



# LANDSCAPE FOR LIFE™

Based on the principles of the Sustainable Sites Initiative™

## *Instructor's Manual*

[www.landscapeforlife.org](http://www.landscapeforlife.org)



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**LANDSCAPE FOR LIFE™**   
*Instructor's Manual*



This manual was made possible in part by the  
National Fund for the United States Botanic Garden  
and the Wallace Genetic Foundation.



# LANDSCAPE **FOR** LIFE™

## *Instructor's Manual*

Based on the principles of the Sustainable Sites Initiative™



## Landscape for Life™

**Landscape for Life** was developed to provide training to homeowners on sustainable gardening practices. It is based on the principles of the Sustainable Sites Initiative™ (SITES™), a program that developed the first voluntary rating system to provide comprehensive guidelines and performance benchmarks for sustainable land design, construction, and maintenance practices. SITES is a collaborative effort between the United States Botanic Garden, the Lady Bird Johnson Wildflower Center at the University of Texas at Austin, and the American Society of Landscape Architects.

### Introduction

**There are now over 7 billion people inhabiting the earth.** This is an increase of about 5.6 billion people since 1900. The growing population places increasing pressure on the planet's soils, waters, forests, and other natural resources.

Sustainable gardens can help alleviate the pressure on the Earth's ecosystems by working with nature to provide clean air and water, fertile soils, wildlife habitat, and other essential ecosystem services. Significant portions of our urban environments are made up of residential land, which can impact the health and well-being of an entire region. Creating and maintaining sustainable gardens can impart a wide range of ecological, economic, and health benefits to homeowners and the surrounding community.

## The purpose and use of this manual

**This manual provides instructors with the basic knowledge required** to lead their own Landscape for Life course. The manual is organized into a series of five classes that explore the roles of soils, water, vegetation, and materials in sustainable garden design. Each of the classes is composed of two lessons designed to last up to three hours each. Instructors may shorten or rearrange these lessons depending on their own schedules. The instructor should review the lessons prior to each class and be prepared to lead a combination of presentations, activities, discussions, and assignments to investigate each of the topics.

There are several sections highlighted throughout the manual that may require the instructor to conduct additional research. Each of the major sections (i.e., soil, water, plants, and materials) contains a resource section, divided by topic, to help the instructor access more information. Instructors can find additional tools, including a downloadable version of the manual and a series of adaptable PowerPoint presentations, on the Landscape for Life website available at [www.landscapeforlife.org](http://www.landscapeforlife.org).



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# Pre-Course Questionnaire

A pre-course questionnaire can be used to inform instructors of the students' current knowledge and course expectations. Instructors should ask students to fill out the questionnaires and return prior to the first class. Below are example questions that can be sent to students via online survey tools, email, or other communication methods. These questions can serve as a topic for the opening discussion at the beginning of the first class to engage students and explore questions and/or concerns.

- Do you garden in an area that is rural, suburban, or urban? Describe the advantages and disadvantages of the area in which you garden?
- In an average month, how many hours do you spend gardening? What is your incentive for gardening? Are there any tangible or non-tangible benefits you receive from gardening?
- What are sustainable gardens? Can you describe any practices or design features that you have incorporated into your own garden to enhance its sustainability?
- What aspects of sustainable gardening are you hoping to learn more about? Of the four main topics that will be covered in the course (soils, water, vegetation, and materials), which are you most interested in? Please indicate any design techniques or specific topics related to soils, water, vegetation, and/or materials that you would like to discuss in more detail.

# Curriculum Map

The curriculum map below divides the manual's 10 lessons into 5 even class periods. This map is two pages and is read left to right across each color heading. As mentioned in the introductory section, lessons can be shortened or rearranged to accommodate the instructor's schedule. Each of the class activities, discussions, field trips, and assignments are highlighted below and clearly marked throughout the manual. Please pay special attention to these sections as they may require additional planning, research, and/or classroom explanation.

| Topic   | Learning objectives After completing this course students will be able to:   |
|---|--|
| <p><b>Pre-Course Questionnaire</b></p>  | <p>The pre-course questionnaire is intended to help inform instructors of the students' current knowledge and course expectations. Students should fill out the questionnaire and return them to the instructor prior to the first class.</p>  |
| <p><b>Class 1</b><br/>Lesson 1: Sustainability in Home Gardens<br/>Lesson 2: The Role of Soils in Sustainable Gardens</p> | <ul style="list-style-type: none"> <li>▪ Explain the concept of sustainability and its application in home gardens</li> <li>▪ Provide examples of the benefits or ecosystem services nature provides to humans</li> <li>▪ Compare unsustainable and sustainable gardening practices</li> <li>▪ Provide examples of the benefits provided by healthy soils</li> <li>▪ Compare sustainable and unsustainable soil management practices</li> <li>▪ Determine the texture, soil structure, and pH of garden soils</li> <li>▪ Recognize common causes and signs of soil compaction</li> </ul>                             |
| <p><b>Class 2</b><br/>Lesson 3: Successful Soil Practices<br/>Lesson 4: The Role of Water in Sustainable Gardens</p>      | <ul style="list-style-type: none"> <li>▪ Describe how to work with existing soils to create successful gardens</li> <li>▪ Explain techniques that can be employed to maintain soil fertility</li> <li>▪ Explain why water conservation is important</li> <li>▪ Compare the water use of sustainable and unsustainable gardens</li> <li>▪ Identify gardening practices that contribute to water shortages and pollution</li> </ul>  |
| <p><b>Class 3</b><br/>Lesson 5: Successful Water Practices<br/>Lesson 6: The Role of Plants in Sustainable Gardens</p>    | <ul style="list-style-type: none"> <li>▪ Explain basic strategies for conserving water in home gardens</li> <li>▪ Select and describe specific design techniques used for cleansing and conserving stormwater</li> <li>▪ Determine how much stormwater can be collected from home gardens</li> <li>▪ Provide examples of benefits vegetation can provide to homeowners and the surrounding community</li> <li>▪ Explain how home gardens and the larger ecoregion interact</li> <li>▪ Identify site conditions, including hardiness zones and microclimates, that should be considered in plant selection</li> </ul> |
| <p><b>Class 4</b><br/>Lesson 7: Successful Plant Practices<br/>Lesson 8: Selecting Materials for Sustainability</p>       | <ul style="list-style-type: none"> <li>▪ Describe garden features that are beneficial to wildlife</li> <li>▪ List vegetation that is well-suited to the site conditions</li> <li>▪ Explain the benefits of using native plants in gardens</li> <li>▪ Demonstrate how to use plants to increase the energy efficiency of homes</li> <li>▪ List strategies for reducing material use in gardens</li> </ul>   |
| <p><b>Class 5</b><br/>Lesson 9: Successful Materials Practices<br/>Lesson 10: Student Presentations</p>                   | <ul style="list-style-type: none"> <li>▪ Make informed decisions when selecting gardening materials</li> <li>▪ Identify local salvage and recycling centers</li> <li>▪ Describe existing features of home gardens that either contribute to or take away from overall sustainability</li> <li>▪ Demonstrate how sustainable practices can be implemented in home gardens</li> </ul>  |

