayak trip to look at trees along waterways or shorelines.
- Identify any "champion or big" trees in your locality and look for specimens to submit. Bring attention to these unique local trees. Also, offer to measure these trees to keep records up to date. Ref.: Virginia's Big Tree program.
- Coordinate a unique tree tour of your locality. This could be for adults and/or children, scavenger hunt/passport to find trees with reward for visiting them all.
- Incorporate trees into geocaching activities.
- The Virginia Department of Forestry has many youth educational booklets and items (rulers, erasers, stickers, posters, etc.) that can be used for programs for scouts, school, environmental clubs and other youth groups.

Specific Tree Considerations by Region

One of the goals of this manual is to encourage VCE MG Tree Stewards to develop local knowledge to help positively impact Healthy Tree Cover in their own counties, cities and neighborhoods. There are commonalities among neighboring locales, and tree stewards are encouraged to share their efforts and experiences. This manual proposes a model for regional descriptions, being an unusual combination of altitude, weather, economic activity, land use, government and population density.

The Guidebook to Virginia's Historical Markers, Third Ed (2007) divides the state into six Cultural and Geographical Regions which address most of these factors, yet are socially, climatically and economically compact. The authors were able to make a reasonably thorough description of the Eastern Virginia region (since that's where we live). We tried to frame some basic conceptual elements for the other regions, but tree stewards who reside in those regions are best equipped to expand upon these beginnings.

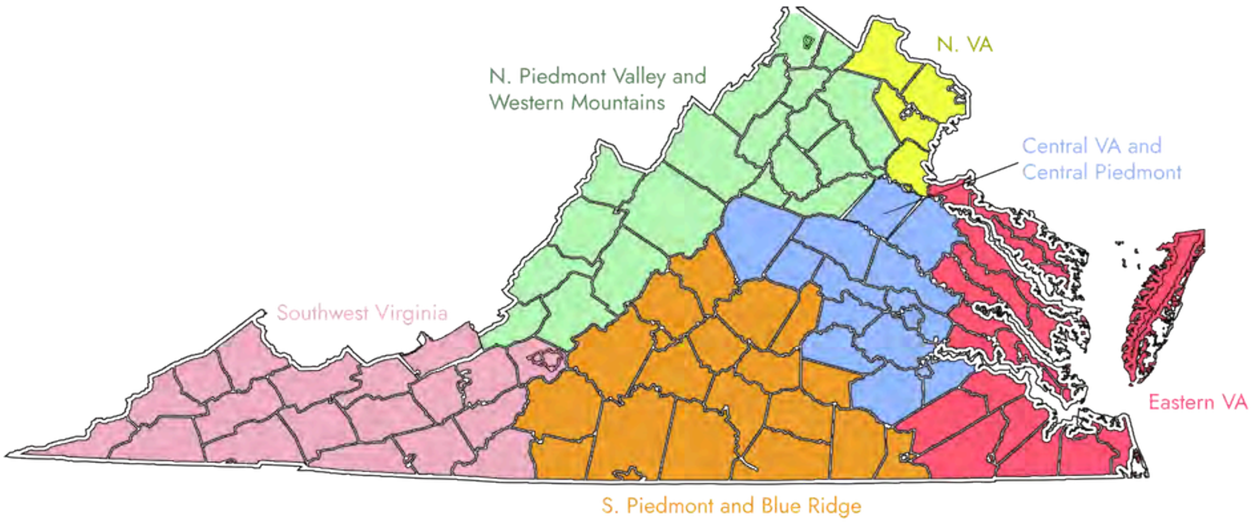


Figure 7-7 Eco-Cultural Regions Notations by Carol King

Each regional description should try to answer these questions:

1. What distinguishes this region from others? Think both in terms of natural characteristics and human history.
2. What are the basic climate parameters? Are there any significant mesoclimates?
3. What are the ranges of altitude, geology, and soil type and pH?
4. What are the major water features and/or issues?
5. What are the main land uses and/or industries?
6. What are the major tree species (genera, families): think native, introduced and invasive?
7. What are the most significant stresses, both on human communities and on the trees?

Eastern Virginia: Primarily consists of the land east of the fall lines of the main rivers (Potomac, Rappahannock, York and James). Subregions are the Northern Neck, Middle Peninsula, Hampton Roads, Chesapeake Bay borders, the Eastern Shore, the Dismal Swamp, Chowan River drainage and the outer cape of Virginia Beach. This is a region of rivers and marshes overlaid by substantial and growing population development. As the first part of Virginia settled by English colonists, history is on display all over, though the economic dynamics of the fall line meant that the political center of gravity moved from this region by 1800. Today, port operations, shipyards and military installations make up a large part of the economic activity. NASA space research has long been a part of the economic picture and is now complemented by commercial space launches. At the same time, watermen still fish and harvest oysters. The counties bordering North Carolina are well suited to peanut production and also grow a lot of cotton and soybeans. This region has the second largest population in Virginia, principally in the Hampton Roads area.

Many of the waterways are tidal and saltwater, at least in part. Mesoclimates can vary considerably along the major rivers along with the large effects of residential and agricultural development resulting from waterfront attraction and discharge convenience, respectively. Significant regulation and public support is directed toward measures to improve the health of the Bay and the many rivers. In addition, the combination of sea level rise and the subsidence of the lands bordering the Bay leads to significant concerns for future high tides, storm surges and hurricanes. Trees which are not tolerant of these conditions may be expected to decline, with a corresponding need to plant resilient species along with appropriate shrubs, grasses, groundcovers and self-seeding annuals.

Temperatures fall in the USDA Cold Hardiness Zones 7b to 8a. The Eastern Shore, Virginia Beach/ Norfolk and the Lower Peninsula have mostly moved into 8a, with the 7b zone farther inland. Hard freezes (10 to 20 degrees Celsius) are possible but not often or enduring. First frost may be early November or not until January, so the soil does not generally freeze solidly. Thus, winter dormancy in trees may be compromised by the odd warm days, and trees (especially young ones with thin bark) are susceptible to freeze cracks and sunscald.

Soils are mostly ultisols (strongly acidic clay), with pockets of sand, plus calcareous ravines in the York County area. Some mollisols (floodplain soils) are found in Norfolk. Tree cover is largely oak and loblolly pines, with magnolias, eastern redcedars, hickories and hollies interspersed. Swamps have several kinds of cypresses, especially along the North Carolina border. The only major stands of longleaf pine (*Pinus palustris)* are located around the town of Zuni, though conservation plantings are occurring the SE area, such as Poquoson. Species with notable presence at the northern end of their range are live oak (*Quercus virginiana),* Bald Cypress (*Taxodium distichum),* and southern magnolia *(Magnolia grandiflora).*

Northern Virginia: Small in area and number of political entities, Northern VA is densely populated and heavily developed. It is also home to the wealthiest cities and counties in the state. European arrivals in the early to mid 18th century established plantations and trading networks, especially around the fall line of the Potomac River. Much of the surrounding area remained largely agricultural until the post-WWII growth of the federal government; after that, suburban development has gradually solidified into a near –continuous urban center, except for the ends of the region in Loudoun and Stafford Counties. Cold Hardiness zones are 6b to 7a, hospitable to many temperate plant species, but there are great challenges represented by altered urban soils, heat island effects and management of storm water from impervious surfaces.

Northern Piedmont, Valley and Western Mountains: This region is noted particularly for its geography, being a series of river valleys separated by mountains from northeast to southwest. The history of modern settlement started in the early 18th century and continued as the region was a popular migration and transport route between Pennsylvania and the Carolinas. The very busy I-81 corridor continues this pattern. The Shenandoah River is the major water feature, flowing toward its juncture with the Potomac. It is a rich agricultural area set among large forest reserves in the George Washington National Forest. Where it intersects the Appalachian Mountain range, it is host to an unusually diverse forest floor biosphere (for example, millipedes and ferns). There is some very interesting geology, including caverns, the Natural Bridge formation, and hot springs. Tourism for both historical attractions and the natural wonders is an important part of economic life. Cold Hardiness zones are 5b to 7a, largely varying with the altitude, and even including a bit of 5a in the extreme western edge. A wide variety of mesoclimates can be expected due to abrupt changes in altitude and also exposure to (or shelter from) winter winds and snows.

Central Virginia and the Central Piedmont: The east-central part of the state derives its identity from the early history of development proceeding up the rivers from the earliest settlements to the limits of riverine navigation at the various fall lines. Subsequent consolidation of political government and industrial production in the Richmond area was reflected in the transportation grids, particularly during the tumultuous years of the Civil War. The area remained largely agricultural except for Richmond and Petersburg until fairly recent years, when the suburbs of Richmond began to push out. This region has the third largest population in the state, just a little less than the Eastern Region. The James River is the major water feature, along with its tributaries. Cold Tolerance zones are 7a and 7b, but with heat island effects in the two large cities.

Southern Piedmont and the Blue Ridge: Most of this region is a counterpart in elevation, terrain and soil to the center around Richmond, but without the extensive political and industrial history. Its past has been one of tobacco, timber and textiles. The land rises gently in elevation from the fall lines of the rivers to the beginnings of the Blue Ridge Mountains. The Roanoke River drains most of this region.

Southwest Virginia: Mountains, valleys, ridges and plateaus dominate this relatively sparsely settled, economically challenged region. The Blue Ridge Mountains dominate the terrain, as does the very busy I-81 corridor. Colonial settlements began in the mid 18th century and have been mostly motivated by the migratory route through the Cumberland Gap. Railroads were an engine of growth after the Civil War, into the 20th century, which facilitated the timber and coal industries. Textile mills were also an economic boon for a while. The decline in coal production has had significant economic and social impact on this region. On a cultural note, this region has a strong musical legacy, stemming from its earliest immigrant folk heritage. Cold Hardiness zones are 6a and 6b, and different mesoclimates due to changes in elevation and wind exposure are common.

Review Questions

1. List some examples of changes or disturbances that impact tree communities.
2. What is an ecosystem service?
3. What is the difference between arboriculture and urban forestry?
4. What are some steps to improve the health of local tree cover?
5. What is the most common tree in your locality? Why is this so?

CHAPTER 8: SITING, SELECTING, AND PLANTING

"Right Place, Right Function, Right Plant"

Chapter Contents:

Introduction

A guiding principle often used in landscaping is **"Right Plant, Right Place."** You hear it over and over in the plant world, but what does it mean? Basically, it means that the qualities of the plant need to match the characteristics of the site in order to have a successful outcome. Oftentimes, a homeowner spies a lovely tree in the nursery and simply must have it: his or her dilemma is then to find a spot at home where it will prosper. Many a tree has failed because there really wasn't a good spot for it. In fact, this pattern is backwards: better to find a tree that suits your site in the first place. So, a revised motto: **"Right Place, Right Plant."**

More than that, however, we need to consider what function we want the plant to perform in the site. People who want an ornamental tree that also produces fruit may be disappointed on both counts, since pruning for fruit can be very much different from pruning for bloom. If we don't choose the plant to match the desired function as well as the characteristics of the site, then we put the plant at a disadvantage and may even create a problematical situation. Furthermore, in a world of changing climate and increasing urban forest challenges, failure to think about extremes of heat, wind and precipitation can multiply the effects of a good or bad decision. If we are going to the time, trouble and expense of planting a tree, we want to make sure our investment pays off with dividends. So it really should be **"Right Place, Right Function, Right Plant."**

Learning Objectives

1. Know how to analyze a planting site.
2. Understand the range of functions a tree may perform in a selected site.
3. Understand what plant features make a tree suitable for a particular function and site.
4. Be aware of potential changes from climate change and socioeconomic factors.
5. Know where to find information on trees for difficult sites.
6. Understand the sources, types and sizes of planting stock.
7. Know how to plant a tree properly.
8. Know the basics of immediate aftercare for newly planted trees.

REVIEW: VCE Master Gardener Handbook 2015 (9/18 update)

- Chapter 2, Basic Botany
- Chapter 16, Woody Landscape Plants

Right Place

The very first step in any planting project is to **understand the ground**. Taken in its broadest sense, this means making notes of all these **site factors**:

- Heat/cold zone
- Soil texture and structure, depth of topsoil, and soil pH
- If this is an urban or disturbed site, how much real soil is there?
- How much soil amendment can reasonably be done?
- Drainage rate in the soil and drainage patterns across the entire site
- Slope patterns, present and potential with regrading if an option
- Light quantity and direction (noting seasonal progression and deciduous trees)
- Precipitation in the local area (average and extremes)
- Any other moisture sources (streams, vernal pools, periodic flooding)
- Salt from ocean spray or saltwater intrusion, including from road ice treatments
- Local climate change trends and potential for increasing climate disruptions
- Hardscapes which are already there or are planned
- Any access easements which may limit planting of large woody plants
- Utilities, above and below ground

- Present lines, pipes, meters and shutoff
- Future plans for new lines for water, gas and sewer
- Are power lines going to be buried anytime soon?
- Old sewer laterals from house to main
- Septic fields should not have woody plants

Depending on the scope of the planting project, this initial survey may be fairly involved or could be as simple as a home landscape in a Southeast Virginia suburb e.g., cold zone 7a, clay, acid soil – moderate to poor drainage – level ground – full sun – sheltered from winds – standard paving and utilities. There are no apparent neighbor issues but increasing potential for hurricanes and saltwater intrusion.

Figure 8-1 A Home Landscape in Tidewater Virginia. (Courtesy Carol King)

Here's an idea for tree stewards to gain experience in this area of effort: practice site surveys, simple or complex, in your own neighborhood. It can be very enlightening to find site-related reasons why certain trees prosper where they do, or don't.

Microclimates are areas in the landscape where conditions differ from the greater local climate. Microclimates can be a natural phenomenon and they can also be man-made. A south facing hill will be naturally warmer than a north facing hill. So you may be able to grow a plant from a warmer hardiness zone on a south facing hill rather than on a north facing hill. Additionally, you may be able to grow a plant from a warmer hardiness zone next to a brick wall. The heat absorbed and then released by a brick wall can make that site warmer than the surrounding area.

If you have an **exposed site**, a site with no shelter from the wind, it can be a bad location for trees that may be marginally hardy. If you have a **protected site**, a site with shelter from the wind, marginally hardy trees may survive for many years but may succumb if there is an extremely cold winter. The southern magnolias below are espaliered against a south-facing brick wall, enabling them to prosper north of Richmond.

Figure 8-2 Southern Magnolias at Lewis Ginter Gardens. (Courtesy Carol King)

The tree steward needs to consider prevailing winds and possible extreme situations. It is also worth remembering that shallow pockets or the bottom of valleys will tend to retain cold air in winter: a natural microclimate of cold.

Space and Geometry. One matter which is often overlooked in site planning is the available space for the true spread of the canopy and of the roots. Above ground, if the space is narrow but tall, then a broad spreading canopy will not work. This is fairly well understood by negative example. What is less well appreciated is the importance of the space below ground, considering the soil type, depth of the soil horizons, drainage and physical infrastructure (now or planned). A situation with shallow drainage but lots of sidewalks is potentially problematic: a shallow rooted tree will tend to disrupt the pavement. So the tree steward might want to look more at a deeper rooted tree with known tolerance for wet soils, such as the swamp chestnut oak [1]. Deep rooted trees including white oaks should also be better able to adapt to increasing periods of drought. [2] Note that even a deep rooted tree will have surface roots in compacted soils, since the space between sod and compaction can be a friendly place for roots to spread. Also, a tree with a wide spread of shallow roots may have its own dynamic stability, as with the beech below, assuming it has been given enough space.

Figure 8-3 American Beech with Enough Space Above and Below Ground. (Courtesy Carol King)

One final thought in site analysis is the **context**, meaning the history and probable future of the site. Left to itself, what would be the noninvasive natural growth? What are the societal and/or economic factors which may affect the site? Are there known plans for building or road construction in the area? Looking longer term, how is the surrounding area likely to be affected by urban sprawl, sea level rise, and overall climate change? Are there site vulnerabilities which are now considered acceptable but which could become problems with increasing climate disruption events?

1. Kirkman, L.K., Brown, C.L., Leopold, D.J. (2007). *Native Trees of the Southeast*. Timber Press.
2. Vose, J.M., Elliott, K.J. (2016). Oak, Fire and Global Change in the Eastern USA. *Fire Ecology, 12* (2), 160-179.

Right Function

Once you have surveyed the site, (or even before), you must think through why the planting project is wanted. A basic set of questions may shed light.

Who is the authority? If a homeowner, this may be relatively straightforward. Otherwise, it is important to know who wants the planting, who makes the decisions, who pays the bills and who will maintain the plantings. Be sure you know if there are any environmental restrictions or requirements. **Why is planting bring considered in this spot?** There are a number of possible reasons, of which several may apply at the same time:

Human Health and Aesthetics: For the flowers, foliage, bark, even fruit. Consider winter interest. And who doesn't love the snow fountain cherry in spring?

Figure 8-4 Ornamental Weeping Cherry. (Courtesy Carol King)

Beyond the purely ornamental aspects, all those pretty trees have real health and social benefits in urban settings, as shown by an increasing number of studies. [3]

Practical: For shade, for screening, for erosion control, for water quality and storm water management. Trees are one of the most important tools in the ecologist's toolbox.

3. Wolf, K.L., Lam, S.T., McKeen, J.K., Richardson, G.R.A., Van den Bosch, M., Bardekjian, A.C. (n.d.). Urban Trees and Human Health: A Scoping Review. *International Journal of Environmental Research and Public Health, 202*(17), 4371, doi:10.3390/ijerph17124371

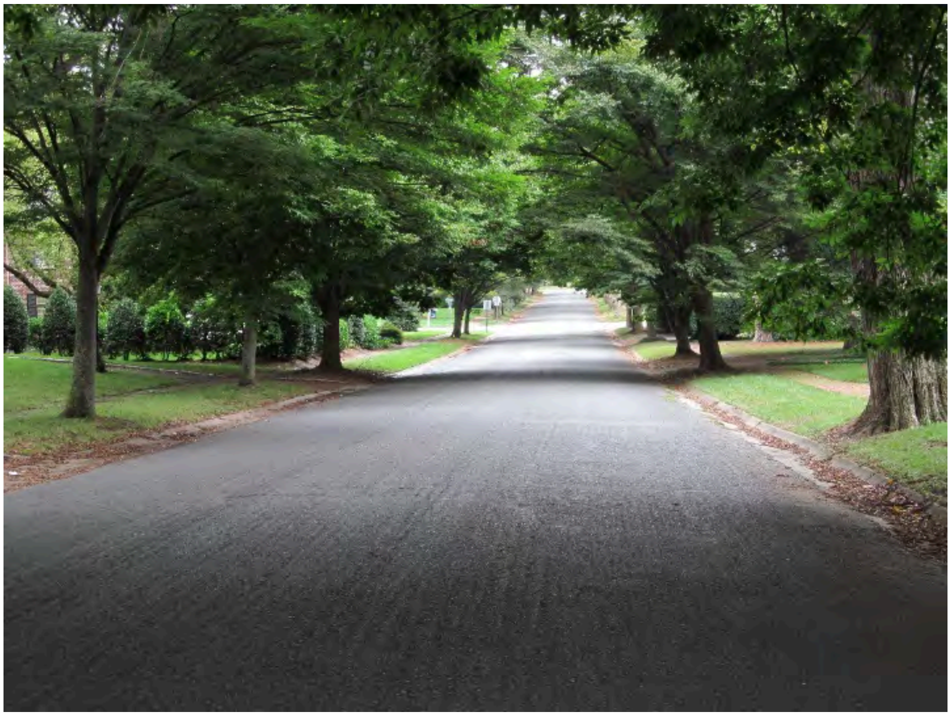


Figure 8-5 Zelkovas Planted to Shade a Richmond Street. (Courtesy Carol King)

Figure 8-6 Screen of Eastern Redcedars Charles City County. (Courtesy Carol King)

Figure 8-7 Erosion Control and Water Quality in a City Park. (Courtesy Carol King)

Production: Sap has historically been one of the most useful tree products: resin from the pines or gum from the sweetgum (look it up!). Tree nectar from the sourwoods is an important feed for honeybees, as are the native basswoods. Hickory nuts are an important food source for wildlife. The osier dogwoods provide the fancy red whips in spring for decorators (or just for people to enjoy). There are secondary production opportunities such as growing certain oaks to serve as hosts for truffles. And not least at all: fruit!

Figure 8-8 Japanese Persimmon on the Eastern Shore. (Courtesy Carol King)

Another major consideration is the **time horizon**. Even if you are thinking of just this year or next for the desired effect, trees have their own, much longer timelines. So, if you decide to plant a larger tree now in order to have a full canopy in a matter of just a few years, you (or whoever comes after you) may be living with that tree for many years. In fact, it is much more important to consider the eventual size of a well chosen and properly planted tree rather than its size in a narrow, human perspective of 5 to 10 years. Note that commercial plant labels may be giving you just that 10 year number: do some research on the species before investing.

Finally, there are **other functional considerations**, of which this list is only a sample:

- City/county ordinances or HOA rules
- Budget (including maintenance)
- Grant requirements or civic themes

Right Plant

Once the site has been analyzed and the reasons for planting have been laid out, it is now time to think about what kind of tree(s) and other plants to choose. It is probably useful to think about what requirements of either site or function will limit the choice of plants: Hardiness, growth habit, growth rate, max size (above and below ground), moisture needs, and particular features (good or bad) are all important in making the right selection. One should also consider tradeoffs of quick growth vs longevity, maintenance needs, and the potential to handle climate changes and disruptive events.

If you are framing the discussion in economic terms, remember that return on investment can be considered in other terms than dollars.

Hardiness

This is the first limiting plant feature. Another way to speak of this trait is that some plants can handle a wide variety of physical and climatic conditions, while others are much pickier. Trees are so much larger and longer lived than other plants that people's short term adaptations (such as irrigation) don't make all that much difference in the tree's long term survival. **Range** is the word used to describe the locations and environments in which a tree species will normally prosper. One of the most important factors in determining a tree species' range is how well it handles low temperatures. USDA publishes a **Cold Hardiness Zone Map** with a colored key. Virginia spans four of these zones: the coldest is zone 5a in the mountains, and the extreme Southeast, plus the Eastern Shore, just edging into zone 8. This represents a variable of 30 degrees Fahrenheit, from -20 degrees to 10 degrees, in the historic extreme minimum temperatures each year: a considerable difference between a Frasier fir and a southern magnolia! A **Heat Tolerance Map**, if available, can be important in urban heat islands or locations with high temperature spikes in the summer. Most plants tags give only the Cold Zone number, but horticultural sources may give both, usually Cold Zone first. Since the numbering systems are similar though not identical, it is important to know which one you are looking at.

Temperate zone trees naturally grow in forests, and that is where we should look first for information about their suitability to different environments such as cities. Tree books often describe what sort of terrain trees prefer, and foresters have insight into this as well. Trees that grow on mountain tops are accustomed to dry, less fertile sites (some oak and pine), while bottomland trees are better at handling poorly drained soils (other oaks, sycamore, elm). Mid-slope trees come somewhere in-between (tulip poplar, beech). And some trees are quite versatile (red maple, persimmon, eastern redcedar, black gum).[4]

In a world of changing climate, we are seeing the distribution patterns of some trees changing in the forests. For example, in the forest biomes covering Virginia, it looks like loblolly pine, sweetgum and a number of oaks are pretty good bets. [5] Check Chapter Seven for suggestions of online resources for projected species distribution. Generally, in human-built environments, we should be looking for trees which are resilient in the face of climate extremes and structurally able to handle disruptive

4. McGlone, J. PhD. (2020, June). [PowerPoint] *Landscape Woody Plant Adaptations: A View from the Forest,* VCE Master Gardener College.
5. Rogers, B.M., Jantz, P., Goetz, S.J. (2017). Vulnerability of Eastern US Tree Species to Climate Change. *Global Change Biology, 23*, 3302-3320, doi:10.1111/gcb.13585

events. Also, the larger and longer trees grow, the better for carbon reduction [6]and stormwater management. [7]

Growth Habit

Each tree has a natural habit or form. Often these are common to an entire species or even genus, but some trees have been developed to have cultivars in all sorts of habits. For example, the bald cypress normally has a conical outline, but you can get one that is weeping instead. Some common tree forms are columnar, oval, round, pyramidal, spreading, weeping and vase. Some tree forms are better suited for certain locations than others. A tree with a natural vase shape is a better selection close to a driveway than a weeping tree where the branches will be constantly hanging down over the parked cars and need pruning. When selecting a tree, be sure to match the form to the function.

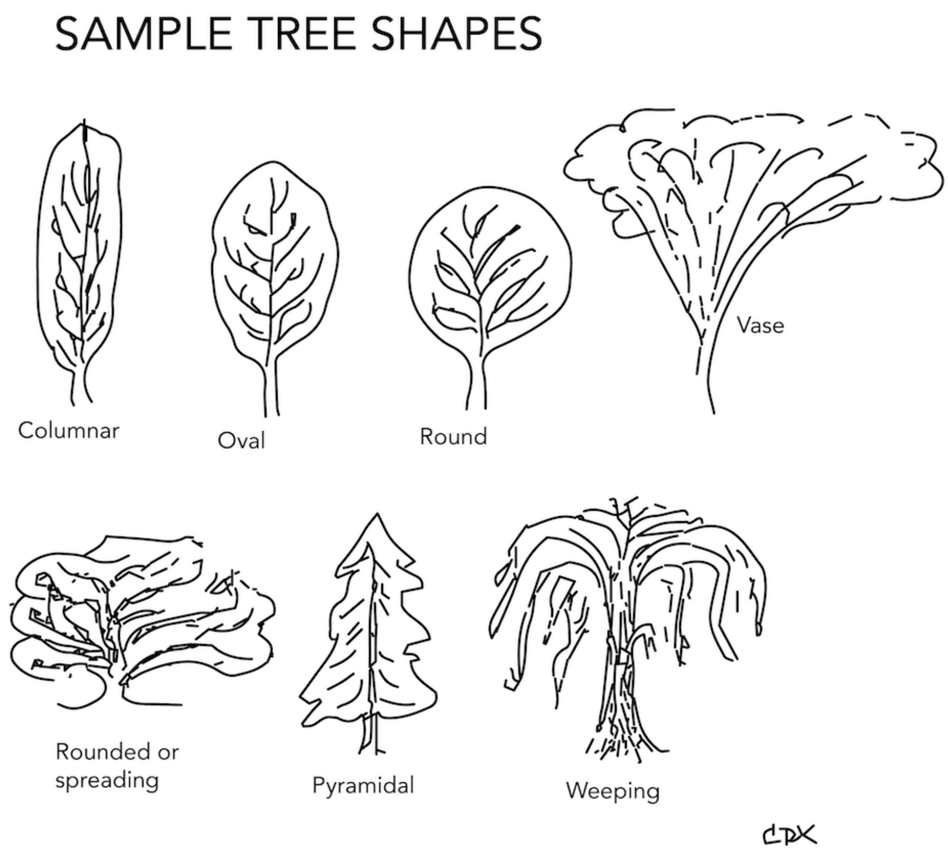


Figure 8-9 Sample tree shapes. (Courtesy Carol King)

6. Nowak, D.J., Stevens, J.C., Sisinni, S.M., Luley, C.J. (2002). Effects of Urban Tree Management and Species Selection on Atmospheric Carbon Dioxide. *Journal of Arboriculture, 28* (3), 113-122
7. Berland, A., Shiflett, S.A., Shuster, W.D., Garmestani, A.S., Goddard, H.C., Herrmann, D.L., Hopton, M.E. (2017). The Role of Trees in Stormwater Management. *Landscape and Urban Planning, 162*, 167-177

Growth Rate

Different trees grow at different rates. Does the growth rate suit the function for that tree? A fast growing evergreen is often selected for screening, with consideration for the strength and health of the roots which may be subjected to winds. Or you may wish to select a slow growing tree such as a specialty Japanese maple near a house where you will most likely not need to do very much pruning. In a larger setting such as a municipal park, it may even be wise to select trees with naturally good branch structure and a less rapid growth rate, such as the blackgum, which will lessen the workload on the maintenance crews over time.

Many times, fast growing trees are often weak trees. A silver maple is a fast growing shade tree, but it is very weak wooded and tends to have multiple trunks from a single point. You would not want to plant a silver maple near a structure, fence or vehicles. As those trunks or branches fall, they can do damage to whatever is below.

Figure 8-10 Silver Maple After a Storm. (Courtesy Carol King)

Maximum Size

Many times trees are planted without thinking about their potential size. This can lead to future problems where people are attempting to control tree size through pruning, which may not be realistic depending on the specific tree. We have all seen instances of a cute little tree planted next to the front porch, which then grows to take over the doorway and path. This comes from not believing the label: it may be 3 feet tall and wide now, but 20 feet by 20 feet is something else again.

Commercial plant labels should be read with some caution, as well: the given max size may be the final size for that species, or an estimate in ten years' time. If the latter, the label will not usually tell you that detail. So, be sure to check a couple of other sources for max size. Finally, even if the label gives a reasonable maximum size for that tree, if the tree is really happy it will ignore the label and set its own record.

A word is in order here about **overhead wires** and their supporting poles. There are a few trees (or rather, varieties or cultivars of certain species) which have been tried out to see if they will remain small enough to avoid the attention of utility tree-trimmers. The VCE Pub on this subject is listed in Table 8-1, later in this chapter. However, individual trees do not always behave as expected and the power line situation gives very little room for miscalculation.

One trend in urban landscapes is homeowners' reluctance to keep or plant trees for fear they will fall. It is important to respect this attitude, but education can point out that healthy, well maintained trees of good structure are much less likely to fail while still providing ecosystem services. For planting new trees, such sites may benefit from small to medium size trees with reasonable longevity and pest resistance, such as yellowwood and redbud. [8]

You should look for information about **how the root system grows** when researching potential trees. You may want to go look at mature specimens to see how they do in your locality and soil. Generally, a shallow rooted tree is not suitable for planting near sidewalks or driveways. It is also hard to establish planting beds under shallow rooted trees. Some trees have aggressive root systems that seek moisture. For example, willow trees seek moisture so they are not a good selection to plant near a septic field.

Moisture Needs

Many of the most successful urban trees are those which grow naturally in challenging environments and tolerate changes in moisture and temperatures. Examples include red maples, sycamores (and their cousins the London planetrees), bald cypress and the dinosaur-survivor ginkgo.

On the other hand, if the planting site is prone to standing water after a heavy rain, then you should avoid trees which don't tolerate wet feet (e.g., redbud) but go instead to those which can handle some extra water from time to time. Some of the best of these will be listed in the various publications about rain gardens. The sweet bay magnolia is an excellent example for eastern Virginia.

8. Kirkman, L.K., Brown, C.L., Leopold, D.J. (2007). *Native Trees of the Southeast*. Timber Press.

Particular Features (Bad and Good)

Problems to avoid: When researching potential trees, also look at **disease and pest concerns**. You may find that the potential disease and/or pest concerns would warrant that you not choose to plant a certain tree. For example, ash trees are wonderful shade trees. However, with the introduced pest, Emerald Ash Borer, moving into the region, you would not want to select that tree for any future plantings. The Leyland cypress is another example of a popular and beautiful tree which is prone to a number of pests and diseases, including in the roots: most of us have seen a lovely long screen of these with gap teeth where individual trees have succumbed.

Research is always important. You may find that the tree you want to plant has disease resistant varieties. For example, there are some selections of crape myrtle trees that are powdery mildew resistant. Or trees may have been developed to avoid undesirable features, as with the thornless honey locust.

Flowers and fruits can be potential issues. A sweetgum, while a great shade tree, would not be an appropriate choice for planting in a lawn. It drops its stiff seed pods, called gum balls, which make the yard not very enjoyable to walk and play in. A saucer magnolia is a beautiful medium sized flowering tree. However, if you plant it overhanging a sidewalk, it can become a slippery mess for a week or so in the spring when all the large, soft petals drop on the ground beneath. Another interesting fruit hazard is the ginkgo. The fruit of the female tree, when ripe and fallen to the ground, has a strong odor. The seeds are an Oriental delicacy, but understandably most landscape plantings are male trees (however see pollen, next below).

Another flower feature worth discussing: **pollen.** Oaks, pines and maples are wind-pollinated, meaning that the trees send out clouds of minute pollen grains to try to contact the equally small female flowers. Note this does not mean that such trees are male/female necessarily. For many allergy sufferers, mid-spring can be quite miserable. Wind-pollinated trees can be recognized because their flowers come out before their leaves, generally speaking. One possible answer is to diversify with other trees whose flowers arrive with or after their leaves. Many of these rely on (and thus benefit) insect pollinators, such as linden/basswood, blackgum and tulip poplar.

One of the most enjoyable parts of process of tree planting is choosing among the many **attractive plant features** available. As we have already said, this step may be where many people start. But if we really want the tree we plant (whatever it turns out to be) to prosper, we don't start choosing plant features until we understand the site and the intended function. If we are growing a tree for harvesting fruit, sap, nuts or other use, then specialty research is definitely appropriate, including soil needs. If the purpose is a screen or windbreak, the key features will be root strength, branch structure, foliage and growth rate. Which brings us to the ornamental qualities of leaves, flowers and bark.

Leaves are, of course, the food producing part of the tree. But they do many other tasks for us: shade, water transpiration (cooling the air), intercepting aerosol and particulate pollution, food for insects, habitat for wildlife. Looking at the ornamental and practical decisions, the first decision is **evergreen** or **deciduous.** Note that all the leaves eventually fall off of trees: evergreens keep the old ones until after the new ones arrive (sometimes over several years). The size of the leaf and the timing of deciduous leaf fall can be important if you will be spending hours raking, but may be worth the glorious fall color.

Figure 8-11 Red Maple in Fall. (Courtesy Carol King)

Conifers are usually among the easiest trees to care for, with evergreen foliage and cones instead of fruit. The eastern redcedar is an example of one which is also very good habitat for wildlife.

Figure 8-12 Eastern Redcedar Foliage and Modified Cones, (Courtesy Carol King)

Leaf thickness is also a consideration. Thick leaves, such as the southern magnolia, usually provide shadier conditions underneath it. This makes it harder to plant or grow anything underneath it. These leaves are also harder to remove or mulch. Thinner leaves usually provide less dense shade and tend to be easier to remove or mulch.

Figure 8-13 Southern Magnolia Leaves and Early Seedcones.
(Courtesy Carol King)

All broadleaf trees produce **flowers**, but not all flowers are notable. However, we may be selecting trees for those notable flowers. The time of the year the tree flowers may also be of consideration. Depending on the species, trees' flowering seasons may be anytime from late winter to late summer.

It may also be considered an asset if the tree provides **nectar** for bees and other insects. Examples are black locust, tulip poplar, and the tilias (native basswood and well-adapted littleleaf linden).

Bark is another feature which may influence landscape choice. Some tree species are noted for unusual bark which can add interest to a garden, especially in winter.

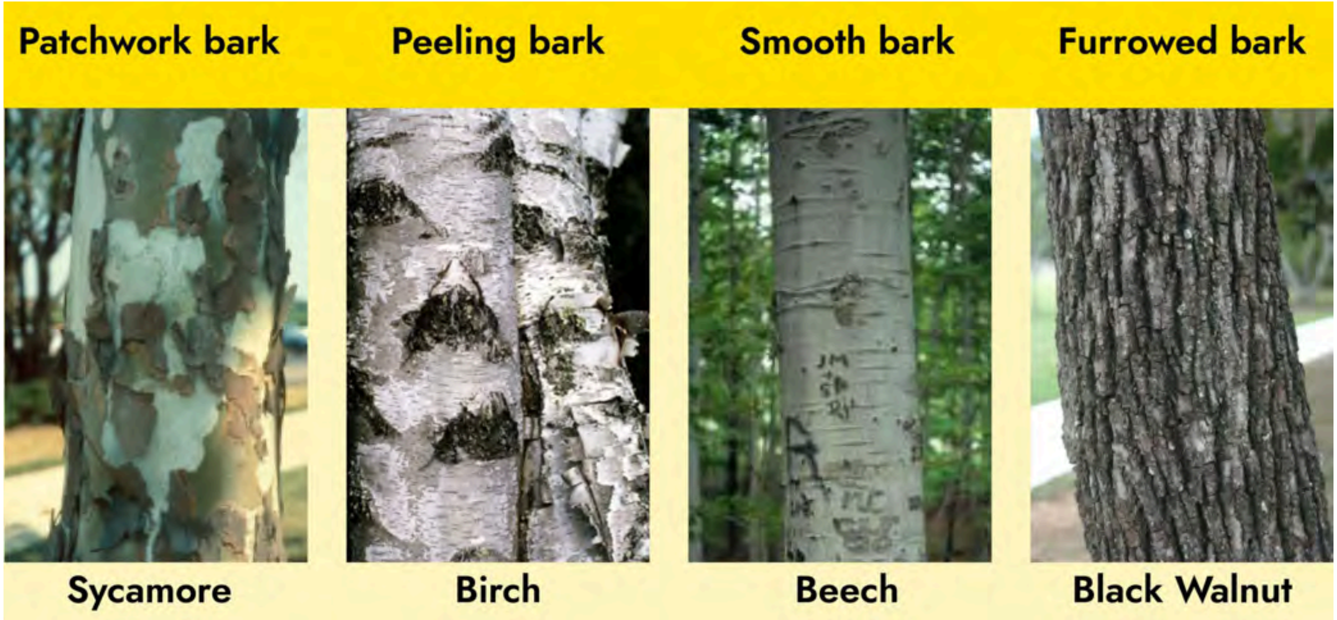


Figure 8-14 Trees with Interesting Bark

Natives versus Non-Natives

Native plant gardening is a current trend in gardening. Planting native trees certainly falls in with that trend. A **native plant** is considered to be one that grew in a certain locality prior to European settlement. The local fauna and other flora evolved with those native trees around. A native tree's natural habitat can give us clues as to where descendant tree may thrive. For example, red maple trees are found in wild bottom lands and moist soils, hence its other common name, swamp maple. Therefore, if you have a damp location, this tree may be a good choice.

Non-native trees, then, are ones that have been introduced to a region after European settlement. Non-natives can open up a whole new range of plant features that may not be available with a native tree choice. They may also be important as we look ahead at the challenges posed by difficult urban environments and general climate change dynamics. Increasing extremes of heat, precipitation and wind may make a nonnative from a harsher climate a reasonable choice in the landscape.

When considering a non-native tree, you also have to address its potential for invasiveness. Nonnative invasive plants have negative effects on biodiversity (i.e., the rich genetic resource of flora, fauna, and microbes) at the ecosystem level and the community and population levels. Examples of how invasive plants threaten the health of natural areas are:

- Replacement of diverse systems with single stands of nonnative plant species.
- Changes in soil chemistry, land form processes, fire regime, and hydrology.
- Competition with endangered plant species.
- Failure to support native insects and animals while displacing plants that do.

To consider just one example, the mimosa is a non-native tree that does very well in poor urban soils, has a beautiful summer flower, and is easy to clean up in the fall. The Virginia Department of Conservation and Recreation lists this tree as having a medium invasiveness ranking. Indeed, you can see this species in disturbed areas where it can easily displace native vegetation that would otherwise grow. As a result, you would not want to select and plant this tree.

Here is a native gardener's dilemma. The modern plant breeding industry is constantly striving to develop new plants with desirable features such as smaller size, better shape, or disease resistance. Do these cultivars and hybrids of native plants support ecological functions as well as their wild relatives? Should we label such cultivars and hybrids, sometimes called "nativars," as native plants? There are no decisive answers to these complex questions, although Doug Tallamy's research at the University of Delaware[9] suggests that in some cases nativars are more attractive to pollinators or leaf-feeding insects than their wild parents, and in others they are less so. It is also possible that designed hybrids may have a role in the changing environment of the future.

Trees for Difficult Locations

Planting the right tree in the right place can be difficult sometimes. There may be environmental conditions or man-made conditions that make that site challenging to grow trees. Virginia Cooperative Extension has many publications available to help with the selection of trees for difficult sites.

VCE publications on trees (look up by the numbers) on VTechworks:

- Selecting Landscape Plants: Rare and Unusual Trees: Publication 426-604
- Trees for Problem Landscape Sites – Air Pollution: Publication 430-022
- Trees for Problem Landscape Sites – Trees for Hot Sites: Publication 430-024
- Trees for Problem Landscape Sites – Screening: Publication 430-025
- Trees for Problem Landscapes – Wet and Dry Sites: Publication 430-026
- Trees and Shrubs for Acid Soils: Publication 430-027
- Trees for Parking Lots and Paved Areas: Publication 430-028
- Trees and Shrubs for Overhead Utility Easements: Publication 430-029
- Trees and Shrubs that Tolerate Saline Soils and Salt Spray Drift: Publication 430-031
- Trees for Containers and Planters: Publication 430-460

9. Tallamy, D. (2007). *Bringing Nature Home.* Timber Press.

Obtaining and Evaluating Planting Stock

Types and Sources of Planting Stock

There are many different sources, types and sizes of planting stock. Every one of these has its pluses and minuses. So, while one type of planting stock may be appropriate for one situation, it may not be appropriate for another. Being aware of these pluses and minuses can help the consumer in making an informed decision. Trees may be purchased **bare root**, in a **container,** or **balled and burlapped (B&B)**, where the root ball is wrapped in burlap type material.

Bare root trees are often the least expensive type. However, they are typically only available during the dormant season. They will usually only be available by mail order, and the tree size is usually only available from seedling size to 8 feet tall.

Container trees are typically available year round. They are easily available in most localities. Their cost is generally more than bare root trees, but less than B&B. The tree size for containers can be from seedling size to typically a 2 inch caliper.

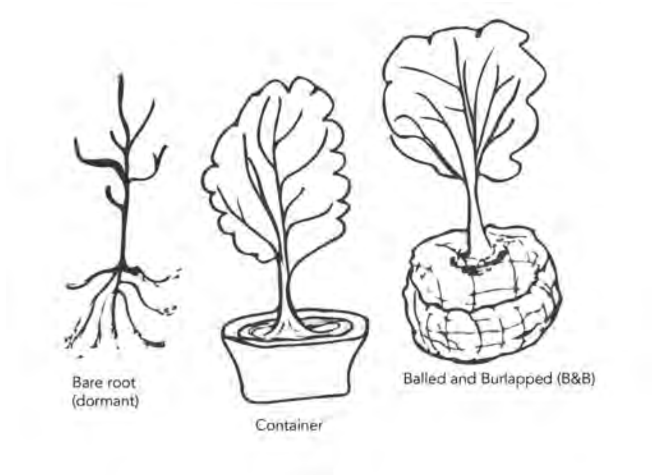


Figure 8-15 Types of Planting Stock

B&B trees are typically available year round. However, sometimes their availability is limited during the late summer/early fall as retailers sell out of stock, since these trees are usually only dug from the field and shipped when they are dormant. These trees are generally going to be more expensive because of the shipping costs for the larger, heavier root ball. Tree size is generally from the 6 to 8 feet range and larger.

When choosing planting stock, bear in mind that the smaller the tree when planted, the less time it takes for the tree to become established in its site. If the tree has been grown properly, whether in container or B&B, it should have some absorbing roots in the root ball and also not have circling or girdling roots (see below). Still, if the crown of the tree is significantly larger than the root ball, it will still take time for the roots to catch up. Thus, the tree steward should not be afraid to plant a very small tree, as long as it can be protected from lawn mowers and deer by tree guards and fencing.

There are many sources of planting stock, but they can typically be put into two categories, **mail order** or **nursery and garden center**. Mail order sources can be great for purchasing rare or unique trees. They typically have smaller material available to ship because of shipping costs. Many times you can get the material as bare root, which must be planted right away or else potted up temporarily until time for planting. Nursery and garden center sources typically have a limited supply, generally just the locally popular trees. The material will usually be either containerized or B&B. You can generally get larger plant material from a local nursery and garden center than from mail order sources. If you are fortunate enough to have a small nursery/garden center in your community which can take orders, by all means give it a try. You may also be able, as tree stewards, to propagate your own trees from local specimens or to find a group already doing so.

Evaluating Planting Stock

Once you have decided on a type, source and size of stock, you will need to check the actual tree to make sure it has a good chance of survival.

The most important inspection is of the **root system**. The main characteristics of the root system are covered thoroughly in Chapter Four. Purchasing a bare root tree allows you to be able to examine the tree's entire root system and take any corrective actions before you plant it. If purchasing a containerized or B&B tree, you should be able to probe gently (check with the store first) to see how deeply the main roots are buried and how compacted the soil is. If you have already purchased the tree, you can wash the soil off the roots to expose the root system for inspection. If you do this, be sure to keep the roots wet and plant the tree promptly after taking any corrective action.

There are some scenarios to avoid when purchasing trees. Avoid plants without sufficiently developed fibrous roots that hold the root ball together. This is usually easily seen in container trees. In B&B trees, avoid root balls where the soil in the ball feels loose and broken up. Avoid trees with circling or girdling roots. Again, this is easier to see with container material, and often difficult to see underneath the burlap and cording of B&B trees. Lastly, avoid trees that have excess soil on top of the root ball. This is typically found in B&B material as extra soil tends to be placed on top of the root ball during the digging process.

The second main inspection area is the **crown and trunk**. Generally, a tree with good crown configuration will have branches in the top two-thirds of the tree. If the tree has had too many lower branches removed, it will have its crown concentrated towards the top of the trunk. This makes the tree more susceptible to winds needing staking. Major branches should not touch and they should be less than two-thirds the diameter of the trunk. The crotch shape should be a U-shaped crotch rather than a V-shaped crotch. Additionally, the leader of the tree should not have been pruned. If it has been pruned, make sure that a new leader was properly selected and trained. Are the branches damaged or broken? Often you can prune out the damaged material, but in pruning it out, you should consider how that will affect the overall shape of the crown.

The trunk should generally be straight and without defects other than proper pruning wounds. Inspect for bark damage to the trunk from shipping. Avoid trees with injuries to the trunk as these can lead to disease and insects. Additionally, look for evidence of sunburn on the trunk. Sunburned bark initially appears discolored; often a reddish-brown, it then becomes dry and sunken. It is often the result of the young, thin bark of the tree suddenly being exposed to direct sun. This can happen often in the nursery or garden center when trees are removed that are providing shade to the trunk of the young tree.

The third step in inspecting planting stock is to evaluate the **overall health** of the tree. If you are able to look at the other trees around it, ask yourself if the tree you are purchasing appears to be in generally good health and vigor as compared to the others. Generally pests and diseases should not be a problem when purchasing a tree, because of the inspections that should be done at the nursery and retailer. However, depending on how long the material has been at the retailer, you may end up seeing disease or insect problems. Look carefully at the foliage. If it is speckled or spotted, it may have a disease or be infested with sucking insects such as spider mites or aphids. When inspecting the trunk and branches look for bumps or raised ridges that flake off with your fingernail. If you expose green or white tree tissue, then this was just a normal growth of the tree. If you see intact bark under the removed bump or ridge, it was most likely a scale insect.

One might ask what the nursery industry does to keep (or improve) the quality of their offerings. First, there are the ANSI standards and the best practices based on them (see Chapter One). Then there are state-level criteria, among which Florida's is an excellent example: Florida Grades and Standards for Nursery Plants 2015, which measures such things as the straightness of the trunk and the shape of the canopy. [10]

Shovels in the Ground

There is an old gardening saying that goes like this: "Plant a $10 tree in a $100 hole, not a $100 tree in a $10 hole." In other words, you can make a real difference in the general health and future growth of a tree by properly preparing the hole that you plant it in.

The basic guidelines for tree and shrub planting can be found in [VCE publication 430-295 "Tree and Shrub Planting Guide."]()

10. Florida Department of Agriculture and Consumer Services. (2015). *Grades and Standards for Nursery Stock* (5th ed.).

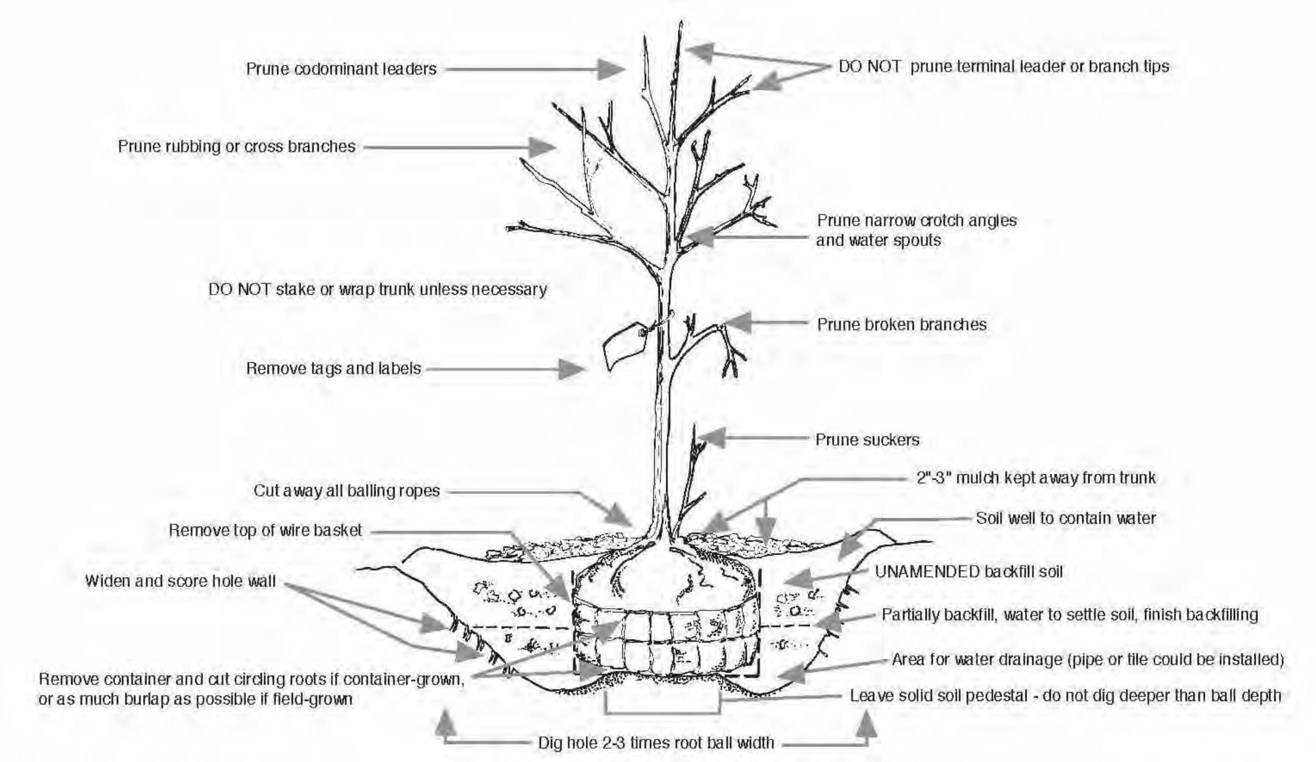


Figure 8-16 Planting Summary (VCE publication 430-295)

Dig shallow planting holes, two to three times as wide as the root ball. Wide, shallow holes encourage horizontal root growth that trees and shrubs naturally produce. In well-drained soil, dig holes as deep as the root ball. In poorly-drained heavy clay soil, you may want to plant a bit higher, with holes one to two inches shallower than the root ball. However, it is really better to select a tree appropriate for a soggy site and plant with the root flare at ground level. If you are planting bare root, the hole should not be any deeper than the depth of the actual roots. Do not dig holes deeper than root balls or put loose soil beneath roots because loose soil will compact over time, leaving trees and shrubs planted too deep.

Carefully place the tree in the hole if it is bare root or B&B. If it is containerized, carefully remove from the container, clean off any accumulated mass of small roots, remove girdling roots, and place the tree in the hole. If B&B, remove cording, burlap, and wire basket if present. Now is the time to remove circling or girdling roots at the point of any hardened major angle. Also, make sure that the root flare has been exposed, and the tree is positioned with the root flare at the soil line.

Backfill the hole with existing, unamended soil. Do not incorporate organic matter such as peat moss into the backfill for individual planting holes. Not only will this inhibit the roots from venturing past the planting hole, but differences in soil pore sizes will be created causing problems with water movement between the root ball, planting hole, and surrounding soil. Backfill the hole around the tree with half the soil and water thoroughly to settle out air pockets. Finish backfilling, and then water again.

Mulch, but do not over mulch, newly planted trees and shrubs. Two to three inches of mulch is best. Use less if the mulch is a fine material, and more if it is coarse. Use either organic mulches (shredded or chunk pine bark, pine straw, composts) or inorganic mulches (volcanic and river rocks). Keep mulch from touching tree trunks and shrub stems. This prevents disease and rodent problems if using organic mulches, and bark abrasion if using inorganic mulches. One traditional approach is the 3-3-3 mulching rule: Have the mulch ring be 3 feet in diameter; 3 inches deep; and 3 inches away from the trunk.

Prune out any broken branches or give a good clean cut to branches that may have been broken off. Try not to prune the end of the leader or any branch tips, since these are the main source of essential growth hormones. After the first year in the ground, and once the tree has begun to shows signs of growth, you may start a gradual regimen of preventive pruning, removing any branches that have narrow crotch angles and any branches that may be crossed and rubbing other branches (to avoid future injury).

Most trees should not have their trunks wrapped unless they need temporary protection from deer or rabbits. Wrapping often increases insect, disease, and water damage to trunks. Make sure to remove any wires, labels or flagging tape to avoid girdling the trunk or branches in the future.

Figure 8-17 Peach Tree Killed by Tag Wire Not Removed. (Courtesy Carol King)

Staking with guy lines should be done only to provide initial, temporary support for a tree in an unstable situation. Examples are trees with large crowns, those situated on windy sites, and those in danger of being pushed over by crowds. Be sure that the portion around the trunk is loose enough to allow the trunk to move a little bit. Guy lines should be removed within a year at maximum. Not only does a forgotten guy line risk the collar girdling the tree as it grows beyond the size of the guy line collar, but unnaturally rigid trunk and roots will not develop the natural strength to handle normal wind loads. Wooden stakes, cut off for safety, may be left in the ground to rot. In fact, stakes without guy wires may be sufficient if the reason for the structure is visibility to pedestrians or mowers.

Aftercare

Watering during dry periods of the first growing season is crucial, especially with container grown plants. Container and B&B tree roots dry out faster than the soil around them, so it is particularly important to take care of their soil moisture. In the nursery, the roots of container and B&B trees become concentrated in a small root ball which is watered daily. After planting, the roots of these trees will eventually spread into surrounding soil. Until that happens, however, the trees continue to draw water mostly from their root balls. Consequently, if the soil near the trunk is dry, the trees need water, at least until the first winter. Water newly planted trees deeply once a week during periods of no rain. It is best to water slowly, as with a garden hose, to soak the soil thoroughly. Always allow the water to reach the top of the berm built around the plant. This will provide deep water penetration and encourage widespread root development. If there has been any rain in the previous week, check the soil moisture to avoid overwatering, as this can kill the plant.

Once the tree has gone dormant in its first year, it will begin to establish its equilibrium. In the next year it should be on the normal schedule for its type of tree. If the site is appropriate for the tree and function, then it should not need special care after this, except in unusual weather. An exception to this guidance is for those brave tree stewards who have planted a seedling: it will need regular watering (weekly or more, depending on summer heat) until it has got to about three feet tall, perhaps two years. The good news is that it will never have the absorbent differential issues discussed above with larger stock.

Whatever your source and choice, watch the new tree and see what it tells you. If it was well matched to the site and function, it will let you know.

Review Questions

1. What are some characteristics that make a tree appropriate for a particular planting site?
2. Where can information on selecting trees for difficult sites be found?

3. What are the sources for stock for trees?
4. What are the types and the sizes of tree planting stock?
5. How is a tree planted properly?

CHAPTER 9: TREE HEALTH CARE AND PRUNING

"To exist as a nation, to prosper as a state, and to live as a people, we must have trees." – President Theodore Roosevelt

Chapter Contents:

Introduction

This chapter discusses the care of trees during their lifetime, with a focus on objectives for pruning trees from the time of initial planting through the mature years of a tree.

The section on "Tree Health Care Best Practices" discusses current practices for mulching, staking, irrigating, fertilizing, and protecting trees.

The sections on "Developing a Preventive Pruning Program for Young Trees" and "Developing a Preventive Pruning Program for Mature Trees" are external publications by Edward F. Gilman, PhD, who graciously gave permission to include these publications in this manual. Dr. Gilman is a researcher and professor of Urban Trees & Landscape Plants in the Department of Environmental Horticulture at the University of Florida. He recently retired from his university position, but continues to give presentations at conferences throughout the country. His research papers and articles are available on the University of Florida website, and he is the author of *An Illustrated Guide to Pruning.*

The section on "Arborist Tree Care" is a brief but important discussion about arborist services and advanced treatments for trees. Tree stewards need to have basic knowledge of arborist tree care in order to properly recommend professional arborist services for homeowners when the need occurs.

Learning Objectives

1. To learn best practices for maintaining tree health.
2. To distinguish priorities and differences in pruning young trees and mature trees.
3. To be able to incorporate preventative pruning programs for trees.
4. To acquire information about advanced arborist tree care and techniques.

REVIEW: VCE Master Gardener Handbook 2015 (9/18 update)

- Chapter 11 – Pruning
- Chapter 16 – Woody Plants

Tree Health Best Practices

Tree health care involves activities to preserve and protect tree health by avoiding damage to tree roots, trunk and crown. Best management practices are outlined in this section.

Remove grass and ground covers

Removing the grass from under the tree canopy is a valid method to support the health of trees. This step eliminates the need to mow under the canopy and reduces injury to tree trunk. Soil compaction is also reduced by eliminating mowing, resulting in greater air and moisture exchange in the soil. Grass removal eliminates competition of grass roots for water and nutrients, resulting in more tree root growth in the top soil layers. If a tree is in decline, it is recommended that all ground covers and grass be removed and replace with a thin mulch layer (2 to 3 inches maximum). In certain situations, turf removal beneath trees may not be practical or desirable, such as in some public or commercial spaces and sites.

Mulching

Ideally, apply mulch out to the drip line of the tree canopy, no more than 2-3" deep. For mature landscape trees, mulching out to the drip line may not be feasible, particularly when trees are close to buildings, sidewalks or roads. Instead, cover a 4-5 foot diameter area around the tree with mulch if possible. The larger the mulched area, the more beneficial it is for the tree. It is important to keep the mulch away from the trunk and root collar of trees. For established trees, keep the mulch 6 to 12 inches away from the tree trunk.

For a newly planted tree, do not apply mulch over the root ball. Apply the mulch beyond the root ball out to the canopy drip line. Mulching over the root ball of a new tree will interfere with the tree roots obtaining the water and moisture it needs. Excessive amounts of mulch cut off the oxygen supply, immobilizes nutrients to the tree, and can cause mulch fermentation. If the mulch is spread too thick, the tree roots will grow up above the soil surface into the thick layer of mulch which retains moisture and the roots are likewise seeking out more oxygen.

Drought and Irrigation

Periods of extended drought can cause decline and death in both young and mature trees. Drought effects seen in trees will appear as thinning and loss of foliage starting in the top center of the canopy.

Tree decline during drought can be prevented by timely irrigation and proper soil management. Applying water preventively before foliage stress occurs is important, rather than waiting until symptoms become advanced. In young trees, wilted, dropped or dead leaves or branches in the top of the canopy indicate that the tree roots are dry. The mulch should be removed from the top of the root ball since it can prevent water from infiltrating to the roots.

Figure 9-1 Watering trees

The frequency of watering depends on how quickly the soil around the tree drains. Soil that drains quickly (sandy soil) will need more frequent watering than soil that drains slowly (clay soil). Too much water will decrease the available oxygen in the soil and prevent the tree roots from obtaining needed oxygen for survival. It also creates favorable conditions for root rot pathogens. Watering too much can be as dangerous as watering too little.

A good way to check soil moisture is to dig a small hole 6 to 9 inches deep to see if the soil is moist or dry. If the soil is dry, watering is indicated. Water at least out to the dripline (or to the estimated root zone) long enough to provide one inch of water, and then check the soil for moisture 6 to 9" below the surface. If the soil is still dry, repeat as needed. Check the soil moisture periodically to determine how many days before the soil dries out again.

Recently transplanted trees require 6 months (in Zones 7 to 8) per inch of trunk diameter to fully establish roots during the first growing season. The roots of trees that are under-irrigated during the establishment period will grow more slowly, and will require regular irrigation during the next growing season. Newly planted trees need 2 to 3 gallons per inch trunk caliper at each watering session. These new trees may need watering daily for the first 2 to 6 weeks, then weekly watering for the next 3 to 6 months until established.

Root Spread

Tree roots extend beyond the drip line of trees. The trunk diameter of a tree is a better predictor of root spread than the height or canopy width of the tree. A young tree with a diameter of 6 inches at breast height (4.5 feet), can have roots that extend out in a radius of 19.7 feet from the trunk. The relationship in studies of root radius in young trees to trunk diameter was 38 to 1. There is less data on the relationship for older trees. Studies of more mature trees suggest that root spread levels off to some extent as trees age. For example, a tree with a 35 inch diameter trunk will probably not have a root system three times larger than a tree with a 12 inch diameter trunk. Studies indicate that older trees put more resources in the production of fine absorbing roots and fewer into large structural roots, thus minimizing the distance that resources need to be transported to the roots.[1] Root zones should be considered when watering, mulching and when determining root protection zones of trees.

Disease and Pests

Monitor for pest problems on a regular basis and treat only as necessary. Not all insects and disease organism are significant threats to the tree or require treatment. Identify the problem first, then determine if any treatment is necessary. Refer to Chapter Ten, Biotic and Abiotic Problems of Trees, in this manual.

Girdling Roots

Stem girdling roots choke off the flow of water and nutrients in the tree. They can compress and weaken the tree trunk at or above the root collar flare, causing the tree to lean and lose stability, ultimately resulting in slow decline and premature death of the tree.

Research indicates that roots that girdle the trunk can be removed, as long as the tree trunk is not damaged during the process. If the girdling root can be cut by power saws, hand saws or chisels and removed easily, then the girdling root should be removed. If removal of the root is difficult, then it is advised to simply cut the girdling root without removing it. The main roots of the tree should be exposed after removing the girdling root. Girdling roots, if left to grow, can cause trunk cracks in the lower trunk, restricted growth of the tree, and/or cause possible tree failure. Circling and girdling roots can occur naturally but may also be associated with nursery practices, or occur as a result of transplanting when roots are cut and lateral roots begin to grow at right angles to their primary root. If the tree has been planted too deeply, the roots will grow upwards toward the surface of the soil and encircle the trunk. For existing trees, it is important to inspect the root collar on a yearly basis.

Figure 9-2 Girdling Roots (Courtesy Carol Fryer)

Tree Root Protection

Trees need to be monitored and protected throughout their lives to maintain maximal health, safety, function and benefits to the site and environment. Trees particularly need to be protected prior to construction and during major landscape installation, utility trenching or changes to the existing soil grade.

Tree roots spread out over a large area and are concentrated at the soil surface.

Every tree has a **critical root zone (CRZ)**, also called the Root Protection Zone (RPZ), which varies by species, age of the tree, soil, and water table. The International Society of Arboriculture defines CRZ as an area (circle) equal to a 1 foot radius from the base of the tree's trunk for each 1 inch of the tree's diameter at 4.5 feet above grade (referred to as diameter at breast height). For example, a tree trunk of 2 inch diameter has a critical root zone of 2 ft; a tree trunk of 20 inch diameter has a CRZ of 20 ft. In some documents, the tree's drip line is used to estimate the CRZ (within green box in diagram). About 85% of the root mass is in this area.

The protection area that extends to the outer edges of the tree roots is referred to as the Total Root Protection Zone (TRPZ) or, the Root Protection Zone (RPZ) in some publications. This area extends out 2 to 3 times beyond the Critical Root Zone.

The tree roots that are most important for survival are in the **structural root plate** (red area on diagram). These large strong roots extend up to 11 feet from the trunk in large trees. Damage to the feeder and transport roots in this area will reduce tree health and survival. Damaging these structural roots is usually fatal to the tree.

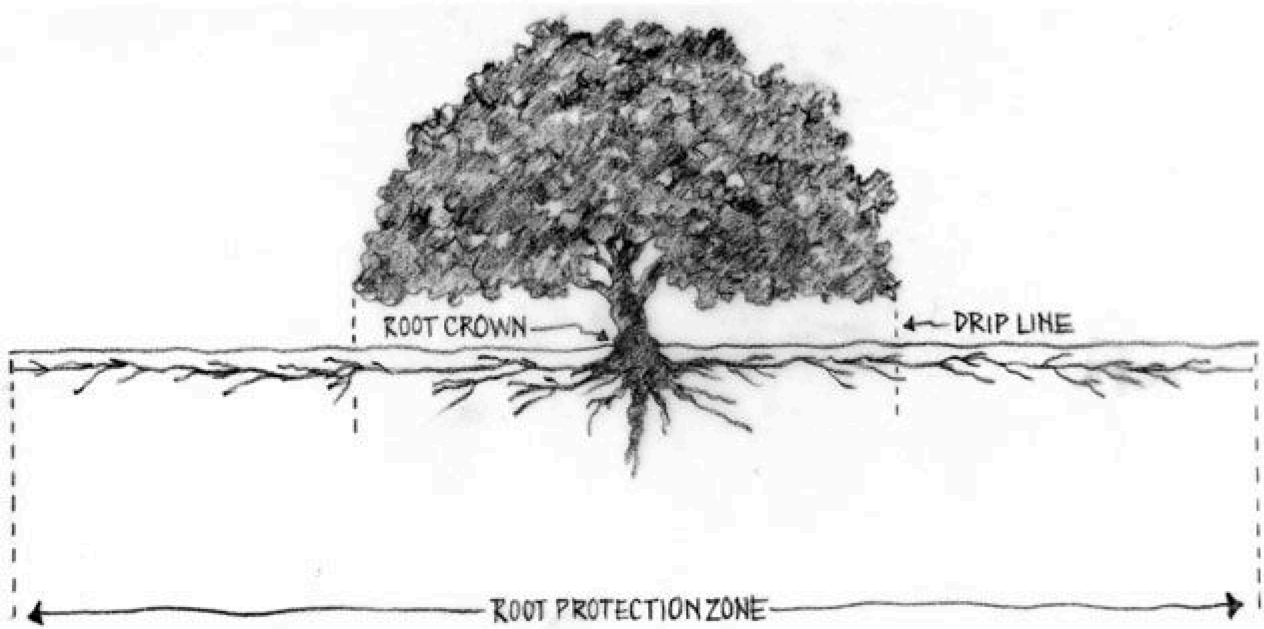


Figure 9-3 Root Zones. Underlying Drawing from "Wise Watering Practices" (Courtesy K. Zuzek, University of Minnesota Extension)

Ideally, all grade changes (raising or lowering the soil level) should be done outside of the critical root zone. Grade changes can cause serious damage or death to a tree. Fill added over existing soils can smother and kill roots. A pile of fill or mulch temporarily placed in the CRZ of a tree for several days can cause long-term negative effects to the roots, though symptoms may not be evident for a few years. Less damage to tree roots is likely when a grade is lowered, unless a great deal of the root mass is exposed or removed. Avoid any grade change that alters the water drainage around the tree or alters the water table.

Staking

Do not stake trees unless absolutely necessary. If the root ball is solid enough, stakes may not be necessary. Some container grown trees may need staking if their root balls are light in weight. Even heavy balled-and-burlapped trees may display very loose stems and roots and be in need of support. Stake trees if they cannot stand up straight, or if the trunk bends over.

One method of staking (Fig 9-4) utilizes two to three wooden dowels that are driven through the edge of the root ball and into the soil to stabilize the root ball without causing any damage to the trunk. The dowels do not need to be removed since they will eventually decompose into the soil.

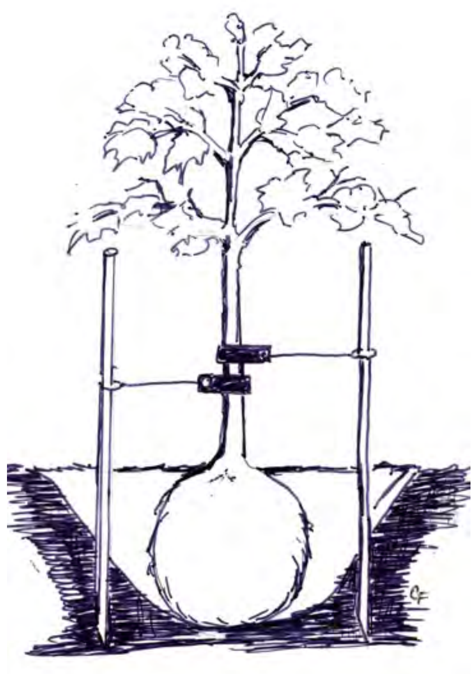


Figure 9-4 Aboveground Staking
(Courtesy Carol Fryer)

Another method of staking (Fig 9-5) uses 1 to 3 stakes that are driven into the native soil outside of the root ball, with commercial strapping to hold the tree loosely between the stakes. Rope or bare wire should not be in contact with the trunk since it easily damages the tree bark. Bicycle inner tube, burlap or strips of carpeting can be wrapped around the trunk then secured to the stakes with ropes or wire. The tree trunk should be able to move slightly with the wind to build up tissue that strengthens the trunk stability and provides structure. If the root ball is unstable use 1-3 stakes attached low on the trunk. If the trunk is bending, use 1 stake attached higher – 6" or more below the first set of branches. The staking should be removed after one growing season, once the tree is checked for stability. If the root ball still moves in the soil or the trunk bends excessively, reattach the staking system and leave in place for one more growing season. Staking should not be left in place for more than two years.

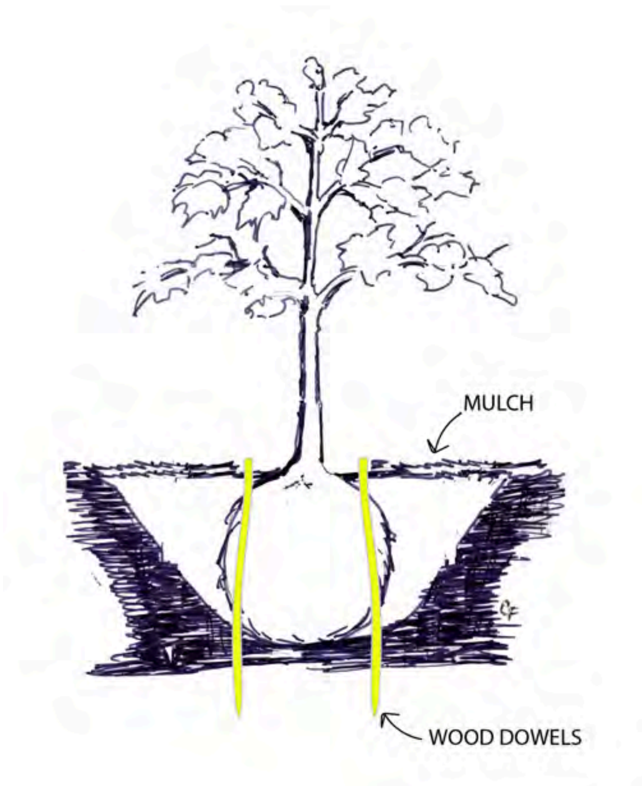


Figure 9-5 Underground Staking

A third method of staking trees (Fig 9-6) involves the use of 2×2 wood stakes. Stake lengths depend on the size of the root ball. One horizontal stake is attached at each end with screws to two vertical stakes. The support is inserted against the side of the root ball. A second support unit is used on the opposite if needed. Ideally, the stake system is set in place when the tree is planted. If later, the stakes are pushed or hammered into the soil until the horizontal stake rests at ground level. The stakes do not need to be removed since they will eventually decompose into the soil.

Trunk Guards

Animal damage to bark of young trees can be prevented by installing a cage around the tree trunk with 1 to 4 inches of space between the trunk and cage. Cages (or tubes) can be constructed from hardware cloth and stakes, or stiff wire fencing with ¼" to ½" mesh squares. The wire mesh tube can be anchored with metal anchoring pins, attached to one or two stakes or pushed into the ground. As the tree grows, the tube will need to be enlarged, and it should be removed when the tree is more established. The cage should not be in contact with the tree bark at any time.

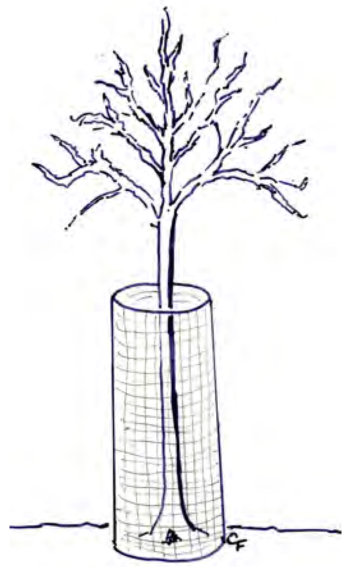


Figure 9-7 Sample Trunk Guard (Courtesy Carol Fryer)

Signs and Wires

Damage occurs when anything is attached to a tree using nails, screws or spikes. Wounds create opportunities for disease and pests. Wires, cables, conduit, mailboxes or signs should not be attached to trees. Bird feeders, swings or other objects hung from wires, ropes or chains around a tree limb can cause girdling of the limb resulting in eventual death of the tree limb. Independent structures for mounting bird houses and feeders are available in most local communities and they provide benign alternatives to trees.

Fertilization

Fertilizers are not recommended for newly planted trees. It is recommended that fertilizers be applied to established trees ONLY if a soil test shows that nutrients are lacking. A tree that has incurred damage to the root system may need nutrients to promote root and plant growth, but waiting two years after damaged before applying fertilizer is recommended. Urban trees may be under stress conditions due to low moisture, construction damage, and competition from grass and shrubs. Again, a soil test is the best indicator of whether fertilization is needed. Refer to Chapter Six in this manual for more information on soil and fertilization.

Herbicides and Unintended Consequences

Weed-and-feed type lawn compounds, designed to kill broad-leaved weeds, can also harm broad leaved trees. Pre-emergent herbicides are generally safe to use near most trees, but it is necessary to read the label whenever applying any chemical to be sure. Refer to Chapter Ten for additional information on chemical agents.

De-icing salts

Sodium chloride, usually mixed with sand or other gritty materials, is widely used during winter weather to improve traction on roads and paths and allow for rapid, even distribution. Salt on paths or roadways usually ends up in the nearby soil or on plants via roadway splashing and/or melting snow piles. In regions of with persistent winter snow, plants as much as 15 feet from the roadway can be damaged by the salt. Calcium chloride used on gravel roads is less toxic than sodium chloride but can cause similar injury to plants. Salt deposits on leaves and twigs can be washed off with a garden hose in late winter/early spring. Severely injured twigs or branches should be pruned off. Salt can be leached from soil that drains adequately by applying large amounts of water. Frequent watering during the summer will help keep the salt at a lower level in the soil.

If you have the choice, use sand or decomposed granite on walkways adjacent to tree and planting beds. If you are dealing with municipal de-icing, then select trees and plants that are more salt tolerant for conditions of road salt, just as you would for plantings in areas with coastal salt spray.

Pollutants

Pollutants in the air are an important contributor to the decline of urban trees. Air pollution may cause short-term or long-term damage and stress, which can open the door for other pests and disorders, hastening the trees' demise. Diagnosing air pollution damage is difficult since the symptoms are similar to those of insect, disease and environmental damage .The major air pollutants in decreasing order of toxicity are **ozone and peroxyacetyl (PAN); sulfur dioxide; and particulates (dust).** Ozone and sulfur dioxide inhibit photosynthesis in leaf tissue and can cause sudden tissue damage and death with high level of the toxic gases. Low levels of the toxins inhibit leaf function. Acute ozone damage to deciduous trees cause marginal leaf burn, spots spreading over the entire leaves, or bleaching of the upper surface. Conifer acute damage results in browning at the same point on all needles in a bundle. Acute sulfuric acid damage causes severe leaf scorch, spotting and defoliation and can lead to tree death over a large geographic area. Chronic damage of these gases cause leaf chlorosis and tree decline.

Particulates (dusts) are produced by industrial sites such as cement plants, rock-crushing plants and quarries. Particulates can reduce photosynthesis by blocked the stomates of tree leaves. Rain or Irrigation usually wash the dusts away, but dry periods of weather can make this problem more serious. Air currents and temperature influence the concentration of pollutants, the duration of tree exposure, and chemical reaction rate of the oxidants. The oxidants cause more severe damage when the weather is sunny and hot, and less damage during cool and cloudy weather.

The Virginia Tech Publication 430-022, Air Pollution, by Bonnie Appleton and others, is available online and provides more complete information and tables of tree with a range of ozone and sulfur dioxide tolerance and sensitivity.

Maintenance Schedule

A schedule, such as the one shown below, will provide you with an on-going plan to care for your trees in the landscape.

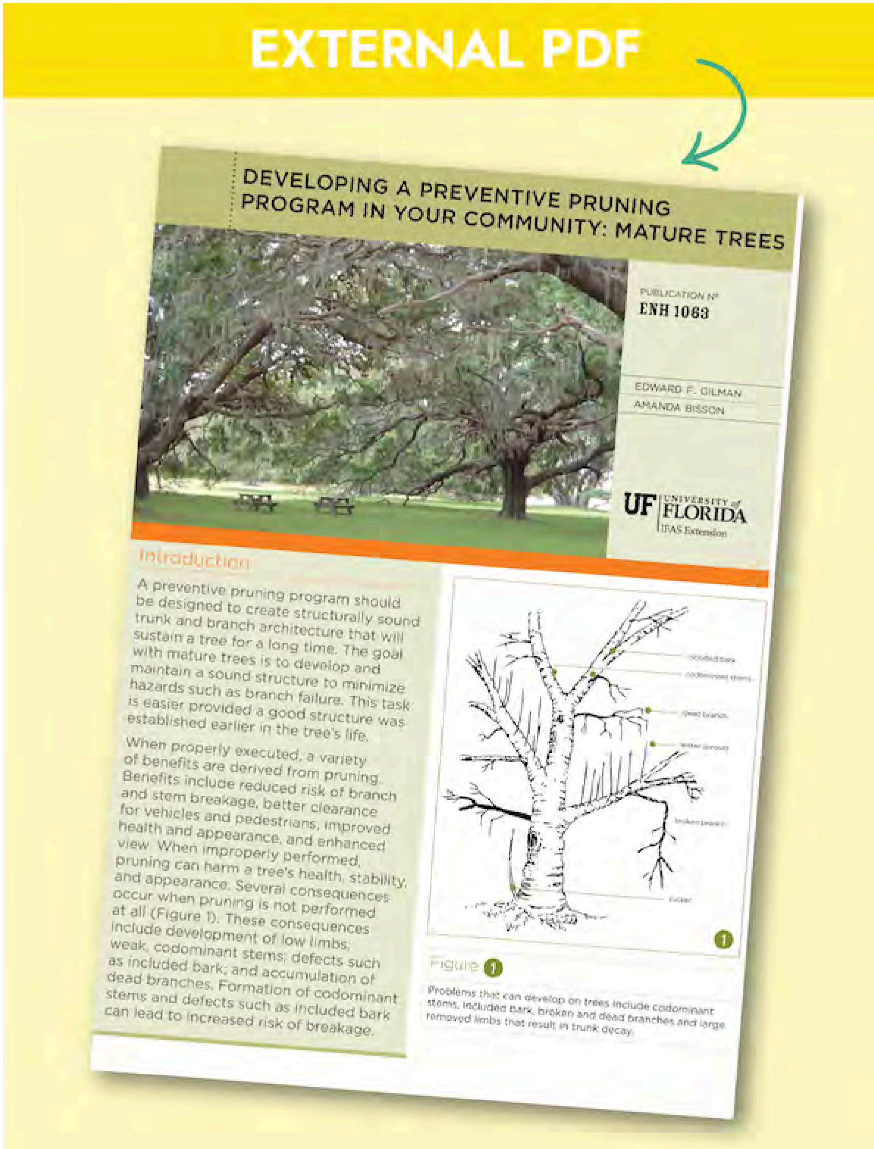
Table 9-1 Tree maintenance schedule

Type of care	At planting	1-3 Years	4-10 Years	After 10 Years
Water	2-3 gallons per inch of trunk caliper	As needed – spring thru autumn	As needed – spring thru autumnAs needed – spring thru autumn	As needed – spring thru autumn
Mulch	2-3" deep, outside root ball to drip line	6-12" away from trunk to drip line	6-12" away from trunk to drip line	6-12" away from trunk to drip line
Clean Root Collar		Clean root collar yearly	Clean root collar yearly	Clean root collar yearly
Check for Girdling Roots	Check before planting	Check yearly	Check every 4-5 yrs.	Check every 4-5 yrs.
Check Health	Select healthy tree	Inspect leaves, branches, crown and trunk yearly	Inspect leaves, branches, crown and trunk yearly	Inspect leaves, branches, crown and trunk yearly
Check Safety		Inspect in summer, winter, after storms	Inspect in summer, winter, after storms	Inspect in summer, winter, after storms
Prune	Remove or reduce extra leaders; remove damaged or broken branches	Lightly in yr 2 or 3 Prune for good structure	Every 3 yrs.	Every 5 yrs. Evergreen as needed
Stake	Only if needed	Check in spring & autumn. Remove after 1-2 yrs.	–	–
Protect Trunk	As needed	Check in spring	–	–

Developing a Preventive Pruning Program: Young Trees

Please read this PDF from the University of Florida IFAS Extension titled "Developing a Preventative Pruning Program in Your Community: Young Trees"

Developing a Preventive Pruning Program in Your Community: Mature Trees



Please read [this PDF from the University of Florida IFAS Extension](#) titled "Developing a Preventative Pruning Program in Your Community: Mature Trees"

Arborist Tree Care

Certified Arborists are specialists in the art and science of planting, caring for, and maintaining trees. They are trained to follow all applicable ANSI (American National Standards Institute) standards. The standards cover safety, soil, planting, construction, pruning and risk management and ensure that the client receives clear and complete information about the work to be performed for the homeowner. There are several procedures that require the services of a professional certified arborist and trained staff.

Figure 9-8 Proper tree maintenance graphic.

Tree Risk Assessment – An arborist with Tree Risk Assessment Qualification can assess the factors affecting a tree that may cause risk to people or structures within the area surrounding a tree under normal loading. Note that exceptional wind strength or weight of ice may overcome even healthy trees. Defects causing risk in normal conditions include large dead or dying branches, cracks or splits in the trunk, leaning of the tree, root damage, cavities or rotted wood, proximity to power lines and/or recent changes in grade or soil level.

Pruning – An arborist can prune to improve tree structure, appearance, and health and to prevent storm damage by thinning and/or reducing the tree canopy. Specialized training and tools allow them to access tall trees safely.

Root and soil treatments and trenching – Non-damaging procedures are available to install irrigation, to diagnose root system problems, or to loosen and enrich compacted soil. Soil aeration and vertical mulching is performed to improve compacted soil, and to promote root growth. An Air Spade treatment uses high speed air to move or loosen the soil around a tree without damaging the roots. Compost and nutrients can be integrated into the soil with an air spade.

Cabling or bracing trees – is performed for damaged or at-risk trees to prevent crotch splitting or branch breakage, and to provide trunk support for tree with significant cavities. Pruning to reduce the size of the canopy is considered prior to installing a support system. Bracing with rods is installed close to the union of trunk/limbs with included bark. Cables are installed at a distance of about two thirds up from the union.

Tree Lightning Protection Systems (TLPS) – A safe ground for lightning can be provided by an advance protection system, installed to divert lighting from the tree top to the ground. Such a system prevents damage to a protected tree that might otherwise cause significant damage to a residence and significant damage to the tree from a lightning strike.

Tree removal – of a dying, or dead tree or removal of a tree planted in an inappropriate or dangerous site.

Emergency Tree Care – following tree damage and/or storm damage.

Review Questions

1. What are the main objectives for pruning trees?
2. What are the possible tree problems if a regular pruning program is not established?
3. What maintenance practices help keep trees healthy?
4. What are the services provided by certified arborists?

CHAPTER 10: PROBLEMS OF TREES

"God has cared for these trees, saved them from drought, disease, avalanches, and a thousand tempests, and floods. But he cannot save them from fools." – John Muir

Chapter Contents:

Introduction

A tree disease is any disturbance that prevents the normal development of the tree and reduces its economic or aesthetic value.[1] The disease triangle is a simple representation of the three fundamental components involved in the cause of disease in a tree.[2]

Disease result from some disturbance in the normal life process of a tree and are caused by non-living (abiotic) agents and living (biotic) agents.

1. The Virginia Master Gardener Handbook. (2015). *Virginia Cooperative Extension.*
2. Francl, L. J. (2001). The Disease Triangle: A plant pathological paradigm revisited, The Plant Health Instructor. https://www.apsnet.org/edcenter/instcomm/TeachingArticles/Pages/DiseaseTriangle.aspx

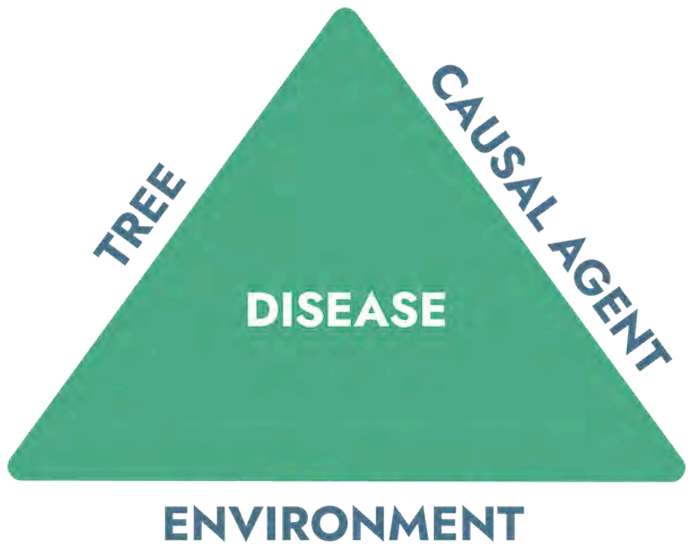


Figure 10-1 Disease triangle

This chapter describes each of the three components above and how they impact trees. The environment contains non-living agents that impact the health and well-being of trees. These non-living, or abiotic, agents may be physical, chemical, or mechanical. Living, or biotic, agents include microbes and animal pests. For a biotic agent to cause disease in a plant, there must be a susceptible host and, generally, contributing environmental factors. Given a specific type of tree, that tree is susceptible only to certain biotic agents and the degree of susceptibility is determined by existing environmental stresses.

The tree steward can play an important role in mitigating tree problems by:

- Detecting the presence of environmental stresses and causal agents,
- Identifying biotic agents through research and use of the Virginia Tech Entomology and Pathology labs,
- Making recommendations for specific treatments and/or cultural changes to eliminate a problem,
- Educating clients on the needs and proper maintenance of trees in order to help prevent future problems,
- Providing the client with sources for science-based information,
- Giving guidance on finding professional assistance,
- Detecting and reporting trends or the existence of invasive pests or significantly destructive diseases in their city or county.

The information in this chapter is intended to provide an overview of the relevant topics in tree diseases. The VCE Master Gardener Handbook provides additional discussion of these and related topics in the chapters referenced below. The internet provides an abundance of information on the topics. Trainees are reminded to use .edu and respected institution websites, such as the Missouri Botanical Garden and Morton Arboretum, to the greatest extent.

Learning Objectives

1. Understand the impact of environmental stress in causing disease in trees.
2. Be familiar with the difference between abiotic and biotic factors.
3. Identify the principle biotic factors that cause disease in trees.
4. Recognize the difference between symptoms and signs.
5. Know the approach for identifying diseases in a tree and determining an appropriate response.

REVIEW: VCE Master Gardener Handbook 2015 (9/18 update)

- Chapter 5: Basic Entomology
- Chapter 6 Plant Pathology
- Chapter 7 Abiotic Stress Effects on Plant Growth and Development
- Chapter 8 Diagnosing Plant Damage
- Chapter 9 Pesticide Use and Safety

Abiotic and Biotic Agents

Agents that cause problems in trees (and other living things) are grouped into two basic categories: abiotic and biotic.

Biotic agents are living, i.e. biological, agents that cause disease. They include microbes that generally cannot be seen with the naked eye, animal pests, and harmful plants. Microbes are living micro-organisms such as fungi, bacteria, and viruses. Animal pests include invertebrate pests, such as insects and mites, and vertebrate pests, such as deer and rodents. Problems caused by microbes and invertebrates are infectious and can be transmitted from one tree to another. Problems caused by vertebrates act more as mechanical agents. Pathogens are microbes and pests that cause tree disease. The term "disease" is frequently used to refer to a disease caused by microbes. However, in some circles the terms "disorder" and "disease" may be used interchangeably.

Figure 10-2 Abiotic vs biotic agents

Symptoms vs. Signs

- Chlorosis – changes in color
- Leaf drop
- Wilting
- Dwarfing
- Necrosis – dead tissues, dieback, canker
- Epicormic shoots, suckers, water sprouts
- Galls – enlargement of plant partInsect entry/exit holes
- Feeding holes of birds

Visible structures produced by causal agents

- Mold growth
- Fungal bodies – conks and mushrooms
- Bacterial ooze
- Specific odors
- Powdery mildew
- Rust
- Insect egg, larvae, and body
- Frass – insect poop

Symptoms and Signs

Diseases in plants manifest themselves via symptoms and signs. When diagnosing the problem with a tree, it is important to understand the difference and use appropriate terminology. Symptoms are changes in the plants appearance that indicate problems in the plant. Signs are visible structures produced by causal agents. Examples of each are provided in Table 1 “Symptoms vs. Signs” below.

Environmental/Abiotic Agents

A given type of tree thrives best under certain environmental conditions. Most types of trees are robust and can survive across a rather wide band of conditions. For example, red maples are indigenous throughout the eastern United States from Texas, throughout Florida, and north into Canada to the Hudson Bay. However, when a tree must endure conditions outside its comfort zone, it becomes stressed and problems occur. These problems may be directly related to the environmental conditions or to damage from biotic agents that are able to invade and damage the tree due to the environment stresses. The native environment for blue spruce is a cold climate at a high altitude. The tree has become popular as an ornamental and is planted in far warmer climates where it tends to suffer from various insect pests.

There are many conditions in the environment that can cause problems in trees when they exceed the tree’s comfort zone. These conditions are considered abiotic agents of diseases. Plant problems arising from these agents are considered physiological diseases or environmental diseases. Although environment problems may impact multiple plants in a given area, abiotic agents are considered non-infectious, that is, they cannot spread from one tree to the next.

The characteristics of the tree, and individual tree, determines its susceptibility to environmental stress. The response of the tree to environmental stress depends of the duration and severity of the stress, the number of exposures to the stress, and whether there is a single stress agent or multiple agents.

In general, symptoms of environmental stress will be widespread and exhibit a somewhat uniform damage pattern across the tree. Environmental stress is thought to account for a large percentage of all plant problems with some sources quoting as high as 70% to 90%.[3]

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3. Pendergast, D. & Pendergast, E. (2003). *The Tree Doctor, A Guide to Tree Care and Maintenance.* Firefly Books.

Physical Agents

Surrounding Green and Manmade Areas – The growth, shape, and health of a tree is impacted by whether a tree is growing within a group of trees, by itself in a field where its roots may spread without impediment, or as a street tree where the roots are confined within curbs and paved areas. The specifics of the growing site determine how much the tree must compete for light, nutrients, and water and the vulnerability of the tree to wind and storms. Manmade structures, such as pavement, brick, and glass, can absorb and reflect heat causing increased temperatures that may impact tree health.

Soil – The quality and quantity of the soil (material, texture, pH) impacts the oxygen available to tree roots, water retention, and nutrient absorption. Lack of adequate space limits root growth. Inadequate soil can lead to nutrient deficiency.

Weather – Temperatures and rain levels outside the acceptable range for a given tree or outside the temperature and water levels to which a tree is acclimated can damage the tree. Prolonged periods of highs or lows, unexpected frosts, unexpected high temperatures at times when the temperature is usually cool or cold periods when the temperature usually warms can all impact the health of tree. Either drought or excessive rain for prolonged periods are damaging.

Wind – Gale force winds can uproot a tree. Strong prevailing winds can shape the form of the tree as it grows.

Lightning – Tall trees in open areas are especially susceptible to lightening. When lightning strikes a tree, it causes the sap to boil, generating steam, and causing cells to explode. Strips of wood and bark may peel or be blown off the tree. Depending on how it is struck, the tree may not survive.[4]

Figure 10-3 Lightning Scar. (Courtesy Carol King)

Other Severe Weather – Hurricanes, floods and droughts can have devastating effects on trees. Hurricanes can cause branches to break off and whole trees to blow down. Flooding can saturate the roots and lower trunks of trees with brackish water. Prolonged droughts of months and years can cause major declines and even death in trees.

Climate and climate changes – If the tree is outside its native range of conditions, it will be more susceptible to both abiotic and biotic agents. Many regions are seeing overall changes in temperature and/or rain. Warmer temperatures and

4. Clatterbuck, W. K., Vandergriff, D. S., & Coder, K. D. Understanding Lightning and Associated Tree Damage. *Texas A&M AgriLife Extension.* https://agrilife.org/treecarekit/after-the-storm/understanding-lightning-associated-tree-damage/

increased days of warm temperatures, such as 80-degree days persisting into October in zone 7, can be stressful for some types of trees while permitting the growth of other trees which may not have been suitable for the area in the past.

Mechanical Agents

Soil Compaction – Soil may be compacted by heavy equipment used in construction or by vehicle and human traffic, pressing the soil particles closer together and reducing the pore space between them. The smaller pore spaces reduce both water infiltration and drainage, and slows down the exchange of gases. Roots have a more difficult time penetrating compacted soil. Overall, the amount of water and oxygen available to the roots is reduced. This can cause dying leaves on mature trees and dying branches on younger trees.[5]

Mechanical Injuries – Mowing and maintenance equipment, such as lawn mowers, weed trimmers, and other lawn and garden equipment, can cause significant damage to trees by cutting through or crushing the bark and breaking branches. Cuts into the bark can severely damage or kill sections of the cambium layer that lies just under the bark. This interrupts the flow of sap between the roots and leaves, causing some twigs or branches to die. Items such as ropes, chains, and straps can cause similar damage. When left affixed tightly to a tree, the tree may eventually grow around the agent. Mechanical damage opens the tree or shrub to abiotic organisms, which can damage the woody tissues underneath and lead to decay. Removing grass and weeds underneath the canopy of the tree and adding a 2 to 3-inch layer of mulch will keep mowers and weed trimmers at a respectful distance from the tree trunk. Remember to leave a few inches between the tree trunk and the beginning of the mulch.[6]

Site Disturbance – Any significant change in the conditions around a tree may impact its health. Major disturbances, such as construction, digging, and re-grading the earth, close to the tree may compact the soil around the tree or raise the soil level around the trunk of the tree above the root flare. Digging a trench for utilities or planting other plants may sever the roots of the tree. Constructing a raised bed around the tree exposes the bark to soil moisture and microorganisms that can over time cause tissues in the lower trunk to die. Eventually this can cause root dieback and root collar diseases. Changes such as removal of nearby trees, building of new structures, paving of driveways and walkways change the microenvironment of a tree and may change the light, water, and nutrients available to a tree. Removing a neighboring tree may provide more light for a remaining

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5. DeJong-Hughes, J., Moncrief, J. F., Voorhees, W. B., & Swan, J. B. (2017). Soil compaction: causes, effects, and control. *University of Minnesota Extension.*
6. Purcell, L. (2014). Mechanical Damage to Trees: Mowing and Maintenance Equipment. *Purdue University Extension.* https://www.extension.purdue.edu/extmedia/fnr/fnr-492-w.pdf

tree; this may have a positive or a negative impact on the remaining tree depending on the type of tree and other factors impacting the tree.[7]

Cultural Practices

Planting – Planting the tree at an appropriate place, at the appropriate depth, in an appropriately sized hole, and ensuring that the roots are loose and non-girdling is critical to the tree's survival.

Pruning – Making incorrect cuts, such as leaving a stub when the branch is removed, or leaving broken branches unpruned provides an open door for biotic agents to infect the tree. Coating pruning cuts with paint or sealer slows the healing and promotes problems.

Maintenance – Inadequate watering, excessive mulch, the use of black plastic under mulch, and inappropriate fertilizing damage the health of the tree.

Chemical Agents

Air Pollution – Air pollutants are released from cars, generation of electricity from coal and oil, and emissions from other industries. In recent decades, the amount of air pollution has been reduced by governmental regulations and an increasing awareness from the public. A heavily traveled highway or a new industrial plant can add pollutants to the air. Air pollution may cause discoloration in the leaves. Some trees such as magnolia and arborvitae are relatively tolerant to air pollution. However, other trees such as catalpa and Virginia pine are relatively intolerant.[8]

Lawn and Garden Chemicals – Use fertilizers, pesticides, and herbicides for trees only in the precise manner recommended on the label. When using a pesticide or herbicide to address a tree disease, use only products recommended in the VCE Pest Management Guide (PMG).[9] Commercial fertilizer-herbicide mixtures for the lawn can be absorbed by tree roots so it is especially important to avoid applying too much or using them too frequently. Using herbicides, such as glyphosate, to manage

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7. Pratt, P. W. & Schnelle, M. A. (2017). Site Disturbance & Tree Decline, Oklahoma State University. *Oklahoma State University Extension.* http://factsheets.okstate.edu/documents/hla-6429-site-disturbance-and-tree-decline/
8. Agriculture Information Bulletin No. 372, Air Pollution Injures Trees. (1974). *Forest Service, U.S Department of Agriculture*. https://www.na.fs.fed.us/spfo/pubs/misc/tree_care/aib372-e.htm
9. Askew, S. D., Wycoff, S. B., Bergh, J. C., Bush, E. A., Day, E. R., Dellinger, T., Derr, J. F., Hansen, M. A., Hong, C. X., Laub, C. A., Likins, M., McCall, D. S., McCoy, T., Miller, D. M., Nita, M., Parkhurst, J. A., Parson, R., Paulson, S. L., Pfeiffer, D. G., Rideout, S. L., Schultz, P. B., Wilson, J., Yoder, K. S.. (2021). 2021 Pest Management Guide - Home grounds and animals. *Virginia Cooperative Extension.* https://resources.ext.vt.edu/contentdetail?contentid=2377

weeds around trees can damage the trees, especially if it is a young tree. Remember that even properly applied herbicides applied to nearby areas can be carried by a breeze and injure a young tree.

De-icing Compounds – Compounds used to melt ice on walkways, driveways, and highways contain sodium chloride (table salt) and/or calcium chloride. These chemicals are toxic to trees in quantity and can injure trees when they are absorbed by their roots and leaves. Avoid or minimize the use of de-icing compounds around trees and be especially mindful of the runoff of melted snow and ice carrying these compounds. It is against the law to use fertilizers for de-icing as they contain salts that can damage plants in a de-icing situation.

Power Washing – Power washing of houses, walkways, and driveways is a common practice. Be aware that the bleach and other compounds used in power washing can damage small and medium trees. Bleach on the leaves can leave white spots and margins. The chemical compounds in the power washing liquid that runs off into a planting bed inhibit plant's absorption of water. To protect plants, close to the house, spray the leaves with water from a hose just before and just after the power washing. This will dilute the mixture reaching the leaves. Also, following the power washing, provide a deep watering to the soil in the planting area. This will dilute the chemicals that have seeped into the soil from the washing.

Living/Biotic Agents

All trees are not susceptible to all biotic agents. A given type of tree tends to be susceptible to only certain specific agents. Generally, the tree must be under environmental stress for even those specific biotic agents to cause diseases. This section considers microbes (living micro-organisms), animals (vertebrate and invertebrate), and certain plants that may be harmful to trees.

Microbes

Fungi and Fungal-like Organisms (FLOs) – Threadlike organisms without chlorophyll. They lack the ability to produce their own food and live off living tissue or dead or decaying organic matter. Fungi are the most common biotic cause of plant disease.[44p126] There are thousands of different species that cause disease in plants. In addition to entering plants through wounds or natural openings, such as stomata, fungi and FLOs can directly penetrate plant tissue using specialized filamentous structures. Fungus structures, such as mold, mildew, mushrooms, and conks, may be easily visible to the eye. However, other fungus structures, such as those that cause leaf spots, are microscopically small. In addition to leaf spots, fungi may cause blights, rots, cankers, wilts, galls, mildew diseases and rust diseases.

FLOs – Include *Pythium*, *Phytophthora*, and organisms that cause downy mildew. FLOs used to be considered fungi. While they share many common characteristics with fungi, FLOs are now understood to belong to a different taxonomic class. Pythium is considered a water mold and tends to develop when growing conditions are too wet. Species of *Pythium* cause crown and root rot in a variety of plants and blight in turf grass. *Phytophthora infestans* caused the potato blight in Ireland and northern Europe in the mid-1800s. Downy mildew is not the same as powdery mildew. While powdery mildew is caused by fungi, downy mildew is caused by a group of FLOs. The symptoms of downy mildew vary depending on the host and the specific FLO.[10]

Bacteria – Microscopic one-celled organisms, smaller and simpler that fungi. Bacteria cells have no defined nucleus. Commonly, bacteria are visible only with a microscope. Several hundred bacteria can cause plant disease. Bacteria require a wound or a natural opening, such as stomata, to enter a plant. Bacteria do not grow inside the plant's cells, but in the spaces between cells. Some produce toxins that cause host plant cells to die. Others produce enzymes that break down parts of the cells and cell walls of the host plant. Still others grow in the area of the xylem causing the host plant to wilt and die. Bacteria can cause symptoms such as galls, wilts, leaf spots, blights, soft rots, and cankers.

Viruses – Particles that live inside cells and infect other living organisms. Viruses are visible only with an electron microscope. They are parasites that require a living host to grow and multiply. By disrupting the normal processes of the cell, viruses take over plant metabolism and use the plant cell to produce more viruses. There are several hundred different viruses that can cause plant disease. They are generally named based on the disease they cause, such as Tobacco Mosaic Virus. Once infected by virus, little can be done to cure the diseased plant but cultural practices are important to avoid spreading the viral infection to other plants.

Of all the microbes viral infections can be the most difficult to diagnose. They produce no readily observable signs and symptoms can be subtle, often looking very similar to nutrient deficiencies or herbicide injury. Common symptoms of viral infection are poor growth, mottling (alternating darker and lighter patterns in the leaves, to include light and dark green or yellow patches or streaks), ring spots and wavy line patterns, leaf crinkling, and distortion.

Nematodes – Simple, multi-cell animals, worm-like in appearance and mostly microscopic. Nematodes infect people, animals, and plants, but those that damage plants do not attack people and animals. Plant pathogen nematodes feed on plants by puncturing the cell wall and sucking out the cell contents. This causes the plant to decline and even die. Roots of infested plants may have knots or galls, root lesions, excessive root branching, injured root tips, and stunted root systems. The damaged root system causes wilting, yellow leaves, and reduced size and number of leaves. The

10. Beckerman J. (2009). Downy Mildew. *Purdue University Extension.* https://www.extension.purdue.edu/extmedia/bp/bp-68-w.pdf

puncture opening enables fungi and bacteria to invade the plant. As with other biotic agents, the types of plants attacked by the nematode depends on the type of nematode.[11]

Animals

This section considers insects, mites, deer, birds, rodents and harmful plants.

Invertebrate Pests

Insects – Adult insects have 6 legs and 3 body parts. Most adults have wings. While most insects are beneficial, some can damage trees. Insects can be categorized as chewing, sucking, and boring. Each group produces a characteristic pattern of damage.

Chewing – Chewing insects eat plant tissue and defoliate plants. Some eat the entire leaf. Others eat the tissue between the veins of the leaf, known as skeletonizing. Still others, known as leaf miners, eat the tissue between the tops and underside of the leaf, hollowing out the leaf. The following are chewing insects.

- Beetles – either the larvae or adult stage, depending on the species. Examples include Japanese beetle, viburnum leaf beetle, and willow leaf beetle.

Figure 10-4 Japanese Beetle (Courtesy USDA ARS Photo Unit, USDA Agricultural Research Service, Bugwood.org)

11. Esser, R. P. What are Nematodes? *Organization of Nematologists of Tropical America Florida, Inc (ONTA).* http://www.ontaweb.org/photos-and-links/what-are-nematodes/

- Caterpillars – worm-like larval stages of moths and butterflies. They may eat the entire leaf or irregular areas. Examples include *Lymantria dispar* , eastern tent caterpillar, webworms, leaf rollers, bagworms, and oak blotch leaf miner.

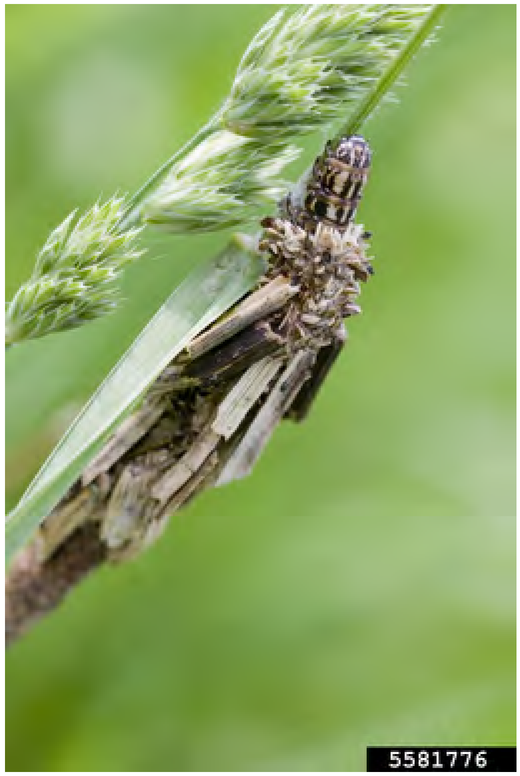

Figure 10-5 Bagworm (Mary C Legg, Mary C Legg, Bugwood.org)

- Sawflies – wasp-like insets whose larvae can resemble naked caterpillars or may be slug-like. The name comes from the saw-like appendage that the female adult uses to lay eggs. Sawfly caterpillars generally eat the entire leaf but the slug-like forms eat the tissue between the veins (skeletonizing).

Figure 10-6 Sawfly Larvae (Courtesy Ansel Oomen, Bugwood.org)

Sucking insects – Sucking insects have piercing mouthparts that penetrate leaves, twigs, branches, flowers, or fruit and feed on a plant's juices by sucking out the sap. Symptoms include fading or mottled leaf color, curling and twisted leaves, wilting foliage, and malformed flowers. Honeydew is a sticky secretion produced by some of the sucking insects. Honeydew creates a growing environment for sooty mold, a common name for several species of fungi, and the presence of sooty mold indicates sucking insect activity. Examples of sucking insects are discussed below.

- Aphids – small, soft-bodied insects that usually cluster on stems or undersides of terminal leaves. Aphids are also known as plant lice. Aphids cluster where they can feed on succulent growth, such as the underside of young leaves and on developing stems. While aphids may be yellow, green, black, or red, the color may be hidden by a waxy white coating. Aphids secrete honeydew as a waste material. The ants in the picture below are 'herding' the aphids for their sweet output.[12]

12. Day, E. R., (2020). Aphids. *Virginia Tech Department of Entomology, Virginia Cooperative Extension.* https://resources.ext.vt.edu

Figure 10-7 Aphids on Milkweed (Courtesy Carol King)

- Scales – During most of their lives, scale insects are legless and motionless and do not resemble insects at all. They may be circular, oval, or pear shaped, flat or convex. Scale can be either armored (hard) or soft based on whether the scale produces a waxy shell that gives the soft-bodied insect under it some protection. After the eggs hatch, the immature form of the insect is known as a crawler because they are able to move about the plant to find a feeding site. Once they select their site, they insert their beak to feed and then molt, losing their legs, eyes, and antennae. The insect then never moves again. The unarmored scale produce honeydew. The scale shown below is crape myrtle bark scale, a recent alien arrival which is making its way around Virginia. Interestingly, the larger somewhat fluffy creature is the larva of a small lady beetle which sucks out the scales. For additional information on scale see "VCE Pub ENTO-106NP, Scale Insects."[13]

13. Day, E. R., (2015). Scale Insects. *Virginia Tech Department of Entomology, Virginia Cooperative Extension.* https://pubs.ext.vt.edu/2808/2808-1012/2808-1012.html

Figure 10-8 Crape Myrtle Bark Scale and Lady Beetle Larva (Courtesy Cynthia Phillips)

- Mealybugs – Mealybugs have soft and mushy bodies covered with a white, waxy coating. Unlike scale, mealybugs can move throughout their lives, although that movement is slow. They produce honeydew. The ladybug above looks very similar, but they have different diets and are found in very different places: carnivorous/tree bark with scale, above vice vegetarian/ soft green plant tissue especially houseplants and plant nurseries.

Figure 10-9 Mealybug (Sally Tucker, Bugwood.org)

- Whiteflies – Whiteflies resemble tiny white moths. The immature stage resembles scale. Both the adults and immature stages suck sap from the leaves of host plants and produce honeydew. They are a common nuisance in greenhouses.

Figure 10-10 Greenhouse Whiteflies (Courtesy Whitney Cranshaw, Colorado State University, Bugwood.org)

- Thrips – Thrips are minute, slender insects with narrow fringed wings held flat on the back and asymmetric sucking mouthparts. Adults may be yellow, brown, or black. Immature thrips are lighter in color and do not have wings. Thrips most frequently damage flower buds, causing them to turn brown and die. They are known for frequently spreading viruses. (Thrips is both singular and plural.)

Figure 10-11 Melon Thrips (Courtesy J. Guyot, INRA, Pointe-a-Pitre, Bugwood.org)

- Leafhoppers – Adults are 1/8 to 1/4 inch long with wedged shaped bodies, pointed heads, and wings that are held over their backs like a roof. The nymphs are similar to the adults but smaller with short wings. They are active and either move sideways or jump when disturbed. Most feed on the upper surface of terminal leaves, leaving the leaves with coarse, white stippling. Most species feed on only one or several closely related species of plants. Some leafhopper species produce curled and stunted terminal leaves. Other species may transmit bacterial capable of producing scorch-like symptoms. A few species of leafhoppers secret honeydew.

Figure 10-12 Leafhopper (Courtesy J. L. Danet, INRA Centrale Recherches de Bordeaux, Bugwood.org)

Boring insects – Insect borers tunnel and feed beneath the bark. They are considered one of the most destructive pests of ornamental trees. Most are larvae of certain moths and beetles. Stressed trees may give off certain chemicals that evaporate into the air and attract adult insects looking for suitable places to lay their eggs. Females lay eggs in crevices or around wounds in the tree bark. When the eggs hatch, the larvae tunnel beneath the bark to feed and grow. The larvae eat inner bark, phloem (transporting nutrients), and xylem (transporting water). This destruction disrupts the flow of nutrients and water between the roots and the canopy resulting in branch dieback, structural weakness, decline and even death of the tree. The borer group of insects include the emerald ash borer, dogwood borer, and lilac borer.

Figure 10-13 Dogwood Borer (Courtesy David Laughlin, Horticultural Student, Bugwood.org)

Mites – Mites are not insects but are more closely related to spiders. They are very small, about 2mm, about the size of a period, and have 8 legs and a one-part body with no distinct heads. Mites suck out the chlorophyll in leaves leaving tiny white spots. Because of their small size, they may be present and not detected on a tree with no obvious damage until the infestation is heavy. At that point, the leaves turn yellow and brown and eventually die. Mites usually attack lower areas of a tree first and then move up the tree. A traditional way of checking for mites is to put a white sheet of paper under the branch, tap the branch, and look for moving black spots on the paper.

Figure 10-14 Twospotted Spider Mite (Courtesy Dave Cappaert, Bugwood.org)

Vertebrate Pests

Various animals, such as deer, birds and rodents can damage trees. While they are living agents, they do not infect trees as do biotic agents but act more like mechanical agents.

Deer – There are certain types of trees that deer particularly enjoy eating. This damages the appearance of the tree and may decrease the ability of the tree to feed itself. To protect the tree, spray the leaves with deer repellent or build a fence around the tree. Bucks rub their antlers against young tree trunks to scrap velvet. Usually the deer select trees around 4 inches in diameter. This can cause significant damage to the tree's vascular system. When the bark has been severed all around the circumference, the tree cannot survive. If less than 50% of the circumference is affected, the tree can usually recover. Deer also may rub trees during mating season to attract females or mark territory. Deer tend to return to the same trees. To protect the tree, apply a wire or plastic sleeve around the tree trunk or build a tall (4 feet) fence around the tree and close to the tree trunk. Deer are also vectors for the introduction of pathogens to the tree.

Figure 10-15 Yellow-Bellied Sapsucker (Courtesy James Solomon, USDA Forest Service, Bugwood.org)

Birds – Many woodpeckers feed on insects living in the decaying cavities of trees and other areas of trees where there is insect activity. The birds are looking for wood-boring beetles, carpenter ants, and other insects. These woodpeckers tend to prefer dead wood and the holes they leave tend to randomly spaced. Some woodpeckers are sapsuckers, meaning that they prefer tree sap as their primary food but will eat insects, seeds, and nuts as secondary food sources. The most common and most destructive sapsucker in North America is the American yellow-bellied sapsucker, a migratory bird that is seen throughout eastern North America. Sapsuckers tend to choose a favorite tree and return to that tree frequently. Unlike the insect-eating woodpeckers who tend to find their insects in dead wood, the sapsuckers are pecking holes and eating sap from live wood, making closely arranged rows of holes in the bark. Although some trees appear to seal the sapsucker wounds without harm (Atlas cedar, for example), the United States Forest Service suggests that the activities of the yellow-bellied sapsucker can degrade the wood of and even kill many varieties of trees. While a small tree can be killed in a single season, two or more years of feeding would be required to kill trees with diameters greater than 8 inches.[14]

Rodents – Mice, voles, squirrels, and rabbits can damage young trees by eating the soft bark around the trunk base. Voles eat roots. In addition to the bark, rabbits may also eat tender buds. This occurs most frequently in the winter. Their eating creates small wounds in the tree that allow fungi and other micro-organisms to attack the tree. If an animal eats the bark entirely around the circumference of the young tree, the tree will die. The tree can be protected from this damage by wrapping a ¼ inch wire mess or other tree guard material around the bottom 24 inches of the tree, sinking the mesh two inches below the ground.

Harmful Plants

Parasitic Plants

Some plants cannot make their own food and parasitize other plants to obtain nutrients and water. Examples include mistletoe and dwarf mistletoe, which have chlorophyll and can photosynthesize so they are not completely dependent on the host tree. However, they take nutrients and water from the host. Mistletoe usually select hardwoods as host trees in the Eastern US. Mistletoe is not a fast grower, and most healthy trees can tolerate some mistletoe plants. Heavy mistletoe infestations can make the tree less vigorous: if the tree has additional abiotic or biotic stressors, the tree could die.[15]

Figure 10-16 Mistletoe (Courtesy Edward L. Barnard, FL Dept of Agriculture and Consumer Services, Bugwood.org)

Dwarf mistletoe is practically leafless and occurs only on conifers. Dwarf mistletoe is mostly seen in the western United States and is considered more damaging that true mistletoe. It can cause witches brooms and swelling of infected portions of the tree branch. Forms of damage include loss of growth, defects in the host, and death of the host.

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14. Knuth, S. (2011). Yellow-Bellied Sapsucker. *Virginia Department of Game and Inland Fisheries.* http://12l8.blogspot.com/2011/03/yellow-bellied-sapsucker.html
15. Glen, C. (2016). Does Mistletoe Harm Trees? *North Carolina Cooperative Extension, Chatham County Center.* https://chatham.ces.ncsu.edu/2014/12/does-mistletoe-harm-trees-2/

Vines

Vines can damage trees in multiple ways. They compete with the tree for light, water, nutrients, and space. They may girdle the tree and constrict the trunk and branches.[16]
Vines can make the tree top-heavy, hold snow and ice and give more surface area for the wind to impact the tree. The extra weight from the vines and the additional effects from wind, snow, and ice can break branches, cause other structural damage, or even cause the tree to fall. A heavy growth of vines at the base of the tree and climbing up the trunk can hold moisture and increases the risk of fungal and bacterial infections. Vines that heavily cover the tree trunk or branches can obscure diseases of the tree such as cankers or decayed areas.[17] Vines, such as kudzu, can shade out the tree's foliage.[18]

Probably the most problematic vines with regard to trees are evergreen vines and fast-growing vines. Some of the most damaging vines are ivy, Japanese honeysuckle, wisteria, and kudzu. Deciduous vines and vines that grow more slowly, such as clematis and passion flower, are less likely to damage a tree. Although highly undesirable, poison ivy is not considered an aggressive grower and is not considered a significant tree killer. However, poison ivy can damage a tree by eventually choking the tree or branches and adding extra weight to the crown.The appropriate way to remove vines is not to pull them off the trees but instead to cut the vine as it surfaces from the ground at the base of the tree. The roots of the vine should then be pulled out of the ground around the tree. The vine on the tree should be left alone to die and fall off.[19]

Epiphytic plants live on the surface of other plants or objects. They are not parasites and do not take moisture and nutrients from the object on which they are growing. Therefore, they do not significantly impact the host trees. 106 While tropical and rainforest climates feature a wide array of epiphytic plants such as bromeliads and orchids, in Virginia the most commonly observed epiphytic plants on trees are mosses and lichens.105 Mosses and lichens do not damage the trees on which they grow.

16. Aulakh, J. S. (2016). *Woody Vines - Identification and Control.* Connecticut Agricultural Experiment Station. https://portal.ct.gov/-/media/CAES/DOCUMENTS/Publications/Fact_Sheets/Valley_Laboratory/WoodyVinesIdentificationandControlpdf.pdf
17. *Climbing Trees are Tree Killers.* (2020) The Tree Care Guide. http://www.thetreecareguide.com/climbing-vines-tree-killers/
18. Spengler, T. (2020, July 20). *Vines and Trees: Do Vines Harm Trees by Growing on Them.* Gardening Know How. https://www.gardeningknowhow.com/ornamental/trees/tgen/do-vines-harm-trees.htm
19. Spengler, T. (2020, July 20). *Vines and Trees: Do Vines Harm Trees by Growing on Them.* Gardening Know How. https://www.gardeningknowhow.com/ornamental/trees/tgen/do-vines-harm-trees.htm

Common Tree Diseases in Virginia

This section provides an overview of some of the more problematic tree diseases in Virginia. The purpose of the section is to provide the tree steward an awareness of these common diseases. When VCE publications are available with more in-depth information, they are referenced at the end of the discussion of the given disease. Specifics for chemical treatments are found in the VCE Pest Management Guide (PMG), discussed in Section 10.

Diseases Caused by Pathogenic Microbes

Anthracnose

Anthracnose is a general term for diseases caused by a several closely related fungi. Each species of the fungus affects only certain specific tree species and symptoms vary depending on the tree species. The following paragraphs addresses anthracnose in flowering dogwoods and sycamore trees as these are especially problematic in Virginia. Anthracnose also commonly occurs on white oaks, elms, and maples. Other species of the fungus infect linden, tulip tree, hickory, birch, and walnut, although this last group is usually only slightly affected.[20]

Anthracnose in Flowering Dogwood – Two types of anthracnose affect flowering dogwoods.

- Spot anthracnose is caused by the fungus *Elsinoe corni*. Symptoms appear in early spring on the dogwood bracts as small circular lesions with purple borders and light centers. Lesions appear later on the leaves. Later in the season, the centers may fall out giving a shot hole appearance. Cool, wet springs tend to produce more severe symptoms. Usually the disease causes little damage. Since the fungus spores overwinter in fallen leaves, the most practical control measure is to remove debris from the base of the tree. If the disease was severe the previous year or a cool, wet spring is expected, spraying with fungicides may be useful.[21]

20. Hansen, M.A. Foliar Diseases of Dogwood. *Department of Plant Pathology, Virginia Tech.*
21. Stripes, R. J. and Hansen, M. A. Anthracnose - Fungal Disease of Shade Trees. *Department of Plant Pathology, Virginia Tech*.

Figure 10-17 Dogwood spot anthracnose (Clemson University – USDA Cooperative Extension Slide Series , Bugwood.org)

- Discula Anthracnose is caused by the fungus *Discula destructiva*. In addition to lesions on the bracts and leaves, discula anthracnose causes dieback in the branches with lower branches dying first. Lesions on the bracts and leaves are irregularly shaped with purple margins and vary in size unlike the uniform, small lesions cause by spot anthracnose. Infected leaves may remain on the tree during winter. The infection can spread to the trunk, causing cankers, and then the death of the tree. The fungus overwinters in leaves and stem cankers. Spores are spread by cool, wet weather in the spring. The disease is most common and severe at high altitudes and is less common in the eastern part of the state. Discula anthracnose is difficult to control and requires both cultural and chemical methods.

Figure 10-18 Discula anthracnose (Terry S. Price, Georgia Forestry Commission, Bugwood.org)

For additional information, see VCE Pub 450-611, "Foliar Diseases of Dogwood," by Mary Ann Hansen, Department of Plant Pathology, Virginia Tech.

Anthracnose in Sycamores is caused by the *Apiognomonia veneta* fungus. Like anthracnose in dogwoods, sycamore anthracnose usually occurs in cool, wet weather in spring. However, the symptoms are different. In sycamores dark, angular areas occur along leaf veins and expand to cover the entire leaf. The disease can kill more than 90% of new shoot growth, cause the dieback of twigs, the development of cankers, and even death in larger branches.[22] Repeated infections can result in abnormal branching to include the growth of witches' brooms. Although the symptoms are severe, the sycamore is usually able to develop a second set of leaves by midsummer and the disease is rarely fatal.

Figure 10-19 Anthracnose on sycamore (William Jacobi, Colorado State University, Bugwood.org)

See VCE Pub 450-604, "Anthracnose – Fungal Disease of Shade Trees."[23]

22. Pests and Problems by Pest, Sycamore Anthracnose. *Missouri Botanical Garden.* https://www.missouribotanicalgarden.org/gardens-gardening/your-garden/help-for-the-home-gardener/advice-tips-resources/pests-and-problems/diseases/fungal-spots/sycamore-anthracnose.aspx

Phytophthora Root Rot

Phytophthora Root Rot is caused by various species of Phytophthora fungi. It affects conifers to include Leyland cypress, arborvitae, and pine. It can also affect dogwoods and various ornamental shrubs such as camellia, boxwood and azaleas.[24] The fungi first infect the fine absorbing roots and may move to larger roots and the root collar. Roots deteriorate, become brown, and severely degrade the ability of the root system to support the tree. Trees wilt, needles turn yellow and fall from the tree. Eventually this leads to the death of the tree.

Phytophthora thrives best in heavy, warm, moist soils and areas where water can collect around plant roots. All species of the fungus are able to live indefinitely in the soil. Once symptoms appear, chemicals are often ineffective in controlling the disease. Do not install susceptible plants in areas that tend to stay moist.

Figure 10-20 Fraser Fir Killed by Phytophthora (Courtesy Linda Haugen, USDA Forest Service, Bugwood.Org)

Figure 10-21 Phytophthora Root Rot (Courtesy Joseph O'Brien, USDA Forest Service, Bugwood.org)

23. Stripes, R. J. and Hansen, M. A. Anthracnose – Fungal Disease of Shade Trees. *Department of Plant Pathology, Virginia Tech.*
24. Benson, D.M. & Jones, R.K. (2000). *Phytophthora Root Rot and its Control on Established Woody Ornamentals.* North Carolina State University, College of Agriculture and Life Sciences.

Fire Blight

Figure 10-22 Fire Blight (Courtesy P. G. Psallidas, Benaki Institute, Athens, Bugwood.org)

Fire blight is caused by *Erwinia amylovora* bacterium. The bacteria can attack about 75 species of the rose family such as pear, ornamental pear, apple, and crabapple trees. It also occurs on pyracantha, spirea, hawthorn, and mountain ash.[25] The bacteria enter the plant though blossoms, new shoots, and wounds. Infected areas produce bacterial ooze that can lead to further infections. First flowers and then leaves wilt and turn brown but stay attached to the tree. Infected areas have a shriveled appearance as if scorched by fire.[26] Twigs and then branches die back. A young tree may die in a single season but more mature trees can endure several years of infection before they die. The bacteria overwinter in cankers (dead wood representing a wound on the tree) and dead, dried fruit.

To control the disease, prune out diseased wood and cankers 10 to 15 inches below the infection. Pruning is best done in late summer or winter. The pruned wood should be destroyed and tools disinfected. Diseased plants should be replaced with resistant varieties. See the PMG for chemical treatments.

Bacterial Leaf Scorch

Bacterial leaf scorch is caused by *Xylella fastidiosa* bacterium. The bacterial is introduced into the tree's xylem by sucking insects such as sharpshooter leafhoppers and spittlebugs. Once the bacterial has enter the system, it impacts water movement in the tree. Symptoms are similar to those caused by drought or root disease. The leaves show yellow and brown areas, generally with a characteristic yellow band between the green and brown areas. Trees impacted by drought or root disease do not have this yellow band.

Other symptoms vary depending on the host species and include yellowing and browning of the leaves and premature leaf drop. Symptoms usually appear in the late summer and fall. Infected trees

25. *Pear Disease - Fire Blight.* (2017). Penn State Extension. https://extension.psu.edu/fire-blight-of-pear
26. Gypsy Moth. *Missouri Botanical Garden.* https://www.missouribotanicalgarden.org/gardens-gardening/your-garden/help-for-the-home-gardener/advice-tips-resources/pests-and-problems/insects/caterpillars/gypsy-moth.aspx

may leaf out later than normal in the spring and leaves may be stunted. While the disease continues from year to year, the severity can vary. Over time the tree gradually declines and eventually dies.

In Virginia, the disease most often infects oaks, elms, and sycamores, but several other species are susceptible to include maple, hackberry, mulberry, sweet gum, and gingko.

There is no cure for the disease, but maintaining the health of the tree can help the trees survive longer. If the tree is removed, it should be replaced with a species that is not susceptible to the bacteria.

For additional information see VCE Pub 3001-1433 "Bacterial Leaf Scorch of Landscape Trees."[27]

Figure 10-23 Bacterial leaf scorch (Brian Olson, Oklahoma State University, Bugwood.org)

Other

In addition to the diseases above, other frequently encountered conditions caused by microbes include botryospharia canker, conifer needle cast, powdery mildew, rusts, and verticillium wilt. These diseases are caused by various fungi.

Significant Insect Pests of Virginia

Emerald Ash Borer

Emerald ash borer (EAB) attacks all species of ash trees that grow in Virginia. EAB was first reported in Fairfax County in 2008 and, as of 2016, has been identified in 46 counties, about half the counties in the state. There are approximately 187 million ash trees in Virginia.[28]

The adult borer is about ½ inch long and bright, metallic green. EAB generally mate in early June and lay their eggs in the crevices of the bark on the ash tree. When the eggs hatch, the larvae create S-shaped tunnels just behind the bark. Woodpeckers often feed on the larvae, leaving jagged holes in the bark. The mature borers emerge through D-shaped holes.

27. Bush, E. (2012). Integrated Pest Management for Plant Diseases in the Home Garden and Landscape. *Virginia Cooperative Extension.* http://pubs.ext.vt.edu/PPWS/PPWS-15/PPWS-15.html
28. *State of the Forest: Annual Report on Virginia's Forests.* (2017). Virginia Department of Forestry. http://www.dof.virginia.gov/infopubs/_sof/SOF-2017_pub_print.pdf

Figure 10-24 Cytospora canker, probably C. pruinosa, developing around wound of emerald ash borer (Whitney Cranshaw, Colorado State University, Bugwood.org)

Observable symptoms of tree decline do not occur until 2-5 years after the tree has been infested. The tree starts to thin out and the crown declines as branches in the top of the tree die. Epicormic branches sprout from the trunk, often occurring in areas where living and dead sections of the tree meet. When dead bark is removed, S-shaped tunnels are observable. The tree rarely recovers after infestation is identified. There is no treatment. Infested trees should be removed and destroyed to prevent further spread of the EAB. Because the borer can be transmitted in firewood from the ash tree, it is important to never move firewood from one geographic location to another. For additional information see VCE Pub 2904-1290, "Emerald Ash Borer" by Eric R. Day and Scott Salom, Department of Entomology, Virginia Tech, 2016.[29]

Lymantria dispar[30]

Lymantria dispar is the most important tree defoliating insect in the eastern United States.[31] Adult moths do not feed and live for only a few days. Adult females are white and in July lay eggs in tan colored masses on tree trunks and the underside of branches. Egg masses may be found on rocks at the bottom of a tree or even on recreational vehicles. Caterpillars merge from the egg masses the

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29. Day, E. and Salom, S. (2016). Emerald Ash Borer. *Virginia Cooperative Extension*.
30. In July 2021, the Entomological Society of America announced a change to the name of the insect known by the common name "Gypsy Moth." Please see this statement from the ESA: *"A The existing common names for the moth Lymantria dispar and the ant Aphaenogaster araneoides were identified as containing a derogatory term for the Romani people. In June, the ESA Governing Board elected to remove the common names for both species from the ESA Common Names of Insects and Related Organisms List. ESA will seek to convene a volunteer group to propose a new common name for L. dispar, which would then be made available for ESA member comment and subject to approval by the ESA Committee on Insect Common Names and the ESA Governing Board. In the meantime, ESA encourages people to refer to the insects by their Latin names."* Entomological Society of America. (2021). "Better Common Names Project." https://www.entsoc.org/better-common-names-project
31. Gypsy Moth. *Missouri Botanical Garden.* https://www.missouribotanicalgarden.org/gardens-gardening/your-garden/help-for-the-home-gardener/advice-tips-resources/pests-and-problems/insects/caterpillars/gypsy-moth.aspx

following April. The caterpillars may be up to two inches long and are hairy with blue and red dots along their backs and a beige head.

Caterpillars rest in the leaf litter at the base of the tree during the day. At dusk, they crawl up the trunk and feed on the leaves, returning to the base of the base of the tree at dawn. Trees that lose a lot of leaves will produce a second set. This second set will tend to be smaller and lighter in color that the initial leaves. Healthy trees can withstand this defoliation once or twice, but unhealthy trees may die after only one defoliation. Death of a weakened tree is not directly caused by the defoliation, but by invasion of secondary organisms.

Lymantria dispar caterpillars favor most species of oak but also feed on aspen, willow, birch, apple, and basswood. When the caterpillar populations are high, older caterpillars may feed on maple, hickory, elm, and many conifers. There are some tree species, such as the tulip tree (yellow poplar), that are never eaten by the caterpillars.

Figure 10-25 *Lymantria dispar* (Courtesy USDA APHIS PPQ, Bugwood.org)

Outbreaks are cyclical with multiple year periods of low activity followed by several years of high activity. Much of the cyclical nature of the outbreaks is dependent on the *Entomaphaga maimaiga* fungus. Wet weather in spring tends to increase the presence of the fungus which attacks the *Lymantria dispar* larvae, leading to a reduction in *Lymantria dispar* activity. Chemical treatment against the moths is usually aerial application of insecticides when the caterpillars are young. *Lymantria dispar* caterpillars are frequently mistaken for eastern tent caterpillar or the fall webworm. *Lymantria dispar* never build tents or webs. See VCE Pub 444-750.[32]

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32. Roberts, E. A. (2001). Gypsy Moth in Virginia: An Update. *Virginia Cooperative Extension.*

Eastern Tent Caterpillar

The eastern tent caterpillar, *Malacosoma americanum*, is recognized by the silky tents that the larvae spin in branch crotches. Adult moths are dark tan and lay their eggs in a 1 inch long, black collar around a twig. The eggs overwinter and hatch in March or April. Caterpillars are brown and hairy with a white stipe down the back, yellow brown borders, and row of blue spots on each side.

The larvae gather in the crotches of branches to spin their web nests. They leave the web to feed during the day and return to the web at night. In 4 to 6 weeks, caterpillars can reach 2 to 2 ½ inches in length. When it is time for the caterpillars to pupate, they leave the web nest and can be seen crawling on other plants, walkways and whatever is around. While these wandering caterpillars are a nuisance, they are not feeding at this time and do not damage the plants on which they may be found.

Figure 10-27 Eastern Tent Caterpillars in Tent (Courtesy Tim Tignor, VDOF, Bugwood.org)

Eastern tent caterpillars favor black cherry, chokecherry, and apple trees but they also feed on hawthorn, pear, plum, and other flowering fruit trees. If the outbreak is especially severe, the entire tree may be defoliated. Since defoliation generally occurs early in the season, wild cherry trees can generally replace their leaves with new ones. If trees do not have enough time to grow new leaves, they may die.[33]

Figure 10-28 Eastern Tent Caterpillars (Courtesy Lacy L. Hyche, Auburn U., Bugwood.org)

To control infestations, cut off twigs with egg masses in fall and winter. In smaller trees, web masses can be removed and destroyed by hand, working at night after the caterpillars have returned to the nest. The caterpillars may be killed with insecticide spray in the spring. Since the webs protect the caterpillars from the insecticide, spraying must occur during the day when the caterpillars are away from the web. See VCE Pub 444-274, "Eastern Tent Caterpillar."[34]

33. Eastern Tent Caterpillar and Forest Tent Caterpillar. (1992). *University of Maryland Extension.*
34. Day, E. R. (2014). Eastern Tent Caterpillar. *Virginia Cooperative Extension.*

Fall Webworm

Fall webworms, *Hyphantria cunea,* form webs over the end of branches. Webs are created by newly emerged caterpillars. As the caterpillars grow, they expand the webs to cover more leaves. Caterpillars feed inside the webs. While the webs are a nuisance, the caterpillars do not significantly damage the tree because defoliation occurs later in the summer and fall rather than during a period of active growth.

Figure 10-29 Fall Webworm Nest (Courtesy Kelly Oten, NC Forest Service, Bugwood.org)

The adult moth is white, usually with dark spots on the wings. It lays its eggs on the underside of leaves from May to July. Caterpillars emerge within two weeks and immediately begin creating webs and feeding on leaves. This feeding stage lasts from 4 to 8 weeks. Caterpillars are covered with silky hairs. Their bodies are pale yellow to green with black strips on their back and yellow stripes on their sides. When it is time to spin their cocoons, caterpillars crawl to a protected space such as ground litter or just below the surface of the soil. Adult moths emerge in late spring or early summer. There are two generations per year.

Fall webworms feed on over 100 species of deciduous trees. Nests can be cut out on smaller trees. Insecticides may be used and are most effective when the webs first appear. See VCE Pub 2808-1013, "Fall Webworms."[35]

Figure 10-30 Fall Webworm Moth and Eggs (Courtesy PA Dept of Conservation and Natural Resources, Bugwood.org)

35. Day, E. R. (2008). Fall Webworms. *Virginia Cooperative Extension*.

Figure 10-31 Fall Webworm Larvae (Courtesy PA Dept of Conservation and Natural Resources, Bugwood.org)

Hemlock Wooly Adelgid

Hemlock Wooly Adelgid, *Adelges tsugae*, is a non-native aphid-like insect that arrived in the United States in the 1920s. The insect has infected hemlocks throughout the Appalachian region. In Virginia it feeds on Eastern Hemlock and Carolina Hemlock. As many as 80 percent of the hemlocks in the Blue Ridge Parkway and Shenandoah National Park have died due to this infestation.

Figure 10-32 Hemlock Wooly Adelgid (Courtesy Steven Katovich, Bugwood.org)

The insect has multiple forms and life stages. During the crawler stage, nymphs attach themselves to the hemlock bark, needles, and twigs. They produce a white waxy substance that provides a protective coating. These cottony masses remain after the insect has gone and give the insect the “wooly” in its name. The insect feeds on the sap at the base of the hemlock needles, depriving the tree of nutrition. Trees usually die within 3 to 5 years but may die in a single year if the infestation is severe.[36]

36. *Hemlock Wooly Adelgid.* (2015). National Park Service. https://www.nps.gov/grsm/learn/nature/hemlock-woolly-adelgid.htm

Systemic insecticides and dormant oil may be used to control the insect. Several beetle species have been imported and released as biological control agents. See VCE Pub 3006-1451, "Hemlock Wooly Adelgid."[37]

Diagnosing Tree Diseases

A given type of tree needs certain environmental conditions to prosper (amount of moisture, type of soil, amount of light, temperature, etc.). Outside those conditions, the tree will be stressed and that stress will eventually be reflected in changes in the tree's condition. The tree is susceptible only to certain pathogens microbes and pests). Generally, a necessary condition for pathogens to cause significant problems in a tree, the tree is already experiencing environmental stress.

This section emphasizes certain essential aspects of diagnosing tree problems. Section 8 of this chapter presents "20 Questions on Plant Diagnosis" a factsheet from the Ohio State University Extension describing a detailed step-by-step process for diagnosing a plant problem. Section 9 defines the process for taking plant samples for VT lab. Section 10 discusses the structure, use, and importance of the VCE Pest Management Guide (PMG) for Home Grounds and Animals.

First, **identify the type of tree**. If the species is not known, then determine the genus or family. Two examples follow:

- The tree is a conifer with scale-like leaves. Then it must belong to the Cupressaceae (Cypress) Family.
- The tree is a deciduous broadleaf and produces acorns. Then it must belong to the Oak Genus in the Fagaceae (Beech or Oak) Family.

Begin the diagnostic process with a basic familiarity of the **desired environment for that tree type**. Books such as Common Native Trees of Virginia and Trees of Eastern North America are excellent resources. The internet contains a wealth of information on trees. As much as possible, stay with educational sites such as the those of state extensions; recognized institutions, such as the Missouri Botanical Garden or Morton Arboretum; or government sites such as those by the federal or state departments of agriculture or forestry service.

Determine the **micro-organisms and pests** to which the tree is most susceptible. The first reference for this should be the PMG. Books such as the Ortho and Southern Living problem solving books discuss plant diseases by plant type. Prior to the internet, these were critical resources and they can still be useful. However, the internet contains an abundance of information that is easily accessed. Just search for "Problems of Tree Type X". Again, stay with the recognized authoritative sites as

37. Salom, S. and Day, E. R. (2016). Hemlock Wooly Adelgid. *Virginia Cooperative Extension*.

described above. Even if the tree's potential problems are contained in PMG, also look on the internet for pictures and additional information on recognized causes of disease.

Knowing the tree type, the environment it needs to flourish, and the pathogens (micro-organisms and pests) to which that tree type is most susceptible, provide the basis for examining the diseased tree. The tree steward should both observe and discuss with the homeowner the environmental conditions that the plant has been experiencing. In these observations and discussions, the tree steward is looking for stresses on the tree. The Tree Steward examines the tree to look for **symptoms and signs** and talk with the homeowner about the **development of the disease pattern** (time, severity, parts of plant/s affected).

The identification of environmental stresses may alone account for the observed symptoms. However, the tree steward should also compare the observed symptoms and signs to the symptoms and signs of the diseases to which the tree is known to be susceptible to determine if there is correlation. In many cases, relating symptoms and signs to an assessment of environmental conditions and potential pathogens will lead to a diagnosis. If the tree steward is not confident with a diagnosis at this point, then he/she should take a sample of affected parts of the tree (leaves, twigs, bark and roots) and provide that example to the VT Diagnostic Lab. The procedure for taking that sample and submitting it to the VT lab is provided in a later section.

Once a diagnosis has been determined, the tree steward should provide a recommendation for addressing the problem. For environmental stress issues, example recommendations could be:

- Water the tree deeply at regular intervals when there is little rain.
- If the present location is too moist (or gets too much light or too little light), move the tree to a more suitable location, if small enough, or replace it.

If the cause of the problem is a micro-organism or pest, discuss remedial actions such as cultural practices and application of a fungicide or insecticide. **The PMG must be the source for any recommendation involving the application of chemicals.**

20 Questions on Plant Diagnosis

This section reprints, with permission, Ohio State University Extension Factsheet "20 Questions on Plant Diagnosis," PLPSTH-GEN-3, which is an excellent step-by-step guide and very much worth reading for its logic, insights and illustrations. However, please note that Sections 9 and 10 of this chapter provide Virginia-specific information that should take precedence over the OSU Factsheet Questions 16: How do I take samples? and 20: What are my recommendations? In all of these instructions, moreover, it should be remembered that tree stewards are not plant pathologists. Their role is to know how to look at a tree and its surroundings for critical information; what kind of questions to ask; and how to research or refer the problem for more expert help. It can be overwhelming to think that you are trying to identify one among a seeming million pests. But you are can be most effective in eliminating possible diseases and concentrating on finding the really useful information. If there is a locally important problem, especially if it concerns a specific type of tree, then it may be worthwhile to bone up on the details: for example, the Emerald Ash Borer, if it has not arrived in your locality. (If it has, you probably already know!)

EXTERNAL DOCUMENT

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20 QUESTIONS ON PLANT DIAGNOSIS

PLPATH-GEN-3
Agriculture and Natural Resources
Date: 02/15/2017

Joe Boggs, Ohio State University Extension, Hamilton County
Erik Draper, Ohio State University Extension, Geauga County
Jim Chatfield, Sarah D. Williams, and Mike J. Boehm, Department of Plant Pathology

This is the third fact sheet in a series of ten designed to provide an overview of key concepts in plant pathology. Plant pathology is the study of plant disease including the reasons why plants get sick and how to control or manage healthy plants.

Proper diagnosis of plant problems is a key factor in plant health management. As urban forester Alan Siewert quips: "Treatment without diagnosis, as in medicine, is malpractice." Despite this, diagnostics is often not given adequate attention.

There are three challenges to consider when embarking on plant problem diagnostics:

- Some plant problems are very obvious, while other problems are very obscure.
- Some plant problems will not be diagnosed with your first effort. In fact, some plant problems may never be fully diagnosed.
- Clients usually want an immediate and clear cut answer which produces great pressure to provide a quick-draw, clear-cut diagnosis.

Typically, diagnostics is a process to come up with the best possible explanation of why a good plant has gone wrong. Unfortunately, it almost always involves unknown variables and uncertainties that make an absolute slam-dunk diagnosis the exception rather than the rule. This reality sometimes conflicts with our desire to provide quick, clear answers. Remember that an incorrect diagnosis will lead to an incorrect treatment. Speed should never supersede accuracy.

Figure 1. Characteristic "leaf skeletonizing" damage caused by Japanese beetles.

However, if the plant problem is an insect pest and the pest is present, a quick and accurate diagnosis can be made by simple pest identification. Diagnosing what is causing leaves on little leaf linden to become skeleton-like with only the veins remaining is relatively easy if Japanese beetles are swarming the

[Please read this publication](#) titled "20 Questions on Plant Diagnosis" from The Ohio State University

Guidelines for Taking Plant Disease and Insect Samples

Megan Tierney, ANR Horticulture Agent, VCE York/Poquoson authored the following guidelines for submitting samples of diseased plants and insect problems through the York Poquoson Extension Office. This procedure should be modified for the local TS Master Gardener extension office.

"A diagnosis is only as good as the sample and information you provide"

Lesson from the York Poquoson VCE office:

Samples are only accepted Monday-Wednesday at the York Poquoson VCE office

so samples don't sit at the post office and expire over the weekend,

which leads to no results.

Include the following with the sample:

1. Plant parts must be living diseased parts (all dead = no results), sections of branches, no single leaves, etc., contained in a sealed bag.

2. A zip top sandwich bag full of soil from the root system of the plant including living root matter (lab cultures for fungus/bacteria that can be the cause for disease and does basic pH test). Plants and soil should be separated or the soil saran wrapped.

3. Completed homeowner questionnaire forms *One per plant, not customer.

4. Include printouts or email pictures that show the overall health of the plant or close-ups of issues in color. Email the pictures to the address specified by the local office.

5. For insect identification, no live insects will be accepted. They must be drowned in rubbing alcohol or sealed in a plastic bag until they die (at least a week) before they can be accepted.

6. For insects, please indicate as much information as possible about the habitat (where they were found: example, kitchen).

7. For weed identification the lab needs as complete a plant as possible, i.e., roots, flowers, fruits, and seeds.

8. Make sure plant owner name is on all bags/containers so that they stay together.

9. Place together for further action by the extension office.

Good Sample: Includes soil sample with roots present, several leaves and pictures– branches would make it better

Figure 10-33 Samples and Photos (Courtesy Megan Tierney)

Figure 10-34 Labeling Samples (Courtesy Megan Tierney)

For more detailed information on submitting good samples to the Plant Disease Clinic, view this webinar from Mary Ann Hansen and Elizabeth Bush of Virginia Tech's Plant Disease Clinic: https://youtu.be/rCEE8NNntMg

Using the VCE Pest Management Guide (PMG): Home, Grounds and Animals

View the 2021 VCE Pest Management Guide (PMG)

The PMG provides over 300 pages of information on managing problems of vegetables, fruits, ornamentals, lawn, and even discusses parasites on pets and other vertebrates as pests. Because of its length and the many topics covered, it can be challenging to use the document in digital form. The intent of this section is to make the TS aware of the relevant portions of the PMG for diagnosing tree problems and provide a general approach for using the document. Page numbers presented here are for the 2017 edition of the PMG.

Chapter 4, p.4-11 through p. 4-73 of the PMG addresses problems with trees. This includes the following sections:

- Diseases of Landscape Trees, p. 4-11
  - Table 4.2 – Fungicide Use
- Insects of Trees, Shrubs, Annuals, and Perennials, p. 4-27
  - Index to Insects and Mites by Host
  - Table 4.3 – Timing for Borer Treatment
  - Table 4.4 – Timing for Scale Insect Treatment
  - Table 4.5 – Control Measures for Major Pests and Pest Groups
  - Table 4.6 – List of Common Insecticide Mixtures
  - Table 4.7 – Directions of Pesticide Usage
- Organic Controls for Insects of Home Ornamentals, p.4-73
  - Table 4.8 – Organic Control Use

As discussed in Section 7, the identification of a tree problem begins with knowing the type of tree. The PMG provides information on the fungi and insects that most commonly cause problems on a given tree type in Virginia. The TS should consult **Table 4-2 – Fungicide Use**, on p.4-13 through p. 4-26, to determine possible fungal infections for the given tree. For example, if the tree is an ash, expected fungal infections are anthracnose and rust, p. 4-13. The TS should then consult the "**Index to Insects and Mites by Host**", p. 4-30 through p.4-32 to determine possible insect or mite infections. In our example, ash trees are susceptible to aphids, Flower gall mites, borers, defoliators, Emerald Ash borer, lacebug, leafminer, leaf roller, rhinoceros beetle, sawfly, scale insects, and spider mites, p. 4-30.

Knowing the fungi and insects to which the tree is susceptible provides a baseline of possibilities to consider when the TS examines the diseased tree. That baseline, of course, has to also include the possibility of abiotic agents as well as biotic agents other than fungi. The TS should consult other references for the other relevant biotic agents for the given tree. The TS then assesses the symptoms, signs, and other relevant aspects of the tree, as described in Section 8, to determine which agent(s) are the most likely cause of the tree's problems. If the tree's symptoms align with a specific fungus, the TS then returns to Table 4-2 to determine the appropriate treatment. Table 4-2 list fungicides applicable to the specific fungi, and recommends when to apply the fungicide, cultural controls, and precautions /remarks. If the ash tree has anthracnose, then chlorothalonil and mancoseb are two of the recommended fungicides. They should be applied at bud break or at the first sign of disease. (This probably indicates that treatment will occur the following spring.) Fallen leaves should be collected and either burned or buried to reduce overwintering of the fungal inoculum.

If the tree's symptoms align with a certain insect or mite, the TS consults Table 4.5 for control measures. If the ash tree is determined to have leafminers, then imidacioprid is the approved control measures, p.4-50. The treatment should occur in mid- to late June after eggs have hatched. When using imidacloprid, see "Bee Advisory Box," The PMG also provides the URL for a related factsheet on leafminers.

Remember, any recommendation of chemicals (fungicides or pesticides) must be consistent with the controls listed in the PMG.

Review Questions

1. What agents cause disease in trees?
2. Which damages the most trees, environmental stress or pathogens?
3. Which micro-organism is responsible for damaging the most trees?
4. Insects can be categorized into three groups by the way they inflict damage on trees. What are those three categories?
5. What bird is most likely to damage a tree and why?
6. What is the first thing to know when diagnosing a tree problem?
7. What is the authoritative source for chemical treatments of tree problems?

The following are additional sources that provided general information used in the development of this chapter:

- Appleton, B. (2015). 24 Ways to Kill a Tree. *Virginia Cooperative Extension.*
- Appleton, B, French, S. Tree and Shrub Planting Guidelines. *Virginia Cooperative Extension.*
- GardenNotes #331. (2011). *Colorado State University.* http://www.ext.colostate.edu/mg/gardennotes/331.pdf
- Heizer, J. (2017). Pests and Diseases of Hampton Roads. *Bartlett Tree Co.*
- Isleib, J. (2012). Signs and symptoms of plant disease: Is it fungal, viral, or bacterial? *Michigan State University Extension.* http://msue.anr.msu.edu/news signs_and_symptoms_of_plant_disease_is_it_fungal_viral_or_bacterial
- Insect and Disease Problems. (2011). *International Society of Arborists.* www.treesaregood.org
- Pests and Problems by Pest. *Missouri Botanical Garden.* http://www.missouribotanicalgarden.org/gardens-gardening/your-garden/help-for-thehome-gardener/advice-tips-resources/pests-and-problems/pests-and-problems-bypest.Aspx
- Tree and Plant Advice: Help with diseases & Help with pests. *Morton Arboretum.* http://www.mortonarb.org/trees-plants/tree-and-plant-advice
- Nortman, D. (2015). Tree Pathology. *Virginia Cooperative Extension, York County/City of Poquoson.* Presentation to Peninsula Tree Class of 2015.
- Ornamental Plant Insect Pests, Insect Pests of the Home Landscape. *PlantsGalore.com.* http://www.plantsgalore.com/care/insects/index.htm
- Raid, R. (2011) Plant Pathology Guidelines for Master Gardeners. *University of Florida, Everglades Research & Education Center.* http://erec.ifas.ufl.edu/plant_pathology_guidelines/index.shtml The Virginia Master Gardener Handbook, 2015 Edition
- Home and Garden Information Center, Trees & Shrubs: Common Problems. *University of Maryland Extension.* https://extension.umd.edu/hgic/trees-shrubs/commonproblems-trees
- Home and Garden Information Center, Mechanical injury – Trees and Shrubs. *University of Maryland Extension.* https://extension.umd.edu/hgic/mechanical-injury-trees-andshrubs
- Insects. *University of Minnesota Extension.* https://www.extension.umn.edu/garden/insects/
- Common Native Trees of Virginia Tree Identification Guide. (2012). Virginia Department of Forestry. http://dof.virginia.gov/infopubs/_fhr/FHR-2017-01_pub.pdf
- Williams, S. D., Boehm, M. J., & Qu, F. Plant Disease Factsheets: PLPATH-GEN-1, PLPATH-GEN-5, PLPATH-GEN-6, PLPATH-GEN-7, PLPATH-GEN-8. *Ohio State University Extension.* https://ohioline.osu.edu/factsheet/plpath-gen-1

CHAPTER 11: STRUCTURAL DEFECTS, TREE FAILURE, AND RISK

If a tree falls in a forest and no one is around, does it pose a risk?

Chapter Contents:

Introduction

The trees that grace our homes and fill our parks and forests provide many benefits: relaxation and recreation, pleasing surroundings, shade and protection for our buildings and activities, wildlife habitat, fruits and nuts for our consumption, and more, all in addition to their critical ecological functions. However, counterweight to their benefits, trees also present us with the potential for damage or harm. Like us, they may fall prey to natural events or human intervention, or finally to old age and death. A small tree that falls in a corner of a backyard or even a large tree in the midst of a forest may not have much impact of note, but the larger the tree and the closer its proximity to us, the more risk it poses to life and property.

Tree failures cause a significant number of fatalities and a substantial amount of property damage every year. In the United States between 1995 and 2007 there were 407 deaths caused by wind-related tree failure. These were spread across varied weather events: 41% were caused by thunderstorms, 35% by non-convective high winds, 14% from hurricanes, 7% from tornadoes, and 3% from snow and ice. Wind-related tree failures were responsible for approximately half of the deaths from thunderstorms and high winds and a third of the deaths from hurricanes.[1] These figures do not include additional damage such as nonfatal injuries, property damage, indirect deaths (e.g. lack of access to medical services due to downed trees), or trees and limbs damaged by the storm that do not fall until later. Property value losses in the state of Georgia from wind-related tree failure alone are estimated to be over $10,000,000 per year.[2]

The definition of tree failure given by the International Tree Failure Database User Manual is "A structural failure or physical breakage of the tree trunk, one or more branches, or one or more tree roots."[3] The vulnerability of a tree to failure is dependent on three factors: the **structure and condition of the tree**, the **particulars of the site**, and the **force to which it is subjected**. In this chapter we will examine each of these factors and hopefully begin to gain an understanding of the complex interactions that affect whether a tree stands or falls. All the information covered in previous chapters has described many of these various elements; in this chapter we will focus on their integration into the relationship between cause and effect.

As Tree Stewards, we may be called upon to help evaluate the safety of a tree. It is important for us to understand the structure of trees; how their stability and strength is impacted by various stressors such as poor condition, environment, weather events and other factors which can cause or contribute to their failure; how to look critically for the presence of these conditions or circumstances; and to have an informed concept of what defines the extent to which a tree poses a "risk". In addition, it is critical to understand the Tree Steward's specific role in observing, evaluating, and explaining the condition of trees, including the limitations of that role, and to be cognizant of the importance and proper role of credentialed tree care professionals.

Learning Objectives

1. Understand the concept of tree failure and how trees fail.

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1. Schmidlin, T. (2009). Human fatalities from wind-related tree failures in the United States, 1995–2007. *National Hazards 50,* 13-25. https://www.researchgate.net/publication/226683183_Human_fatalities_from_wind-related_tree_failures_in_the_United_States_1995-2007
2. Coder, K. D. (2001). *Storm damaged trees: prevention and treatment.* The University of Georgia Cooperative Extension Service. http://counties.agrilife.org/harris/files/2011/05/Stormdamage.pdf
3. Smiley, E.T., Matheny, N., & Clark, J. (2006). *User manual.* International Tree Failure Database. http://ucanr.edu/sites/treefail/files/4358.pdf

2. Understand how tree and site conditions contribute to a tree's vulnerability to failure.
3. Understand how weather events affect trees.
4. Understand the concept of "risk" and how it is evaluated by Tree Stewards and by professionals.
5. Understand the limitations of Tree Stewards in advising clients.
6. Understand what Certified Arborists are, what their function is, and when their services should be recommended.

Tree Conditions Contributing to Failure

There are a multitude of factors that influence the structural integrity and strength of a tree. It begins with the genetic characteristics of its species which lay the foundation for its innate structure, strengths and weaknesses. As the tree grows, these are integrated into its individual dynamics such as growth pattern which are then influenced by climate and site conditions, its "life experiences". The tree's health and vitality then help determine its susceptibility to pests, disease, and decay which are again, circularly, influenced by its genetic resistance to these.

In addition to its biological functions in support of growth, each component of a tree constitutes a piece of the equation that defines the tree's structural integrity and mechanical strength. As each particular component individually loses health or becomes injured, it also contributes to a synergistic effect which degrades the strength of the organism as a whole and affects its ability to deal with load stress as a unit.

Scientists have used several theoretical models in an attempt to understand how trees as physical structures respond to wind load. Some models view the tree as a static (rigid, nonporous) object subjected to a constant force. Others conceptualize it as a dynamic interaction which considers variable factors such as wind gusts. A third view is based in fluid mechanics, where trees are seen as "flexible porous structures that change their shape as the wind blows."[4] A 2006 study found that trees do not simply sway back and forth under dynamic loads, but instead move in a complex looping pattern. As the branches move around in the wind, they dissipate wind energy, which reduces the load transferred to the trunk and increases the mechanical stability of the tree.[5]

4. Matheny, N, & Clark, J. (2009). *Tree risk assessment what we know (and what we don't know).* Arborist News. http://www.isa-arbor.com/education/resources/educ_portal_risk_an.pdf
5. Matheny, N, & Clark, J. (2009). *Tree risk assessment what we know (and what we don't know).* Arborist News. http://www.isa-arbor.com/education/resources/educ_portal_risk_an.pdf

Thus, the vulnerability of a particular tree or part of a tree to failure is a summation of a number of complex and interrelated factors. In this section we will attempt to describe some of these structural factors, how they may be caused, what they look like, how they may interrelate, and finally how to evaluate their potential for harm within the limitations of our knowledge.

Roots

Roots are literally the foundation of the entire tree; they are the most critical component for its stability and literally hold the tree in the ground. Ideal root development would be an evenly distributed circle of major roots which grow fairly straight away from the tree with unimpeded horizontal space to allow them to stretch to their fullest. Approximately 90-95% of roots grow within the top three feet of the soil, more than half of which are in the top foot.[6] Optimum anchorage depends on the ability of the tree to grow its roots to a length proportionate to its crown (approximately 2 to 4 times the width of the canopy or dripline), at their natural depth, and in a place where a stable soil structure and adequate nutrients, water, and oxygen are available.

Trees with **shallow root systems** are more prone to uprooting than deeper rooted types.[7] Those growing in compacted clay soil, in a site with a high water table, or over hardpan will usually have root systems which do not grow to the optimum depth that they might elsewhere[8].

Trees with **limited root space** are not allowed to grow to anywhere near their appropriate breadth, which limits the size and also threatens the health of the tree. Confined root systems typical of urban plantings in areas such as sidewalk cutouts, street side planting strips, and parking lot islands result in limitation not only of total root mass but, more important for stability, the horizontal root growth necessary for anchoring. Trees which have roots covered by an impervious paving material will likely decline or die because of their inability to access the water and oxygen they need.

Root girdling prevents the outward growth necessary for good anchoring ability, in addition to strangling the tree and possibly causing its death. Those growing too close to the surface can be exposed to man-made injury such as mower damage.

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6. Johnson, G.R. (1999). *Protecting trees from construction damage: a homeowner's guide.* University of Minnesota Extension. http://www.extension.umn.edu/garden/yard-garden/trees-shrubs/protecting-trees-from-construction-damage/#root
7. Hauer, R.J., Hruska, M.C., & Dawson, J.O. (1994). *Trees and ice storms: the development of ice storm-resistant urban tree populations.* University of Illinois at Urbana-Champaign. http://web.extension.illinois.edu/forestry/publications/pdf/urban_community_forestry/UIUC_Trees_Ice_Storms.pdf
8. University of Florida IFAS. (2015). *Inadequate root anchorage.* http://hort.ifas.ufl.edu/woody/inadequate-root.shtml

Damage to the roots, especially major roots, will not only impact their ability to carry out their part in maintaining the health and vitality of the tree as a whole, but also the health and strength of the roots themselves, and thus reduces their mechanical strength. Shortening them, by cutting through them or by damage that weakens them, will reduce their ability to hold on to the ground. Wind load is shared equally by roots on the windward and leeward side of the tree, so structural roots on all sides of the tree are critical to stability.[9] If there are only two or three main roots, or if roots are missing or rotted on one side, then the tree is more likely to blow over. It is considered at high risk if more than a third of the main structural roots are missing.[10]

Finally, **decayed root systems** may have very little to provide in the way of anchoring ability if the roots are weakened to the point of easy breakage.Root damage to a tree can kill it suddenly, within a year or two, or the tree may appear healthy and show no sign of decline for twenty years and then begin to decline gradually or die quickly due to long-term problems which had not been visible.

Trunk

Trunk ("stem") structure is a major factor in defining the mechanical strength and load distribution in the tree. Ideally a tree would have a single trunk which is fairly straight, the root flare visible at the bottom, and tapering somewhat with height. The strength of the trunk structure (and each major branch) depends on its ability to maximize its elasticity and its resistance to breaking when bent; it is most effective at doing this when the tension from load stress is evenly distributed. Any irregularity, i.e. defect, interrupts this flow and creates a point of vulnerability and weakness.

Splits and cracks create weak areas that are more vulnerable to load stress. Cracks can be lengthwise or crosswise depending on the cause, and can occur due to previous wind stress (bending or twisting), drought, growth expansion (usually horizontal across trunk or large branches), frost cracking (from temperature change between a very cold night followed by a warm sunny day), incomplete graft unions, bark inclusion, or a stem girdling root. When trees are bent past their ability to absorb the stress, they begin to crack horizontally as the wood collapses inward, often leaving external wood or bark at the top of the crack projecting outward.[11] This is an incomplete failure which should be evaluated immediately by a certified arborist.

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9. Dahle, G. (2014). *Characterizing strain and load transfer in the root flare.* Tree Fund. http://www.treefund.org/archives/9170
10. University of Florida IFAS. (2015). *Root rot.* University of Florida IFAS. http://hort.ifas.ufl.edu/woody/root-rot.shtml
11. University of Florida IFAS. (2015). *Cracks in the trunk.* University of Florida IFAS. http://hort.ifas.ufl.edu/woody/potential-failure.shtml

Codominant joined trunks are, in fact, not connected; they are separated by included bark. The apparently joined length over the indented area indicates a defect that extends the length and through the width of the join.[12] Over time, the trunks grow in length and subsequently further away from each other, increasing the likelihood of failure.Sections or long strips of **bark loss** can be indicative of a previous lightning strike which has gone down one side of or through the tree. The internal effects of lightning damage are unpredictable. Loss of bark may include loss of the cambium.

Cavities and large decayed areas create points of weakness. Cavities from large branches that have been pruned or broken near the trunk may have decay that extends far down into the trunk. Branches of more than approximately half the diameter of the trunk are more likely to decay, especially if flush cut, resulting in cavities, cracks, and hollow areas. Wood that forms around cankers grows quickly in order to support the weak area. A larger canker has a significant impact on the overall trunk strength; even when callousing occurs to strengthen the area, it also creates an irregularity in relation to the rest of the wood.The extent of internal damage, whether from lightning, rot, decay, or any other means, cannot be accurately assessed by external evaluation; even professional arborists have only a few tools at their disposal.

The **root flare** is a critical juncture which provides a mechanical transition point between the vertical trunk and horizontal roots, where the effect of load forces are concentrated. Roots grow fairly close to the surface near the trunk to help distribute the force more smoothly at the point where this transition occurs. The area between the root flare and the lowest main branch attachment is the most vulnerable area for failure. Any cavities, decay, or damage at or near this area has a significant impact on susceptibility to failure. Note that cracks or inclusions in the root flare are normal for some trees (e.g. laurel oak, red cedar, arborvitae) but they may still be cause for concern.[13]

Damage to the **lower trunk area** including root girdling, cambium loss, rot due to too-high mulch or soil level, or lawn implement damage (such as mowers or string trimmers) will greatly impact the tree's health and stability. Cambium loss will kill the tree if it girdles it, so sections with bark loss are suspect because they often include cambium loss. Loss of a substantial section of cambium may kill a portion of the canopy (for many trees, that portion directly above it).The degree to which a tree's mass is directly centered over the trunk base greatly influences its ability to resist mechanical stress by distributing the load most evenly. When the tree's mass moves off center then gravity compounds the effect of the load and increases the chance of failure by uprooting. A change of

12. University of Florida IFAS. (2015). *Cracks in the trunk.* University of Florida IFAS. http://hort.ifas.ufl.edu/woody/potential-failure.shtml
13. University of Florida IFAS. (2015). *More on trunk cracks.* University of Florida IFAS. http://hort.ifas.ufl.edu/woody/cracks-more.shtml

center of gravity during a storm can occur due to root or soil failure, stem (trunk) bending, or branch loss; if the trunk or crown are off center to begin with, then it will exacerbate the effect.[14]

A **leaning tree** may or may not indicate instability; if it has been leaning for quite some time (as evidenced by corrective trunk and branch growth patterns) it has grown to adjust to its situation and may be relatively stable. However, if the lean is recent or getting worse it is a matter of concern. If the **root plate** is heaving (the roots and/or soil surface on the side away from the lean is raised, and/or there is a corresponding indentation on the side it is leaning toward) then it is an indication that the roots are pulling out of the ground in response to a previous wind load, soil grade change, or damage to the roots themselves. This indicates a failure of the roots' ability to anchor the tree. It may or may not take a significant wind force (or any force) for the tree to fall; it should be assumed that failure may be imminent.

Trees respond to mechanical load (i.e. wind or snow and ice) by adding **reaction wood** to reinforce areas under stress so that the force can be distributed more evenly. This is called "wind firmness", which is directional. Hardwoods add reaction wood toward the wind load on branches and trunk; conifers add it on the side away from the wind.[15] This may cause trunks or major branches to be oval-shaped in cross section instead of round. The tree has made an adaptive response, but the presence of this response indicates exposure to a long term load stress which may be ongoing.

Unusual bulges, accented ridges, spiraling deformations, or indented areas indicate an abnormality that affects the trunk's structural integrity. The presence of any of these likely indicates an area that has been previously exposed to external mechanical stress (bending or twisting) that has left an internal irregularity (fault) which the tree has tried to strengthen by adding wood. This fault may increase the chance of storm damage and make the trunk more prone to failure.

Crown and Branches

Crown and branching structure and size are the major determinants of load (wind or weight) distribution. Optimally the crown and individual branches are well balanced with a good live crown ratio (LCR) where the crown takes up at least two thirds the height of the tree; where major branch circumference is half or less of the circumference of the trunk at the point of attachment; and with a U-shaped rather than a sharp V-shaped (almost vertical branch) or very wide (almost horizontal branch) attachment angle between trunk and branch.

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14. Coder, K.D. (2016). *Ice storm impacts on trees: prioritized causes of damage.* University of Georgia Warnell School of Forestry & Natural Resources. https://www.warnell.uga.edu/sites/default/files/publications/WSFNR-16-05%20Coder.pdf
15. Coder, K. D. (2001). *Storm damaged trees: prevention and treatment.* The University of Georgia Cooperative Extension Service. http://counties.agrilife.org/harris/files/2011/05/Stormdamage.pdf

Reaction wood is a strengthening adjustment formed by the tree as a response to frequent exposure to a load. It is either **compression wood**, which resists a force pushing against it, or **tension wood**, which resists a force pulling away from it. Conifers form compression wood on the underside of the branch and tension wood on the top. Hardwoods build tension wood on top of branches and, when that no longer holds the branch up adequately, it reinforces itself by adding additional normal wood on the underside.[16] Branches may break in storms in response to a strong downward, upward, or twisting load, but are most vulnerable to an unusual upward or twisting force. When subjected to an unusual upward force, conifers tend to break because the compression wood under the branch is not strong enough in tension to withstand being pulled upward. Hardwood branches fail because the tension wood on top of the branch isn't strong enough to withstand the compression of being pushed upward.[17]

Numerous studies on ice storms have cited "**poor form**" as leading to damage.[18] Poor form was generally defined as poor branch architecture including large branch angles, forks, greater branch and twig density, weak branch connections, and branches growing opposite or whorled at nodes.[19] Specific branch structural problems included large decay columns, large and/or open cracks, old injuries to wood and bark, unsound branch connections, and decay pockets (visible or not) as having created faults that then failed under ice loads.[20] Increased crown size was reported as more important to risk of failure than density or surface area; trees with larger canopies failed in greater proportion than those with smaller.[21] Tree total height increased the risk of uprooting, and larger height-to-diameter ratios increased the risk of damage from high-wind events.[22]

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16. University of Florida IFAS. (2015). *Reaction wood.* University of Florida IFAS. http://hort.ifas.ufl.edu/woody/reaction-wood.shtml
17. University of Florida IFAS. (2015). *Branch vs. trunk wood.* University of Florida IFAS. http://hort.ifas.ufl.edu/woody/branch-vs-trunk.shtml
18. Coder, K. D. (2015). *Trees, sites & ice storms: attributes leading to tree damage, failure, & mortality.* University of Georgia Warnell School of Forestry & Natural Resources. https://www.warnell.uga.edu/sites/default/files/publications/WSFNR-15-18%20Coder.pdf
19. Coder, K.D. (2016). *Ice storm impacts on trees: prioritized causes of damage.* University of Georgia Warnell School of Forestry & Natural Resources. https://www.warnell.uga.edu/sites/default/files/publications/WSFNR-16-05%20Coder.pdf
20. Coder, K.D. (2016). *Ice storm impacts on trees: prioritized causes of damage.* University of Georgia Warnell School of Forestry & Natural Resources. https://www.warnell.uga.edu/sites/default/files/publications/WSFNR-16-05%20Coder.pdf
21. Coder, K.D. (2016). *Ice storm impacts on trees: prioritized causes of damage.* University of Georgia Warnell School of Forestry & Natural Resources. https://www.warnell.uga.edu/sites/default/files/publications/WSFNR-16-05%20Coder.pdf
22. Beach, R. H. Sills, E. O., Liu, T., & Pattanayak, S. K. (2008). *Tree characteristics.* The Forest Encyclopedia Network. http://www.forestencyclopedia.net/p/p5/p3265/p3275/p2991/p2998/p3001

Forks and codominant branches have been cited as one of the most significant causes of branch failure.[23] In addition, opposite branches growing from the trunk are problematic; they can grow aggressively, pulling resources from and weakening the leader. The height at the place of attachment on the trunk of two large opposite branches is a weak point where the trunk may break.

Narrow angles of branch attachment increase the possibility of included bark. This is where the inside of the joint of the trunk and branch has been covered with bark at earlier stages of growth. Branches with joints that have included bark are more likely to fail since there is a layer of bark in the inside of the crotch which has kept the supportive wood layers from forming to adhere the branch securely to the trunk. On the contrary, the included bark keeps the two physically separated. Proper branch attachment allows space for successive layers of wood to wrap around and correctly strengthen the joint as the branch and trunk increase their respective diameters.

Branches which are distributed along the height of the trunk (leader), or foliage and small branches spread evenly along the length of the main branches, will distribute a load more equally. When most of the crown is at the top of the tree or most of the foliage is at the end of a branch ("**lion-tailed**"), the trunk or branch is more prone to failure. If foliage or crown is disproportionately located at the ends of branches or the top of the tree, wind or snow load will be focused on those areas with little force on the central portion. This acts as a lever arm and the stem or branch is then more easily broken. Similarly, when trees develop large low branches that grow until overextended to the point that the outer part is disproportionate to what can be maintained by branch taper and diameter, the branch is likely to break under its own weight. The wider the branch angle and the longer the branch, the more damage is incurred during ice storms compared to more upright branches.[24]

In an ice storm the surface area on a larger crown will increase the amount of overall ice accumulation, but the resulting damage will be less for an equivalently-sized crown if it is symmetrical since the load would then be evenly distributed.[25] Trees with excurrent branching patterns (i.e., conifers) are generally more resistant to ice storm damage, especially if there is strong branch attachment and less surface area of lateral branches.[26]

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23. Coder K. D. (2017). *Tree damage from major ice storms.* Arborist News.
24. Coder, K.D. (2016). *Ice storm impacts on trees: prioritized causes of damage.* University of Georgia Warnell School of Forestry & Natural Resources. https://www.warnell.uga.edu/sites/default/files/publications/WSFNR-16-05%20Coder.pdf
25. Beach, R. H. Sills, E. O., Liu, T., & Pattanayak, S. K. (2008). *Tree characteristics.* The Forest Encyclopedia Network. http://www.forestencyclopedia.net/p/p5/p3265/p3275/p2991/p2998/p3001
26. Hauer, R.J., Hruska, M.C., & Dawson, J.O. (1994). *Trees and ice storms: the development of ice storm-resistant urban tree populations.* University of Illinois at Urbana-Champaign. http://web.extension.illinois.edu/forestry/publications/pdf/urban_community_forestry/UIUC_Trees_Ice_Storms.pdf

A type of damage known as "summer branch drop" may occur when wet weather follows a period of drought. Wood may crack internally from lack of water during the dry weather, but when it becomes re-saturated after a significant amount of rain the cracked wood is then not strong enough to support the normal weight of the branch.[27]

Note that an overall sparse or poor-looking crown may indicate a generally poor condition of the tree as a whole, but unless it is indicative of general decline or a specific problem it usually reflects a source problem at the roots. The transfer of nutrients happens just under the bark and in most trees these conduits run vertically, so an isolated section of dead or unhealthy canopy on only one side of the tree may often be traced to problems with the major root(s) directly underneath. (This depends on the species and circumstance; there are exceptions.)

Insects and Disease

Insects and pathogens are often a secondary problem that arises in a tree that is already under stress from environmental conditions or root problems. When a tree is stressed, it attracts pests and is more vulnerable to the effects of both pests and diseases, which then compound the original problem. Thus, the overall environment and condition of the entire tree must also be examined to look for underlying problems.

The actions of pests and diseases can have a substantial impact on the vitality and structural integrity of the tree. Pathogens can cause weakening of portions of the tree and may spread throughout it. Depending on the specific pathogen and how much damage it does, it may destroy the tree. Borer tunneling may be extensive enough to jeopardize branches or trunks, or the borers may spread a disease which is a considerable threat on its own. Presence of cankers, mushrooms, or fungal growths at the base of or on the trunk can be signs of a disease which may weaken or kill the tree. **It is important to diagnose what has infected or infested the tree in order to gauge the extent of the damage that it may already have caused or potentially could cause.** Again, the extent of internal damage to the tree that has already occurred is often not directly visible and can only be conjectured without further investigation by a certified arborist.

Decay

Wood decay has been described as "the biological process by which cellulose and lignin, the two most abundant organic compounds on earth, are converted to carbon dioxide and water with a

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27. University of Florida IFAS. (2015). *Branch vs. trunk wood.* University of Florida IFAS. http://hort.ifas.ufl.edu/woody/branch-vs-trunk.shtml

release of energy to maintain forest processes." [28] Decay is a necessary part of the cycle that moves nutrients, water, and energy to other uses, from dying trees that cannot use it to living plants that can. It is obviously destructive when it affects a tree, dead or living. Decay is an efficient process, but a living tree's ability to resist it can provide a fairly effective defense.

Decay starts in either living or dying sapwood and spreads into dead heartwood. The sapwood compartmentalizes the decay organism, with greater or lesser effectiveness depending greatly on the species of tree. The decay organism may continue to move through the heartwood but the tree continues to add new wood on the outside; this is how trees become hollow. If the tree maintains at least a two inch to four inch depth of crack-free wood in the outer trunk, it may well have sufficient strength for it to survive.[29] Survival depends greatly on the tree's ability to compartmentalize well in order to isolate and close the wound, and whether it has a rapid growth rate and can quickly add reinforcement to the outer supporting wood.

The decay process begins with wood discoloration which does not initially cause a loss of strength. It is a response to the invasion of pathogens and slows the process of decay so that the cambium can continue to grow. Subsequent decay begins a breakdown of tissue which results in loss of strength. Decay progresses quickly in exposed sapwood, more slowly in heartwood underneath it, and is walled off by the **barrier zone** formed after the infection. Oxygen is needed for active decay; if compartmentalization completely isolates the wound then decay stops. Bacteria thrive in low-oxygen environments where "bacterial wetwood" may develop.[30]

Different types of pathogens attack either only living wood, either living or dead wood, or only dead tissue. **Heartwood-decaying fungi** are often seen attacking dead wood on the forest floor. Fungi that attack both living and dead wood are the most common decay fungi seen on live trees. Some are weaker pathogens that attack sapwood exposed by wounding, but others are much stronger and attack, and can kill, the wood or bark of roots, root flare, trunk, and branch stubs. Advanced decay may cause breakage of the stem under wind force.[31]

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28. Shortle, W. C. & Dudzik, K. R. (2012). *Wood decay in living and dead trees: a pictorial overview.* U.S. Department of Agriculture, Forest Service, Northern Research Station. https://www.nrs.fs.fed.us/pubs/gtr/gtr_nrs97.pdf
29. Shortle, W. C. & Dudzik, K. R. (2012). *Wood decay in living and dead trees: a pictorial overview.* U.S. Department of Agriculture, Forest Service, Northern Research Station. https://www.nrs.fs.fed.us/pubs/gtr/gtr_nrs97.pdf
30. Shortie, W. C. & Dudzik, K. R. (2012). *Wood decay in living and dead trees: a pictorial overview.* U.S. Department of Agriculture, Forest Service, Northern Research Station. https://www.nrs.fs.fed.us/pubs/gtr/gtr_nrs97.pdf
31. Shortie, W. C. & Dudzik, K. R. (2012). *Wood decay in living and dead trees: a pictorial overview.* U.S. Department of Agriculture, Forest Service, Northern Research Station. https://www.nrs.fs.fed.us/pubs/gtr/gtr_nrs97.pdf

Root-rot fungi attack roots below or above ground, particularly through cracks at and below the root flare. The fungi spread into the roots and then move into the stem through the less resistant area between the buttress roots. Compartmentalization is less effective in containing these fungi because they kill bark and cambium and thus block the tree's attempts at barrier zone formation and wound closure. [32] Root rot is difficult to detect since the roots are largely not visible unless uncovered for examination; canopy dieback or decline may be the only evidence.

Canker-rot fungi infect branch stubs, usually those between ¾ inch to one inch in diameter, at a height of six to fifteen feet. They are effective at removing these stubs which aids the tree in compartmentalizing the site. However they also kill live wood and bark, so the fungi does not become completely compartmentalized. In pines, pitch at the base of the branch stubs may be seen early in the infection process indicating the presence of the fungus.[33]

Cracks which may form along compartmentalization boundaries, (i.e. ring cracks, closure cracks, or callousing) all create weak points which will be more vulnerable under stress. Cracks may actually be of more concern as weak points than the actual decayed area.[34]

Evaluation of decay can only be done by estimation since the internal decay cannot be seen. Questions to ask to help gauge the current strength and viability of the tree include: what specific decay organism is present and what its ability is to damage the tree; whether sufficient new wood is being added to counterbalance the wood lost to decay; whether trunk growth and wound closure is adequate to maintain the tree's mechanical strength; and whether there are cracks in the main trunk or between the buttress roots. Root and stem rots, cankers, insect infestation, or any previous damage increases vulnerability to wind damage.

Stress and Decline

Stress and decline are often the underlying cause precipitating the presence of pests or disease, resulting in an unhealthy tree. Young trees are much more adaptable to various conditions and are generally more resistant to stressors; mature trees are less so and are more likely to be affected by them. Stressors can be many: insufficient or too much water, too much or too little sun,

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32. Shortie, W. C. & Dudzik, K. R. (2012). *Wood decay in living and dead trees: a pictorial overview.* U.S. Department of Agriculture, Forest Service, Northern Research Station. https://www.nrs.fs.fed.us/pubs/gtr/gtr_nrs97.pdf
33. Shortie, W. C. & Dudzik, K. R. (2012). *Wood decay in living and dead trees: a pictorial overview.* U.S. Department of Agriculture, Forest Service, Northern Research Station. https://www.nrs.fs.fed.us/pubs/gtr/gtr_nrs97.pdf
34. University of Florida IFAS. (2015). *Decay development.* University of Florida IFAS. http://hort.ifas.ufl.edu/woody/decay-development.shtml

inappropriate temperature range, limited or damaged roots, chemical or mechanical injury, and more. Each of these compounds the effects of the others. Examination of the tree can help to identify it as being under stress or in decline, and observation of the environmental conditions may reveal possible causes. Note that there is often a substantial lag time between cause and effect. The effect of root damage may become apparent within a year or so, or impacts of damage may not become visible for twenty years or more. Unfortunately, most trees affected by decline will usually die even with supportive treatment.[35]

Symptoms of decline are often seen in the crown where the foliage may be sparse, or the leaves may be smaller than normal or may turn color and drop earlier in the fall than is the norm for that species in the same location. Epicormic growth may be seen as thin vertical sprouts along the upper surface of branches where the tree has rapidly sent up shoots to increase photosynthesis. Fruits or nuts may fail to mature and drop off the tree early. Trees may flower out of season or produce an abnormally large quantity of seed. Dieback of twigs and of progressively larger branches may be seen beginning in the upper crown and moving downward. Leaf or needle drop may move from nearer the trunk outward.

When evaluating a tree for decline, some techniques when making observations include: viewing all sides of the tree for damage; walking both clockwise and counterclockwise; examining the root flare for rot including probing at and below the soil line and between the buttress roots; and comparing new twig growth against prior years' (length between nodes) for an estimate of annual growth and how long the tree has been declining.[36]

Inherent Species Characteristics

Many characteristics related to vulnerability to failure are greatly determined by what is typical for a particular species, and it can be very helpful to have that information available. The tree form (excurrent or decurrent) and the general tendency toward a particular growth pattern can either help or hinder a tree's symmetry and load pattern, which is an important factor in resistance to storm damage, as is wood strength (although see the last bullet below). Good or poor compartmentalization is a critical factor in resistance to decay. Knowledge of the average life span of a species may provide a helpful frame of reference to evaluate decline since its genetics alone will set a general limit to its viability.

35. Pratt, P. W., Schnelle, M. A. *Site disturbance and tree decline.* Oklahoma Cooperative Extension Service. http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Document-1106/HLA-6429web.pdf
36. Pratt, P. W., Schnelle, M. A. *Site disturbance and tree decline.* Oklahoma Cooperative Extension Service. http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Document-1106/HLA-6429web.pdf

Below are a few examples of some types of species-specific differences. Always be aware that some studies may not agree; as in any research, the complexities and specificities of what questions are being asked, how the data is being collected, and what other variables are at play all define the challenge of finding valid results.

- Hurricane damage: Conifers tend to be more susceptible than hardwoods.[37]
- Wind damage: Conifers' susceptibility to wind damage increases rapidly after about age fifteen, but the amount of hardwood trees' damage increases more gradually with age.[38]
- Ice and Snow: Trees with excurrent form are better able to shed ice and snow than decurrent forms. Vase-shaped trees are especially vulnerable.[39]
- Ice Storms: Species is cited as a moderately important factor in the amount of damage sustained during ice storms.[40] Roughly two thirds of ice storm studies designate evergreens as more susceptible to damage.[41]
- Exotics vs. natives: A number of non-native trees in urban forests tend to experience more damage than native trees.[42]
- Native range: Species planted outside their native range may be more susceptible to damage.[43]
- Roots: Some trees can survive the loss of half of their roots, but other species are extremely sensitive, even to root cutting outside of the dripline.[44]
- Strength: The significance of tree species' strength values in resistance to ice storms continues to be debated.[45]

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37. Beach, R. H. Sills, E. O., Liu, T., & Pattanayak, S. K. (2008). *Tree characteristics.* The Forest Encyclopedia Network. http://www.forestencyclopedia.net/p/p5/p3265/p3275/p2991/p2998/p3001
38. Beach, R. H. Sills, E. O., Liu, T., & Pattanayak, S. K. (2008). *Tree characteristics.* The Forest Encyclopedia Network. http://www.forestencyclopedia.net/p/p5/p3265/p3275/p2991/p2998/p3001
39. Beach, R. H. Sills, E. O., Liu, T., & Pattanayak, S. K. (2008). *Tree characteristics.* The Forest Encyclopedia Network. http://www.forestencyclopedia.net/p/p5/p3265/p3275/p2991/p2998/p3001
40. Coder K. D. (2017). Tree damage from major ice storms. Arborist News.
41. Coder, K. D. (2015). T*rees, sites & ice storms: attributes leading to tree damage, failure, & mortality*. University of Georgia Warnell School of Forestry & Natural Resources. https://www.warnell.uga.edu/sites/default/files/publications/WSFNR-15-18%20Coder.pdf
42. Coder, K. D. (2015). *Trees, sites & ice storms: attributes leading to tree damage, failure, & mortality.* University of Georgia Warnell School of Forestry & Natural Resources. https://www.warnell.uga.edu/sites/default/files/publications/WSFNR-15-18%20Coder.pdf
43. Beach, R. H. Sills, E. O., Liu, T., & Pattanayak, S. K. (2008). *Tree characteristics.* The Forest Encyclopedia Network. http://www.forestencyclopedia.net/p/p5/p3265/p3275/p2991/p2998/p3001
44. Johnson, G.R. (1999). *Protecting trees from construction damage: a homeowner's guide.* University of Minnesota Extension. http://www.extension.umn.edu/garden/yard-garden/trees-shrubs/protecting-trees-from-construction-damage/#root

There are many places to look for lists of species characteristics; below are a few. Again, keep in mind that, as is true of most research, it is extremely difficult to separate the effect of the various factors and so all conclusions may not agree. In addition, the research is constantly being refined and modified.

- Compartmentalization:
  - http://hort.ifas.ufl.edu/woody/compartmentalization.shtml
- Grade Changes:
  - https://extension.umd.edu/hgic/grade-changes-trees-and-shrubs
- Life Span:
  - http://bigtree.cnre.vt.edu/lifespan.html
- Root Severance, Soil Compaction, Flooding, Soil pH, Damage-causing Roots:
  - http://www.extension.umn.edu/garden/yard-garden/trees-shrubs/protecting-trees-from-construction-damage/#root
- Storm Damage (Ice Storm):
  - https://www.warnell.uga.edu/sites/default/files/publications/WSFNR-15-20%20Coder.pdf
  - https://www.warnell.uga.edu/sites/default/files/publications/WSFNR-15-17%20Coder.pdf
  - http://web.extension.illinois.edu/forestry/publications/pdf/urban_community_forestry/UIUC_Trees_Ice_Storms.pdf
- Storm Damage (Wind/Hurricane):
  - http://www.forestpests.org/storm/
  - http://hort.ifas.ufl.edu/woody/resistant.shtml
  - http://hort.ifas.ufl.edu/treesandhurricanes/documents/pdf/EffectsOnSEUSCoastalPlainTreeSpecies.pdf
- Storm Damage (Various)
  - http://counties.agrilife.org/harris/files/2011/05/Stormdamage.pdf
- Trees with Special Concerns:
  - http://hort.ifas.ufl.edu/woody/special-concern.shtml

Site Conditions Contributing to Failure

The complex micro- and macro-environment of a site surrounding a tree, including topography, wind direction, exposure, size, location of an individual tree within a group, soil content and depth, and any changes to the site, all affect the tree's response to load stresses from weather events.

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45. Coder, K. D. (2015). *Tree strength and resistance to damage under ice storm loads.* University of Georgia Warnell School of Forestry & Natural Resources. https://www.warnell.uga.edu/sites/default/files/publications/WSFNR-15-17%20Coder.pdf

Research has only begun to tease out some of these interrelationships and attempt to unravel how a tree is actually affected by a given set of circumstances in order to understand and quantify the impact of major storm events: "Landscapes provide complex and chaotic variability in ice loading and tree resistance."[46]

Hurricanes and tornados (wind and water) and winter storms (wind and ice or snow) are the two weather events with the most severe impact on trees. Much of the research and general information we will discuss here is primarily related to ice storms but, especially since the effect of wind load is a critical common factor in both, much of the theory can be extrapolated to hurricanes as well. Even in the absence of an ice load (accumulated weight), additional wind will cause an increased load which may well result in an equivalent or greater total load. The total load experienced during any event is a sum of all mechanical stressors.

Exposure

Exposure describes how the vulnerability of trees in a particular site is affected by topographical elements including elevation, slope, and slope aspect (the direction it faces). These factors influence the wind load and ice accumulation, which also have an interactive effect on each other. The formation of a storm event itself and the duration of the resulting ice load are also both associated with the topography.

Note that trees in cities are exposed to very different wind patterns than in forests or even in suburban areas. They experience greater turbulence from wind movement around or between buildings (funneling), with consequently greater bending force than those in forests at the same wind speed.[47]

Elevation: The higher the elevation in mountainous terrain, the worse tree damage is seen in ice storms. Elevation increases exposure to ice and wind and is one of the most influential factors associated with a greater amount of ice storm damage, but it is difficult to isolate its specific effects (type or amount of damage that can be attributed solely to it) because it is so interdependent with other variables.

Slope: The degree of the slope is related to the tendency of trees to uproot. Steeper slopes have thinner soil, and the root impervious zone (depth at which the substrate does not allow roots to penetrate, e.g. rock) is closer to the surface. Less soil volume is available for secure rooting, so it will

46. . Coder, K. D. (2015). *Trees, sites & ice storms: attributes leading to tree damage, failure, & mortality.* University of Georgia Warnell School of Forestry & Natural Resources. https://www.warnell.uga.edu/sites/default/files/publications/WSFNR-15-18%20Coder.pdf
47. Matheny, N, & Clark, J. (2009). *Tree risk assessment what we know (and what we don't know).* Arborist News. http://www.isa-arbor.com/education/resources/educ_portal_risk_an.pdf

take less total ice and wind load for them to fall. An increase in the degree of slope is correlated with a decrease in crown damage but an increase in severe trunk damage.[48]

Aspect: The aspect of the slope is an important determinant of wind loading and of the duration of the ice load. Windward positions (facing the direction of the storm) and exposed slopes and ridges tend to have greater total loading (wind plus ice) and subsequent damage. The additional wind load on an exposed location can counter the effect of a smaller ice accumulation and can result in an even greater net amount of damage. On a slope with less sun exposure it will take longer for the ice accumulation to melt; the sustained load compounds the effect. Northeastern and eastern exposures are generally associated with more damage.[49]

When a given ice load accumulates, an additional mechanical load is produced by wind velocity in the form of either average wind speed or peak gusts. Storm loads can vary from heavy rain with no wind (vertical downward load of lesser amount) to heavy ice with strong winds (substantial lateral load in addition to downward). The direction of the load force, vertical or lateral, will modify the effect on an individual tree.

Stand Characteristics

Stand characteristics describe the environment of a group of trees as a whole and how these characteristics form an effect profile that, depending on where an individual tree is located in relation to the surrounding stand (group) of trees, is very different from a solitary tree.

Stand Density: The Basal Area (roughly the density of tree footprint in the ground space) within a stand greatly affects how much exposure to wind and ice load an individual tree is subjected to. A lesser density allows for freer air movement through the stand and allows the wind force to dissipate thus reducing wind exposure. Conversely, greater density allows a tree to be supported by its neighbors. Greater density is associated with more bending but less breakage, and with greater ice storm damage because of increased surface area for ice accumulation. The presence of vines has the same effect of increasing surface area and is associated with greater ice accumulation and increasing wind drag.

Relative Tree Height: Greater height increases the exposure of trees which are taller than the rest, putting them at increased risk for damage. The taller the tree is relative to surrounding trees, the

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48. Coder, K. D. (2015). Trees, sites & ice storms: attributes leading to tree damage, failure, & mortality. University of Georgia Warnell School of Forestry & Natural Resources. https://www.warnell.uga.edu/sites/default/files/publications/WSFNR-15-18%20Coder.pdf
49. Coder, K. D. (2015). Trees, sites & ice storms: attributes leading to tree damage, failure, & mortality. University of Georgia Warnell School of Forestry & Natural Resources. https://www.warnell.uga.edu/sites/default/files/publications/WSFNR-15-18%20Coder.pdf

more it is exposed to potential wind and ice load. This relative height is the strongest factor determining susceptibility to wind damage in a stand.[50] Generally, smaller trees are more likely to bend severely in response to ice loading, mid-sized trees show both bending and trunk breakage, and larger trees experience less bending or breaking, but show increased crown damage and branch loss. Immature trees that have not developed a taper (especially "pole" trees, often found in commercial forest stands) are more vulnerable to damage because their trunk structure is not as strong.

Location within the Stand: Location within or on the edge of the stand changes the amount of wind force that a tree is exposed to. Those on the edge of a stand are more exposed to wind but have developed reaction wood over time which provides additional strength; however, they are still more susceptible to damage than interior or protected trees. Edge trees which have been recently exposed are more prone to damage until they have had time to form reaction wood. When stands are thinned, storm damage to interior trees is increased until they can adjust to their new loading exposure by adding new wood. Long-established exterior trees and interior trees can have a similar damage potential unless the edge tree has an unbalanced crown.

Edge trees tend to have larger, more unbalanced crowns, with more lower branches on the open side where they receive more sun. They accumulate more ice on the open side due to the increased exposure, resulting in more branch failure, crown breakage, and uprooting.[51] Interior trees generally have smaller crowns and fewer lower branches due to less available light, and typically show less storm damage than edge trees. However, the greater the amount of ice accumulation during a particular storm, the less difference location within the stand makes. The tendency for damage also varies depending on species.

When in close proximity to larger buildings such as a home, a tree on the leeward side of the building has a more protected location. Microclimates, which are small areas with differing characteristics than the surrounding larger site, create a unique site environment that must be viewed as an independent factor in addition to the tree's position in the larger area.

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50. Beach, R. H. Sills, E. O., Liu, T., & Pattanayak, S. K. (2008). *Tree characteristics.* The Forest Encyclopedia Network. http://www.forestencyclopedia.net/p/p5/p3265/p3275/p2991/p2998/p3001
51. Hauer, R.J., Hruska, M.C., & Dawson, J.O. (1994). *Trees and ice storms: the development of ice storm-resistant urban tree populations.* University of Illinois at Urbana-Champaign. http://web.extension.illinois.edu/forestry/publications/pdf/urban_community_forestry/UIUC_Trees_Ice_Storms.pdf

Soil characteristics

Soil characteristics largely determine the health of the roots and their ability to anchor the tree in the ground.

Volume: An appropriate volume of soil allows optimal root growth and strength; reducing the available soil increases the chance of uprooting. The presence of erosion, boulders, bedrock, and physical barriers to root growth limit available soil volume. Heavy clay soils are more difficult for roots to penetrate deeply, and loose soils such as sand do not have the holding ability of denser soils.

Saturation: Soil saturation increases the possibility of a tree uprooting. It is one of the most prevalent factors involved in windthrow due to the instability of the soil.[52] In addition, periodic flooding or increased moisture levels over time, if the tree is not adaptable to wet soils, will reduce the roots' access to oxygen and suffocate them.

Compaction: Compaction due to frequent walking, vehicles being driven, construction activity, or any weight-bearing impact, leaves a dense soil which is less able to move water and oxygen to the roots resulting in limited root growth. Clay soil has a particular tendency toward compaction.

Salinity: Salinity is seen in soils near some coastal areas (including well water) or very low-rainfall regions. Most trees are not tolerant of high salt levels which dry out the roots. Trees near roads which are treated with deicing salts, especially if they are on the downhill side, are also vulnerable to salt damage.

Site modifications

Site modifications that affect trees often occur during construction, utility work, landscape planting, or grounds maintenance, and especially include any activity that modifies or comes in contact with the roots. Depending on the extent of the activity, it can be extremely harmful to or kill an existing tree.

Raising the grade: Raising the grade (increasing the soil depth), even temporarily, will suffocate roots due to lack of oxygen; the greater the added depth, the more severe the impact. This includes planting too deep, adding soil to the root ball, or adding mulch to a depth of more than three to four inches. If the trunk flare is not visible, then the tree is too deep and the roots are suffering from

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52. Beach, R.H., Sills, E.O., Liu, T., & Pattanayak, S.K. (2008). *Site conditions & location.* The Forest Encyclopedia Network. http://www.forestencyclopedia.net/p/p5/p3265/p3275/p2991/p2998/p3000

insufficient oxygen. Adding heavier soils, such as clay, has a greater impact than lighter soils. Problems can occur with only an inch of clay soil added.

Toxin-producing bacteria can thrive in the resulting anaerobic environment. Adding soils different from the base soil may cause differences in drainage and moisture level, ground temperature, and oxygen availability. Covering roots with an area of impermeable pavement such as asphalt or concrete will likely cause them to suffocate and die.

Lowering the grade: Lowering the grade likewise causes serious problems. Roots may be severed or exposed to sun and air, become desiccated, and die. Even removal of a small amount of soil exposes roots close to the surface to dry out and die. Removal of protective leaf litter or mulch causes ground temperature and moisture changes.

Cutting Roots: Cutting large roots jeopardizes the health of the roots and the tree itself, and leaves the tree structurally unstable and subject to falling even without wind. Cutting roots on one side of the tree may cause decline or death on that side. Decline due to root loss may be immediate or progressive depending on the size of the roots cut. Tilling or extensive working of the soil under the tree will damage medium and smaller roots that are critical for tree health.

Root cutting impacts the tree in two ways. In terms of the effect on its general health and vitality, any root cutting should optimally be limited to outside of the **Critical Root Zone** (CRZ), which is a circle with radius extending one foot from the trunk for each inch of the tree's Diameter at Breast Height (DBH; the trunk's diameter at 4½ feet from the ground). For example if the DBH is 40 inches (the tree measures 40 inches in diameter at a point 4½ feet high), then the CRZ extends radially from the trunk 40 feet in every direction. Any root impact including cutting, damage, grade change, and compaction, should be avoided within this area. Trees that are old, unhealthy, or more sensitive to root cutting should be given a CRZ of 1½ feet (instead of 1 foot) per inch of DBH.[53]

Roots greater than 1½ inches in diameter should not be cut, but instead tunneled under.[54]

However, when the intent is only to prevent destabilization (that is, considering only the effect on the tree's stability) a more commonly used guideline is to restrict root cutting to three to five times the DBH.

Trees in urban areas located next to sidewalks, parking lots, and roads are in particularly poor environments for root growth and tree health. Soil volume is limited by the closely abutting

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53. Johnson, G.R. (1999). *Protecting trees from construction damage: a homeowner's guide.* University of Minnesota Extension WW-06135. http://www.extension.umn.edu/garden/yard-garden/trees-shrubs/protecting-trees-from-construction-damage/#root
54. Pratt, P. W., Schnelle, M. A. *Site disturbance and tree decline.* Oklahoma Cooperative Extension Service. http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Document-1106/HLA-6429web.pdf

impermeable paving materials. Compaction is invariably present, caused by the previous construction, and these trees seldom receive sufficient water. Trees generally struggle to grow in these situations, but when the roots are interfered with or damaged then the tree's ability to survive becomes even more tenuous.

A study on urban trees adjacent to sidewalks found that after thunderstorms and windstorms, trees which had experienced root or trunk collar impact or damage during a previous sidewalk repair were more than twice as likely to pull out of the ground (resulting in at least 50% of roots protruding) as those which underwent sidewalk repairs where the roots and trunk flare were not impacted, or those where there were no repairs performed.[55] When resources for root growth are severely limited and the roots are then damaged, their ability to anchor the tree is significantly impacted.

Chemicals – Construction chemicals, some types of treated wood, mechanical fluids (e.g., oil or gasoline), or other household or yard substances including herbicides are toxins that can leach into the soil and be taken up by the roots.

Changing the pH – Changing the pH of the soil may have an adverse effect on the tree depending on the amount of the change and the tree's sensitivity to pH level. Changes in acidity level can occur from the use of alkaline clays or limestone used for fill or paving, or by concrete coming in direct contact with the ground when being mixed or washed out.

Weather

Recent weather events or historical weather tendencies also play a part in creating the characteristics of the site, either over time or at a particular point in time. Repeated stressors often have a cumulative effect, exacerbating suboptimal site conditions and aggravating previous damage to the tree, increasing its vulnerability to failure. The closer together the weather events occur, the more stress the tree is under and the more opportunities there are for new damage and faults to occur.

Non-critical weather factors can have a significant impact on a tree, even if they are indirect. Following an ice storm the duration of the ice accumulation affects its cumulative load. The length of time that goes by until the ice melts is affected not only by sun exposure (versus valleys or shaded hills), but also by how quickly air temperature increases after the storm and the warm or cold air flow at the site.

Ground saturation or erosion from recent storms can cause trees to uproot more easily by modifying the soil characteristics. The ability of roots to maintain their anchoring ability is greatly

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55. Johnson, G. (2014). When wind and trees collide: The influence of sidewalk repair, trunk flare, and wind-loading events on boulevard tree failures. *Arborist News, 24*(6):50-57.

decreased by very wet soil or shallow soil, especially when roots are newly uncovered by flooding or erosion. Frequent or prolonged saturation can drown or damage roots and encourage the growth of rot organisms.

A normal amount of rain after a year or more of drought can cause tree death. Roots often die back during a drought and the tree is weakened, then renewed moisture encourages the growth of fungal soil pathogens which may attack the weakened tree.

Often it is an abrupt change in conditions which can cause problems. Frost cracks on trunks are caused by the bark's inability to adjust quickly enough between a very cold nighttime temperature to a warm sunny day immediately following. These cracks are generally seen on the southwest side of the tree since that side usually faces the winter sun.

Even time of year can be a factor. Hurricanes usually occur while deciduous trees are still in leaf which adds to their wind resistance.

Tree Failure and Precipitating Events

We have looked at various factors describing the tree and site conditions which may increase the tree's susceptibility to failure. The most determinative factor, however, is the force to which the tree is subjected. Trees of various types have evolved to be able to successfully resist the various forces that constitute their "normal load," that is, the most common weather they are exposed to in a particular location. However, the strongest tree in the most advantageous location may be maximally optimized for strength and survival, but there is always a point beyond which it will fail when it has been exposed to a load more severe than it is capable of handling. It is not an absolute limit- it will vary because of the interaction of factors we have discussed previously- but a limit does exist. There is a specific load which, when applied to a specific tree in a specific place at a specific point in time, will cause it to fail. The description and quantification of load mechanics, measurements, prediction, and other specifics is far beyond the scope of this manual. In this section we will describe the short-term and long-term effects of the damage incurred when a tree is impacted by a force beyond its ability to withstand.

Types of Tree Failures

The concept of tree "failure" implies a level of structural destruction that is severe, but we can introduce the topic a little more precisely by further defining where and how the damage occurs and what physical change occurs in the tree. A description of these are given below.[56]

56. Coder, K. D. (2001). *Storm damaged trees: prevention and treatment. T*he University of Georgia Cooperative Extension Service. http://counties.agrilife.org/harris/files/2011/05/Stormdamage.pdf

Blowover- Blowover occurs when the tree is physically pushed over by a constant wind or gust (hurricanes, downdraft, or tornados). This occurs when the wind force is too great for the wood structure.

Stem Failure – Stem failure occurs when old or new wound create a spot that is weak or is enough of an interruption in the tension distribution that it is more susceptible to giving way. When a wind force strikes a tree, the tree is pushed to its further limit away from the wind. When the force is removed the tree snaps quickly back to its upright position or, depending on the amount of the initial force, swings back toward the source of the wind. Trees with heavy crowns can be overloaded by snap-back during intermittent wind gusts and calm, causing stem breakage.

Crown Twist – Asymmetrical crowns are particularly susceptible to crown twist. When the crown is lopsided, there is more wind load on the larger or heavier side causing a twisting action on the major branches and stem. The tree can adjust internally to the effects of twisting, but this exacerbates old injuries and can cause the wood in the stem to split or branches to collapse.

Root Failure – Both woody structural roots and fine absorbing roots help to provide anchorage for the tree, one by means of strength, the other through quantity. If the root collar is damaged in some way, or if the volume of the trunk and crown incurs greater stress than the root collar can handle, the roots' mechanical strength is overwhelmed and the roots can pull out of the ground or snap, resulting in the tree falling or leaning.

Branch Failure – The attachment of branches to the trunk can be good in relative terms, but in an absolute sense it is not a strong attachment. It has evolved to be that way for a reason: it allows the branch to be flexible and to be easily shed if needed. Unusually strong storms may cause a branch to tear downward or snap from an ice or snow load or the force of a downburst.

Lightning – Lightning is an immediately life-threatening event for the tree. It destroys tissue by electrical disruption and heat. It either moves down the tree from the branches through the stem to the roots, or along a path that encompasses the entire tree. There can be massive unseen root damage.

Storm Effects

Trees may fail at any time. If a tree's structural strength has degraded enough or its stability is jeopardized sufficiently, it may reach a point where it will simply break or fall at the behest of gravity. However, more often than not, failure will be precipitated by an event that subjects it to forces beyond its everyday equilibrium.

Wind Events (Hurricanes and Tornados) – Wind causes perhaps the most obvious and most immediately destructive force commonly occurring during a storm event. "'Wind loading' [is defined as] a straight wind from one direction applied evenly over the stem, branches, and leaves… 'Wind release' [refers to] the removal of load causing the crown and stem to snap back. Gusts and calm alternately load and release the tree."[57]

The Enhanced Fujita (EF) Scale, which is used for ranking tornado intensity, provides a frame of reference for the range of destruction that may occur at various wind speeds. At speeds of 74 to 75 mph, hardwood and softwood trees may incur breakage of branches greater than 1 inch in diameter; at 91 and 87 mph (respectively) hardware and software trees may uproot; and at 110 and 104 mph hardwood and softwood trees may snap.[58]

The Saffir-Simpson Hurricane Wind Scale states that Category One hurricane winds (74 to 95 mph) are able to snap large branches and may topple shallowly rooted trees; Category Two (96 to 110 mph) will see "many" shallowly rooted trees uprooted; Category Three (111 to 129 mph) will snap or uproot numerous trees of any root depth; and Category Four (130 to 156 mph) will snap or uproot "most" trees. As tree uprooting increases, there is an increased amount of damage to houses and other buildings, and increasingly greater impact on community access due to multiple road blockages.[59]

Ninety-three percent (93%) of tornado-related deaths occur at EF scales F2 and above (over 113 mph winds), but of the seven percent (7%) of tornado-related deaths that occur at levels F0 or F1 (under 112 mph), 38% are due to wind-related tree failure. In other words, a greater proportion of tornado-associated deaths due to wind-related tree failure begin to occur at lower wind speeds than deaths due to building or vehicle damage.[60]

Hardwood trees usually survive breakage. When tops are lost, new branches will sprout, but loss of large branches also allows entry of decay fungi. Most species of pine will die if the tops are completely broken and no live limbs remain. However for loblolly or slash pines, if at least three or more live limbs are left at the top, there is about a 75% chance of survival. One of the remaining branches will become the new terminal branch and the tree will continue to grow, eventually showing only a sharp crook where that occurred. Young trees may suffer bark damage from extreme bending, which makes them more vulnerable to disease. Small trees less than fifteen feet

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57. Coder, K. D. (2001). *Storm damaged trees: prevention and treatment.* The University of Georgia Cooperative Extension Service. http://counties.agrilife.org/harris/files/2011/05/Stormdamage.pdf
58. Schmidlin, T. (2009). *Human fatalities from wind-related tree failures in the United States, 1995–2007.* Natl Hazards 50:13-25. https://www.researchgate.net/publication/226683183_Human_fatalities_from_wind-related_tree_failures_in_the_United_States_1995-2007
59. National Hurricane Center. *Saffir-Simpson hurricane wind scale.* http://www.nhc.noaa.gov/aboutsshws.php
60. Schmidlin, T. (2009). *Human fatalities from wind-related tree failures in the United States, 1995–2007.* Natl Hazards 50:13-25. https://www.researchgate.net/publication/226683183_Human_fatalities_from_wind-related_tree_failures_in_the_United_States_1995-2007

tall usually straighten even after severe bending. Pine trees that bend to the extent that they crack and the resin flows may be invaded by bark beetles and disease-causing organisms.[61]

Cyclonic winds from tornados and some hurricanes cause twisting and separation of wood fibers in the main stem. The trees may still appear normal but internal damage of some type has occurred. Pines may show some pitch flow along the trunk.[62]

Uprooting of trees causes soil disruption and erosion. After storms which result in extensive tree deaths there is an increased risk of wildfires, pest and disease attacks, and infiltration of newly opened areas by aggressive invasive plants.[63]

Indirect damage may be caused by flooding or saturated soil. In standing water, available oxygen is quickly used; loss of soil oxygen leads to root mortality and tree death. Most trees are injured by flooding, especially during the active growing season. Weakened trees are then often attacked by insects and disease.[64]

A Florida study which compiled data from several hurricanes attempted to quantify tree survival by various factors, as follows below.[65] (Note that the study included some tree species that are not common in Virginia and that the soil of coastal Florida is dissimilar to most Virginia soils; however most observations should still be generally applicable.)

- Wind speed:
  - Urban forest tree loss increased with greater wind speed.
- Foliage and Crown:
  - More leaf loss was equated with better survival. Losing leaves and small twigs during the hurricane increased survival and resulted in less crown damage.
  - Trees with dense crowns lost more branches but survived more often (84%) than moderately dense (74%) or open crowns (67%).

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61. Barry, P.J., Doggett, C., Anderson, R.L., & Swain, K.M. (1993). *How to evaluate and manage storm-damaged forest areas.* University of Georgia. http://www.forestpests.org/storm/
62. Barry, P.J., Doggett, C., Anderson, R.L., & Swain, K.M. (1993). *How to evaluate and manage storm-damaged forest areas.* University of Georgia. http://www.forestpests.org/storm/
63. Barry, P.J., Doggett, C., Anderson, R.L., & Swain, K.M. (1993). *How to evaluate and manage storm-damaged forest areas.* University of Georgia. http://www.forestpests.org/storm/
64. Barry, P.J., Doggett, C., Anderson, R.L., & Swain, K.M. (1993). *How to evaluate and manage storm-damaged forest areas.* University of Georgia. http://www.forestpests.org/storm/
65. Duryea, M.L., Kampf, E. & Littell, R.C. (2007). Hurricanes and the urban forest: I. effects on southeastern United States coastal plain tree species. *Arboriculture & Urban Forestry, 33*(2):83-97. http://hort.ifas.ufl.edu/treesandhurricanes/documents/pdf/EffectsOnSEUSCoastalPlainTreeSpecies.pdf

- Form and Wood:
  - Species with shorter, thicker stems and denser wood tended to uproot instead of break. Species with lower density wood had greater mortality.
  - Generally, pines tended to snap (stem breakage) versus the tendency of broadleaf trees to uproot.
  - Trees with higher wood density had better survival rates and were less likely to fail by uprooting or breakage.
  - Decurrent trees had better survival (80%) than excurrent (69%), but experienced more branch damage (22% versus 17%).
- Size:
  - Larger trees lost more branches (30%) than medium (25%), smaller (20%), or the smallest (12%) trees.
  - In forest stand environments, trees with larger stem diameters were more likely to be damaged by wind as opposed to smaller trees which were more likely to be indirectly damaged by other falling trees.
- Stand:
  - Trees in groups had proportionally better survival (80%) than those that were more isolated (70%), although branch loss was the same.
- Species:
  - Species responded differently for uprooting, stem breakage, and crown damage.
  - Most data showed that native trees survived better than non-natives.
- Soil:
  - Increased rainfall from the hurricane and saturated soil resulted in more tree mortality, especially due to uprooting.

Ice Storms – Ice storms affect trees through the synergistic effects of wind load and ice or snow weight; the ability of the tree to resist these combined forces is key. The accumulation of ice can increase the weight of a branch by thirty times or more. At an accumulation of ¼ inch to ½ inch, small branches and weak limbs break; at ½ inch to 1 inch larger branches may fail.[66]

Changes in the position of the center of mass over the root plate as the tree moves in response to wind magnifies any existing asymmetry in the crown and, with the addition of ice and wind loads,

66. Hauer, R.J., Hruska, M.C., & Dawson, J.O. (1994). *Trees and ice storms: the development of ice storm-resistant urban tree populations.* University of Illinois at Urbana-Champaign. http://web.extension.illinois.edu/forestry/publications/pdf/urban_community_forestry/UIUC_Trees_Ice_Storms.pdf

will compromise the stem's resistance to loading.[67] As the weight load increases, the load resistance points in the tree will shift, concentrating on previous faults or weak areas in the wood. The tree becomes stiffer and less able to move in response to the wind, which produces more drag (resistance) initiating more damage and new faults which may then lead to failure.[68] However, the strength of sound branches may not be as consequential as the ability of the tree to withstand breakage at branch junctures, or the density of fine branches or a broad crown that can add to the total amount of ice accumulation.[69]

A compilation of 45 studies on ice storms summarized 56 factors associated with tree damage. The importance of each was scored between 0.0 and 1.0 (low to high importance).[70] Ratings were as follows:

- Ice thickness (weight) and increased wind loads were four to five times more important in causing damage (1.0 and 0.8, respectively) than the next highest factors.
- Ice load duration, leaf type (needle or broadleaf), and asymmetrical crown were rated as 0.25.
- Tree size, degree of slope, amount of canopy surface area, and branch and twig density were rated 0.21.
- Topography, stem diameter, poor branch architecture, poor tree form, tree age, and branch structural problems ratings ranged from 0.21 to 0.16 (respectively).

The primary causes of ice storm damage, then, are outside of the ability to be modified through human intervention, but changes made by correct pruning may help somewhat in reducing the likelihood of damage.

Post-Storm Outcomes – The aftermath of a storm or other damaging event is only the beginning, at that point in time, of a sequence of events that may unfold over ten to twenty years or more. Within this time frame all the previous vulnerabilities that we have described earlier in this chapter will again come into play: immediate mechanical damage; new faults in the tree leading to reduced structural integrity; openings for insects, disease and decay to invade; root damage and death; and even site changes. In this post-event period after a storm of significant intensity, the changes that

67. Coder, K.D. (2016). *Ice storm impacts on trees: prioritized causes of damage.* University of Georgia Warnell School of Forestry & Natural Resources. https://www.warnell.uga.edu/sites/default/files/publications/WSFNR-16-05%20Coder.pdf
68. Coder K. D. (2017). Tree damage from major ice storms. Arborist News.
69. Hauer, R.J., Hruska, M.C., & Dawson, J.O. (1994). *Trees and ice storms: the development of ice storm-resistant urban tree populations.* University of Illinois at Urbana-Champaign. http://web.extension.illinois.edu/forestry/publications/pdf/urban_community_forestry/UIUC_Trees_Ice_Storms.pdf
70. Coder K. D. (2017). *Tree damage from major ice storms*. Arborist News.

occur may be immediate or long-term; they can simply add a few more factors that affect the tree's vitality and stability or they can be the final stressor that causes tree failure or death.

After a weather event it is helpful to have an idea of what the tree's prognosis might be and what steps might be taken to care for or determine whether to remove injured trees. Some of the information below is based on ice storms but should also be generally applicable to other weather damage and can also be cautiously extrapolated to tree survival after damage in general.

The compilation of 45 studies on ice storms cited previously found that estimation of the amount of canopy loss from storm damage generally predicted mortality of damaged trees at three to five years:[71]

- Less than 25% canopy loss was "insignificant".
- Less than 50% was "usually survivable".
- More than 75% loss was "usually fatal".

The USDA Forest Service similarly states that "potential for survival is related to the extent of loss of the crown" and provides further details on these severity categories:[72]

- If less than 50% of the live crown is damaged there is a high chance of survival. Growth may slow due to canopy loss.
- If 50-75% of the live crown is damaged, trees may survive but with reduced growth and increased chance of infections, especially where damage includes larger branches or tops, shattered branch bases, or torn bark. Trees should be monitored.
- If more than 75% of the live crown is damaged, there is a low chance of survival. Those trees that do survive will probably become infected.

The University of Georgia gives the below guidelines in "Community Tree Damage Control Based on Future Tree Health Expectation" to assist in making decisions on disposition of damaged trees.[73]

- For any of the following, the tree should be removed to eliminate liability, additional costs, and further tree problems:
  - Dead tree.
  - Stem (trunk) broken from snapping or twisting.
  - Major branch collapse (greater than 50% of live crown affected).

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71. Coder K. D. (2017). *Tree damage from major ice storms.* Arborist News.
72. USDA Forest Service. (1998). *How to determine percent live crown loss in hardwoods before leaf-out.* USDA Forest Service. https://www.na.fs.fed.us/fhp/ice/durham/pubs/info_sheets/is_fs_01.pdf
73. Coder, K.D. (2001). *Storm damaged trees: prevention and treatment*. The University of Georgia Cooperative Extension Service. http://counties.agrilife.org/harris/files/2011/05/Stormdamage.pdf

  - Roots broken- tree pushed over or leaning.
  - Leaning or bent pine.
  - Lightning strike- hardwoods if more than 30% of bark circumference affected; any pines should be removed.
  - Mechanical damage to main stem if more than 30% of bark circumference affected.
  - Branch damage leaving severely lopsided crown (70% or more of crown on one side of tree).
  - Large stress or twist cracks in main stem.
  - Interferes with utility right-of-way safety and maintenance.
  - Split tree (remaining stem may fall).
  - Live branches broken or damaged are more than 50% for hardwoods, 30% for pines.
  - Top broken, if more than 50% of the live crown was lost for hardwoods, 30% for pines.
- For any of the following, minimize stress and water the tree; wait for one growing season to fertilize and prune:
  - Lightning strike- hardwoods if less than 30% of bark circumference affected (pines should be removed).
  - Mechanical damage to main stem if less than 30% of bark circumference affected.
  - Twigs and small branches blown off or broken.
  - Foliage destroyed.
- For any of the following, prune dead and dying branches, cut back to next major living branch (drop crotch) and water the tree; wait for one growing season to fertilize and prune to shape:
  - Top broken, if less than 50% of the live crown was lost for hardwoods, 30% for pines.
  - Live branches broken or damaged less than 50% for hardwoods, 30% for pines.
  - Stagheaded (dead lateral branches at the top of the tree).

When roots have been damaged, the crown size should be reduced somewhat to temporarily lessen the demand on the roots. Thinning or reducing the crown will also help with wind resistance in future storms. This type of pruning has been shown to reduce movement in any wind speed, but raising the crown (limbing up) did not.[74] Raising the crown too much or stripping out the interior of the canopy shifts wind force to the edges, which can reduce the tree's ability to dampen movement and result in limb breakage.[75] If a tree has developed a recent lean due to a storm or other known factor, it should be evaluated by a certified arborist before making a decision as to whether to leave

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74. Gilman, E. F., Masters, F. & Grabosky, J. C. (2008). Pruning affects tree movement in hurricane force wind. *Arboriculture and Urban Forestry, 34* (1): 20-28, http://hort.ifas.ufl.edu/woody/abstracts/efg/efg0702.shtm
75. University of Florida IFAS. (2015). *Force distribution*. University of Florida IFAS. http://hort.ifas.ufl.edu/woody/force.shtml

it in place. Trees which have been placed into a lean of no more than 20˚ may survive but must be assessed by a professional as to whether it is an acceptable risk.[76]

Lightning

Lightning strike is a devastating event. The extent and types of injury it causes are unlike any other type of damage:

"Each strike of lightning can reach more than five miles in length, and produce temperatures greater than 50,000 degrees Fahrenheit and an electrical charge of 100 million volts… Along the path of the strike, sap boils, steam is generated and cells explode in the wood, leading to strips of wood and bark peeling or being blown off the tree." [77]

"The most serious tree injuries caused by lightning are from the acoustic wave (explosive shock wave) radiating from the lightning path… The explosive shock can also cause the tree to flex and energetically rebound, causing bark and wood loosening or expulsion. The shock wave shears-off cellular connections, pulls wood fibers apart, and loosens bark, phloem, cambium, and xylem. Multiple strokes in a single lightning strike can generate multiple shock waves. The shock waves bounce off the inside of the tree stem and cause tree tissue shifts along the stem's circumference."[78]

The most visible injury from a lightning strike is bark splitting and radial cracking. Leaves will wilt from disrupted water transport; permanent wilting on a major area is also an initial symptom identifying a lightning strike. If all leaves on the tree wilt immediately it will likely die within a few days, but if it does survive and leafs out the next spring it has a good long-term prognosis.[79] Some trees may have intermittent foliage (coming and going) over several months, leading to twig death.[80]

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76. Coder, K.D. (2016). *Ice storm impacts on trees: prioritized causes of damage.* University of Georgia Warnell School of Forestry & Natural Resources. https://www.warnell.uga.edu/sites/default/files/publications/WSFNR-16-05%20Coder.pdf
77. Clatterbuck, W.K., Vandergriff, D. S. & Coder, K. D. *Understanding lightning and associated tree damage.* Texas A&M AgriLife Extension. https://agrilife.org/treecarekit/after-the-storm/understanding-lightning-associated-tree-damage/
78. Coder, K. D. *Lightning struck trees.* Georgia Forestry Commission. http://www.gfc.state.ga.us/community-forests/ask-the-arborist/LightningStruckTrees.pdf
79. Clatterbuck, W.K., Vandergriff, D. S. & Coder, K. D. *Understanding lightning and associated tree damage.* Texas A&M AgriLife Extension. https://agrilife.org/treecarekit/after-the-storm/understanding-lightning-associated-tree-damage/
80. Coder, K. D. *Lightning struck trees.* Georgia Forestry Commission. http://www.gfc.state.ga.us/community-forests/ask-the-arborist/LightningStruckTrees.pdf

Twenty percent or more of trees will have no visible injuries, but there is likely to be significant damage internally or in the roots (lightning dissipates into the ground). The tree will still be prone to increased stress, lowered defenses, and be more susceptible to pests. It may decline and die while still having little or no visible damage.[81]

A tree may take anywhere from days to several years to decline and die from a lightning strike. It may recover, but recovery usually takes several years. If the strike was only on one side there is a good chance of wound closure and survival. If the strike passed through the tree (bark and wood damage is seen on both sides) it usually will not survive.[82]

If the tree appears that it may survive, dead and hazardous branches should be pruned immediately but other corrective pruning should be put off for two to six months and then the tree should be evaluated by an arborist. Lightning-struck trees, especially pines, are very susceptible to pests.[83] Survival is dependent on good site conditions, particularly water, to support new growth.[84]

Fire

The extent of damage caused by fire depends on the part of the tree affected and the profile of the fire. The tree's survival greatly depends on its ability to resist pest infestation that may follow.

Trees are usually killed outright by crown fires or high intensity fires. Severe crown scorch is caused by hot gases from ground fires which "bake" foliage and twigs into a set position from which they cannot recover. Low intensity fires may cause partial tree kill.[85]

The recovery and growth of a fire-damaged tree depends on its ability to continue with its basic processes, especially photosynthesis. The degree of crown scorch, foliage loss, bud death, and damage to trunk bark and cambium are the key factors determining the likelihood of survival.

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81. Coder, K. D. *Lightning struck trees.* Georgia Forestry Commission. http://www.gfc.state.ga.us/community-forests/ask-the-arborist/LightningStruckTrees.pdf
82. Coder, K. D. *Lightning struck trees.* Georgia Forestry Commission. http://www.gfc.state.ga.us/community-forests/ask-the-arborist/LightningStruckTrees.pdf
83. Coder, K. D. *Lightning struck trees.* Georgia Forestry Commission. http://www.gfc.state.ga.us/community-forests/ask-the-arborist/LightningStruckTrees.pdf
84. Clatterbuck, W.K., Vandergriff, D. S. & Coder, K. D. *Understanding lightning and associated tree damage.* Texas A&M AgriLife Extension. https://agrilife.org/treecarekit/after-the-storm/understanding-lightning-associated-tree-damage/
85. Washington State Department of Natural Resources. (2012). *Fire injury to trees.* https://sflonews.files.wordpress.com/2012/09/fhalert-fire-injury-to-trees-2012.pdf

Conifer survival depends mostly on the viability of their buds. Fire-related mortality is greater the second year than the first; ninety percent of mortality occurs within three years.[86]

Pest infestation is a major problem after fire damage. Newly killed and fire-damaged trees are very attractive to bark beetles and wood borers. Borers introduce decay fungi and bacteria which aid decomposition of dead and dying trees but may also infect and kill surviving trees. Most mortality from bark borers occurs within the two years following the fire.

Any surviving trees should be evaluated the following spring. If there is 70% healthy-appearing crown the next spring, the tree has a reasonable chance of survival.[87] Conifers may be assessed by the amount of needle scorch in the crown and the health of buds and twigs. If needles are still green, the buds may still be alive: check by slicing one open.

The best means of **minimizing future tree failure** is attention to good tree care throughout its life. Selecting an appropriate species suited to the site, following proper planting and watering guidelines to aid in strong root growth, avoiding any impacts to roots, and proper pruning when needed by a certified arborist, are the best insurance for the health and safety of a tree. A **certified arborist** should always be consulted in any case where there are questions related to safety or hazard.

Tree Risk Assessment

Now that we have discussed how to look at a tree and discern possible problems and issues of concern, how should we respond to a homeowner who asks us how dangerous their tree is and whether they should have it removed? Can we as Tree Stewards evaluate the risk and provide an answer?

What is "risk" and how can it be assessed? The process of evaluating the risk posed by a tree is part science, part experience, and part uncertainty. It is a challenge to tree care professionals who have much more training, experience, and diagnostic tools than any Tree Steward will have. The probability of any particular event occurring can never be absolutely predicted, so how do we respond? The homeowner poses a question that does not have a simple answer, and that Tree Stewards must undertake to answer with all due care.

86. Washington State Department of Natural Resources. (2012). *Fire injury to trees.* https://sflonews.files.wordpress.com/2012/09/fhalert-fire-injury-to-trees-2012.pdf
87. Washington State Department of Natural Resources. (2012). *Fire injury to trees.* https://sflonews.files.wordpress.com/2012/09/fhalert-fire-injury-to-trees-2012.pdf

Understanding Risk

To return to the adapted quote at the beginning of the chapter: if a tree falls in a forest and no one is around, does it pose a risk? If it is large, old, rotted, badly leaning, with its roots lifting, is it a risk? What if it's in a playground? What if the playground is closed and secured and no one ever goes there?

Risk occurs at the intersection of the likelihood of failure, the severity of the possible outcome, and the chance of impact. The more likely a failure is to occur, the more severe the consequences might be, and the greater the chance of it occurring while someone or something is present to be impacted, then the greater the "risk" posed by a given situation. Like the assessment of a tree's structural stability, an assessment of risk is also multi-faceted and is arrived at after the examination of a number of factors (of which tree condition is only one). Risk exists at a point on a spectrum; its evaluation, and the evaluation of each of its contributing factors, encompasses a range of possibilities and degrees.

The presence of a **target** is the first requirement for a situation to be considered a possible risk. Without a target that could be impacted if a tree fails, there is no risk involved. There may be multiple potential targets; they may be human, animal, property, or use of the space.

Associated with the target is the **severity of possible consequences**. This can be personal or monetary, and can range from a minor impact such as a piece of broken furniture, to very severe such as injury, death, or loss of use of a critical facility like a hospital. Consequences can also include disrupted activities such as a loss of business.

The next factor is the **likelihood of tree failure** (failure of the entire tree or significant tree part). This consists of evaluation of all the observations that can be made of the tree and its environment to determine items of concern and the degree of hazard that they pose. These components are what we have covered in the previous sections of this chapter.

The final factor that brings together target, failure, and consequence is the **chance of impact**. This introduces the elements of time and distance by examining the **usage pattern** (frequency and timing) of access to the target zone, the **proximity** to the target, and the **mobility** of the target. The target zone could be a busy city street which is constantly filled with passersby; a school yard which is only occupied on weekdays during the day; a back yard which is only used occasionally, or a remote hiking trail that is rarely used. The more frequently the space is occupied, the greater the probability that the tree will fail at the same time that there is a target present. If the target is not moveable (e.g., a house) then impact would inevitably happen if a tree failure were to occur.

Risk may be **mitigated** (reduced) by making a change to one of these factors. The target can be moved, rerouted, or access to the space can be restricted; or the tree can be pruned, supported, or removed. These efforts can serve to reduce the risk posed, but it is never completely eliminated unless the tree is removed. Risk cannot be definitively calculated; it represents a spectrum of possible outcomes and likelihoods, under a "normal" (or commonly expected) load, in a given situation which changes at different points in time. What residual risk remains after any mitigating actions should hopefully be at an acceptable level. Each tree-owner will have a level of risk which is tolerable to them, where they are prepared to accept the level of consequences that may occur.

Certified Arborists and Professional Risk Assessment

This subsection is included to provide EMG Tree Stewards with an understanding of how certified arborists assess trees in order to expand your comprehension of the assessment process. Note that it is NOT an attempt to teach any professional method or process to Tree Stewards. Tree Stewards are neither encouraged, nor authorized, to follow specific industry assessment protocols or to represent themselves as qualified to assess risk or safety.

The basics of proper tree care are enumerated in the American National Standards Institute (ANSI) A300 Standards, interpreted and explained by Best Management Practices (BMPs), which are voluntary industry guidelines that describe optimal tree care practices. Tree Risk Assessment is included in the A300 standard (Part 9).

An assessment will usually include the following steps: visually examine the structure of the tree; describe any defects; evaluate the likelihood of failure; and note the possible damage if failure were to occur. A certified arborist assessment may consist of one of three levels. Level 1, a limited visual assessment, covers only what may be seen from one side, and is used for quickly scanning a number of trees (often by vehicle or utility company flyover) to pick out the most obvious problems. Level 2, a basic assessment, is what is usually performed to examine a tree individually with attention paid to all sides and components of the tree. Level 3, an advanced assessment, includes more extensive means of examination to provide additional information (including attempts to determine internal decay by means of various equipment) such as climbing, drilling, tomography, etc.

The evaluation of something so subjective is difficult, and when performed on different trees in different situations by different individuals there is likely to be a wide divergence in the resulting assessments. The International Society of Arboriculture (ISA) has developed a protocol to create a single standardized system of evaluation for use throughout the industry by arborists trained and qualified in its use. This is the **Tree Risk Assessment Qualification (TRAQ)** program. It is based on a systematic process of reviewing each of the components of risk, and then using the weighted results to arrive at a final quantified assessment of the level of risk. The process is supported by the

ISA Basic Tree Risk Assessment Form[88] (along with its instructions)[89] using risk categorization methodologies from ISA's Tree Risk Assessment BMPs. The information contained on the form is described below. The first sections describe the targets and areas of concern observed on the tree or in its environment; the remainder assesses the level of risk.

Many of the components will be familiar to you from the previous sections of this chapter, but it is informative to see how the targets are evaluated, how the factors are quantified, and how both are then combined to reach an overall assessment. In addition, becoming exposed to the descriptive terminology, which is designed to be in line with legal and insurance nomenclature, is in itself helpful.

Target Assessment for *each potential target* within striking distance:

- Description of the target.
- Factors which might serve to protect it or to minimize impact or damage.
- Target Zone: Whether the target is within the drip line; within striking distance if the tree falls (1x height of the tree); within range of large flying debris if the tree falls (1.5x height of the tree).
- Occupancy rate: Rare; occasional; frequent; constant.
- Whether target could be moved and/or access can be restricted.

Site Factors that may influence tree failure:

- History of failure.
- Topography.
- Site changes: None; grade change; site clearing; changed soil hydrology; roots cut.
- Soil conditions: Limited volume; saturated; shallow; compacted; pavement over roots.
- Prevailing wind direction.
- Common weather.

Tree Health and Species Profile:

- Vigor: Low; normal; high.
- Foliage: None (seasonal); none (dead); % normal; % chlorotic; % necrotic.
- Pests; biotic or abiotic problems.

88. International Society of Arboriculture. (2017). *Basic tree risk assessment form.* http://www.isa-arbor.com/education/resources/BasicTreeRiskAssessmentForm_Print_2017.pdf
89. International Society of Arboriculture. (2017). *Using the ISA basic tree risk assessment form.* http://www.isa-arbor.com/education/resources/isabasictreeriskassessmentform_instructions.pdf

- Species failure profile, to list any relevant species-specific tendencies (typical problems).

Load Factors including dynamic (variable) and static (constant) loads and related factors:

- Wind exposure: Protected; partial; full; funneled.
- Relative crown size.
- Crown density: Sparse; normal; dense.
- Interior branches: Few; normal; dense.
- Presence of vines, mistletoe or moss which would increase weight or wind resistance.
- Changes in load factors.

Tree Defects and Conditions Affecting Likelihood of Failure for trunk, crown, branches, roots, and root collar:

- Crown unbalanced.
- Live crown ratio (LCR; ratio of crown height to tree height).
- Dead twigs and branches.
- Broken, hanging, or over-extended branches.
- Pruning history: Cleaned; thinned; raised; reduced; topped; lion-tailed; flush cuts.
- Trunk or major branch cracks.
- Lightning damage.
- Codominant branches or trunks.
- Included bark.
- Weak attachments.
- Cavity or nest holes.
- Previous failures.
- Dead or missing bark or bark with abnormal texture or color.
- Cankers, galls, or burls.
- Damage or decay to sapwood or heartwood.
- Conks or mushrooms.
- Response (reaction) growth.
- Poor trunk taper.
- Trunk lean and whether it shows corrected growth.
- Sap ooze on trunk or root collar.
- Root collar buried or not visible.
- Stem girdling.
- Cut or damaged roots.
- Root plate lifting.
- Soil weakness affecting anchorage.
- List of conditions of concern, including size of tree part and fall distance.
- Load expected on tree defect: Minor; moderate; significant.

- ***Likelihood of Failure***: Improbable; possible; probable; imminent.

Risk Categorization for each target:

- Description of the target; tree part; conditions of concern.
- ***Likelihood of Failure*** (from above): Improbable; possible; probable; imminent.
- ***Likelihood of Impact*** for that target: Very low; low; medium; high.
- ***Combined Likelihood of Failure and Impact*** for that target within a given time frame, e.g. 2-3 years (based on cross reference of ***Likelihood of Failure*** with ***Likelihood of Impact***): Unlikely; somewhat likely; likely; very likely.
- ***Consequences of Failure*** are an estimated amount of possible harm or damage to that target: Negligible; minor; significant; severe.
- ***Risk Rating*** for that target (based on cross reference of ***Combined Likelihood of Failure and Impact*** with ***Consequences of Failure***): Low; moderate; high; extreme.

Mitigation options for each risk.

Residual risk remaining after recommended mitigation: Low, moderate, high, extreme.

Overall Tree Risk Rating is the highest risk for the tree and highest rated target.

Overall Residual Risk is the remaining risk after the highest-risk tree part is mitigated.

The Role of the Tree Steward in Risk Assessment

As a Tree Steward or Tree Steward intern you will have learned a great deal more about trees and tree hazards than most people will know. With this knowledge and your position as a Virginia Cooperative Extension Master Gardener volunteer comes significant responsibility. We must always present ourselves clearly as **non-professionals** who have some advanced training, and make sure the homeowner knows that **we do not have the training, professional certification, or experience to provide an expert opinion**. Homeowners may well make decisions based on what we tell them. Knowing this, we must be sure to disavow them of any impression that we are more highly qualified than we actually are, and to be cautious in the opinions we express. What we communicate can affect people's lives and property; we do not want our words to have the unintended result of injury or destruction. In addition, since we represent VCE there is likely to be an automatic assumption of us as an "authority", which will not only give our words an added weight but may also place a legal responsibility on us to make only recommendations and evaluations which are appropriate to our position.

When examining a homeowner's tree we should be as thorough as possible. There is a 2021 VCE Pub SPES-313P, How to Evaluate a Tree, which can help both the Tree Steward and the homeowner. Review mentally or make a list of the elements to observe related to the tree and its environment that may be relevant to its health and structural stability. It is helpful to document what we observe. Each item of concern should be discussed with the homeowner, and an explanation provided for the impact that it may have on the tree. The mission of VCE is, first and foremost, education, and this is what we provide to the homeowner. We may examine their trees, but our appropriate function is to teach them some basics of tree biology and structure which will help them to understand the implication of the concerns we point out to them. ***By communicating scientific observations and providing unbiased, research-based explanations, we are helping them to become informed consumers and more knowledgeable tree owners.***

We may make statements to the effect that defect x may be due to or associated with reason y, which would then make it a concern because of possibility z. We may NOT make statements of an absolute nature such as that defect x is due to reason y, or that defect x or reason y will cause outcome z. Most important, we can NEVER state that defect x or reason y will NOT cause outcome z, i.e., that a tree or part of a tree is SAFE or is NOT a danger, because there is no way that that can be determined. We do not have the ability nor the authority to make such a statement.

We can say, if we are certain, that a specific thing is normal and is therefore not usually a concern. We can say that a condition (or the tree generally) could be a concern, discuss the relevant observations, and recommend that they consult a certified arborist for a professional evaluation. We can (and should) say if we have concerns that it may be a serious hazard or pose an imminent danger, and strongly recommend that they have a certified arborist assess it as soon as possible.

In summary, our role as VCE MG Tree Stewards in tree risk assessment is to **observe**, **educate**, and **provide a frame of reference** as to whether the tree is **probably not a concern**, **may be a concern**, or **is an urgent concern** that should be professionally evaluated immediately.

Consulting an Arborist

When advising a homeowner to consult a certified arborist, they will often ask for a recommendation. VCE is not allowed to provide recommendations or give out names of any businesses or individuals. However, we can give the homeowner some guidance on how to find one by providing them with the following information.

VCE Publication ANR-131, ***"Hiring an Arborist to Care for Your Landscape Trees"***, contains helpful information when searching for a qualified (certified) arborist. It describes what an arborist does, when to call one, how to evaluate them and more. It also refers the reader to the following two organizations' websites that can be used to search for a certified arborist: https://resources.ext.vt.edu/contentdetail?contentid=975

The ***International Society of Arboriculture (ISA)*** is the organization responsible for verifying that an arborist has met certain criteria to then be designated as "Certified". As the name implies, this is an internationally-recognized designation and it is the industry standard. There are several specializations as well as a Master Board-Certified Arborist, but what is needed is the Certified Arborist designation. The query asks for the country (USA), and then the best results seem to be found by searching within 100 miles of a zip code (instead of a city name). It will give the names of individual certified arborists and what company they work for (which will likely also include arborists employed by noncommercial entities such as a city, utility, government agency, etc). https://www.treesaregood.org/

The ***Tree Care Industry Association (TCIA)*** is a trade association which developed the ANSI A300 standards. It accredits tree service companies which have met its criteria for operation and have undergone an audit. Its query will return a list of tree service companies which are TCIA members or, if selected, only the member companies that have also been accredited by TCIA. Membership in or accreditation by TCIA is not an industry-wide standard or requirement, so there may be other good companies besides those listed. The best results seem to be found by searching with the first 2 or 3 numbers of a zip code, or for the entire state and then looking for nearby companies. https://www.tcia.org/TCIA/MEMBERSHIP/Find_Quality_Tree_Care/TCIA/Directories/FindQualifiedTreeCare.aspx

Any companies to be considered should be able to answer these questions in the affirmative:

- Do they provide a current certificate of insurance?
- Do they provide a written contract?
- Do they have a certified arborist who will do the evaluation and estimate?
- Do they follow the ANSI (American National Standards Institute) standards or BMPs (Best Management Practices)?

In other words, the Certified Arborist title shows the individual's qualifications; following the ANSI standards and/or BMPs shows that the company uses approved methods in their work.

Review Questions

1. What are the three factors that contribute to tree failure?
2. What are the parts of a tree that need to be evaluated when looking for problems?
3. For each of these parts, what are some important symptoms or problems that may be of concern?
4. What are some general guidelines on the extent of root or trunk damage which may affect the tree's stability or likelihood of failure?
5. What are the factors at a given location that affect the health and structural stability of a tree?

6. Describe how the effect of wind or ice/snow is different for a tree located in a group as opposed to an isolated location. Describe the difference for a tree located on the edge of a group as opposed to within the group.
7. How does the tree protect itself against collapsing under a frequent or continual load? How might that load change and what might happen if it does?
8. Describe how the soil at the location can affect the tree's risk of damage.
9. What kind of changes at a location could be damaging to the tree?
10. What are the six ways that a tree can fail?
11. What are some of the general guidelines on the extent of crown or trunk damage to consider in whether a tree is likely to survive extensive damage?
12. What one element of supplemental care is the most important to a tree's recovery from damage?
13. When planning a new landscape or planting a tree, what are the most important things to consider to prevent future damage?
14. When (under what circumstances) should a Tree Steward suggest a consultation with a certified Arborist?
15. What are the limitations of a Tree Steward when making recommendations to a client about a tree? What kind of statements should we be cautious about or avoid making?
16. Questions to consider as you move into working as a Tree Steward: Think about the trees in your area. What different types of locations are they growing in? What trees do well or poorly in your area? What are the most common problems with them? What are the most common site and weather stresses for them?

CREATING A LOCAL PROGRAM

"You don't need to predict the future. Just choose a future – a good future, a useful future…" – Isaac Asimov

Introduction

This section is intended for local Tree Steward course planners. It contains suggestions for documents related to local EMG TS courses and help with the transition between the tree steward training course and the students' accomplishment of their intern projects.

Learning Objectives

1. Be aware of Tree Steward course policies and requirements.
2. Use local procedures to develop and obtain approval of EMG TS intern projects.
3. Use local resources to improve the situation of trees in the local community.

Local Forms

Suggested items to include:

- Local EMG TS course requirements and policies.
- Local EMG TS class schedule.
- Project development guidance. Possible worksheet and proposal forms are shown on the next two pages, as a suggested place to start for local training programs.

Sample Worksheet for Developing a Program Project

Step 1: Scope out the possibilities: what is needed in your city or county?

- Tree guide for a new trail in a wooded park?
- School or children's group education?
- Pruning training module?
- Educational tree planting?
- Improvement to county/city management of tree stocks?
- Write a VCE publication?
- Organize an educational campaign in your local news media?

Step 2: Many projects are better done by groups of TS. Look around to see if anyone in the class is looking at the same things you are. A solo project is also fine, if that seems best to you. Then discuss your idea with the TS Class Staff to arrange a TS Mentor for further development and execution advice.

Step 2: Determine the target audience. This could be a group of people, an organizational or civic entity, a recreational activity, etc.

Step 3: What do you expect as the outcome? Think both short and long term. Is it a document, an event, a physical installation, a new management program, or something else? What kind of measurement is appropriate?

Step 4: How will you know if you have achieved your desired result? Think about alternative outcomes: if the result is not what you intended, how can you use this to the good? Note that if the goal and method are appropriate and approved, whatever result you get will satisfy the TS certification requirement.

Step 5: What resources will you need? Where will they come from?

Step 6: Set up a timeline with progress checkpoints. Your project may have multiple stages or could be an open-ended effort if appropriate.

Step 7: Turn in proposal for approval, through the TS Class Staff to your Agent.

Sample EMG Tree Steward Program Project Proposal

Your Name(s)________________________ Your MG Unit(s)____________ Date_________

Title of Project ____

Type of Project (check all that apply):

Inventory/Survey_____

Educational Guide _____

Presentation/Class _____

Publication _____

Experiment _____

Government Process _____

Other _____

What need do you see and what do you think can be done about it?

____

____

____

What impact do you hope for:

Short term____

Long Term____

Intended Audience:

Target____

Other Entities or People Involved ______________________________________

Resources Needed/ Where to Get:

____

____

TS Mentor(s)/Advisor(s) ____

Agent Approval____

Governmental and Other Institutional Information

We recommend you collect government and other institutional documents to provide to your Tree Stewards. These materials could be researched by the students as part of their course work or intern project development. Items in this section could include:

- Instructions on accessing city or county Multi-Year Plans regarding trees.

- City or county tree ordinances.
- Contact list of offices, boards, groups or individuals involved in tree planning, maintenance and public education.
- List of public and accessible private arboretums, gardens, parks and forests.

Local Tree Stewards and Tree History

This section is to provide the context of the local EMG TS group(s) and activities, as well as significant historical tree info of local importance. Such items could include:

- EMG TS roster.
- History of past and ongoing TS projects (not just past intern projects).
- VCE Agent goals regarding local tree issues or ecological concerns.
- VA Dept of Forestry Urban Tree programs in the area.
- Local guide books and Tree Trail maps.
- Virginia Big Tree Champions in the local area.

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