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**Activities/Demonstrations/Fieldtrips**
**Class Assignment**


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- **Discussion:** Close-out discussion Lesson 1 (Pg. 19)
- **Activity:** Using soil maps to explore common characteristics of soils in the region (Pg. 24)
- **Activity:** Determining soil texture and structure (Pg. 28)
- **Discussion:** Close-out discussion Lesson 2 (Pg. 34)

- Site Assessment—Basemap & Soils (Pg. 33)

- **Activity:** Using the soil texture triangle to determine soil structure (Pg. 40)
- **Activity:** Building a compost pile or vermicompost bin (Pg. 52)
- **Discussion:** Close-out discussion Lesson 3 (Pg. 57)
- **Discussion:** Close-out discussion Lesson 4 (Pg. 63)

- Site Assessment—Water (Pg. 64)

- **Activity:** Determining the amount of rainwater that can be harvested from a house and driveway each month (Pg. 72)
- **Activity:** Determining the size of a rain garden needed to capture rainwater runoff from a home (Pg. 78)
- **Discussion:** Close-out discussion Lesson 5 (Pg. 81)
- **Field trip/Activity:** Identifying plants commonly grown in the area (Pg. 89)
- **Discussion:** Close-out discussion Lesson 6 (Pg. 90)

- Site Assessment—Plants (Pg. 89)

- **Field trip/Activity:** Identifying native and non-native appropriate plants (Pg. 97)
- **Activity:** Identifying and controlling common invasive species found in your area (Pg. 100)
- **Discussion:** Close-out discussion Lesson 7 (Pg. 110)
- **Discussion:** Close-out discussion Lesson 8 (Pg. 117)

- Site Assessment—Energy Efficiency (Pg. 110)
- Finalize Basemap and Site Assessment (Pg. 118)

- **Discussion:** Close-out discussion Lesson 9 (Pg. 128)
- **Activity:** Exploring Sustainable Design Strategies (Pg. 132)
- Course evaluations (Pg. 133)

# 1



## Class Preparation Checklist

- Review results of pre-course questionnaire
- Prepare the computer, projector, screen, and other necessary equipment required to lead the Class One PowerPoint presentation
- Research the common characteristics of soils in the region, page 24
- Collect several samples of soil types commonly found in the area, page 26
- Collect samples of sand, silt, and clay, page 27
- Collect supplies for the class activity: Determine soil texture and structure, page 28
- Complete the example "jar test" prior to the class, page 28

# Class 1

## Lesson 1: Sustainability in Home Gardens

## Lesson 2: The Role of Soils in Sustainable Gardens

**Learning objectives** *After completing this course, students will be able to:*

### Lesson 1

- Explain the concept of sustainability and its application in home gardens
- Provide examples of the benefits or ecosystem services nature provides to humans
- Compare unsustainable and sustainable gardening practices
- Provide examples of sustainable design practices

### Lesson 2

- List examples of benefits provided by healthy soils
- Compare unsustainable and sustainable soil management practices
- Determine the texture, soil structure, and pH of soils
- Recognize common causes and signs of soil compaction

# Lesson 1

## Sustainability in Home Gardens



DARREN BAKER, BIGSTOCK

### Overview

**U**nsustainable landscape design and practices can damage a garden's ability to clean air and water, reduce flooding, regulate local temperatures, and provide other natural processes that support life on Earth. In contrast, creating sustainable gardens can protect and restore the environmental, economic, and human health benefits provided by nature. The Landscape for Life educational series, in combination with the website, provides the tools needed to transform home gardens into beautiful and healthy refuges that benefit not only the homeowner, but the surrounding community. This lesson introduces sustainability and its application in home gardens. The major concepts provide a foundation for more detailed lectures on soils, water, materials, and plants.

## Sustainable gardens

At its core, **sustainability** is the process of attempting to meet the needs of today without compromising the needs of tomorrow. The design, construction, and maintenance of sustainable gardens maximize environmental and human health benefits for current and future generations.

The word sustainability may be relatively new, but its underlying ethic has deep roots in the history of North America. Native Americans have long embraced the “seven generations” rule, meaning that all decisions should consider the impact on the next seven generations. As one Native American proverb states, “We do not inherit the earth from our ancestors, we borrow it from our children.”

The concept of sustainability involves a dynamic balance between the following three factors:

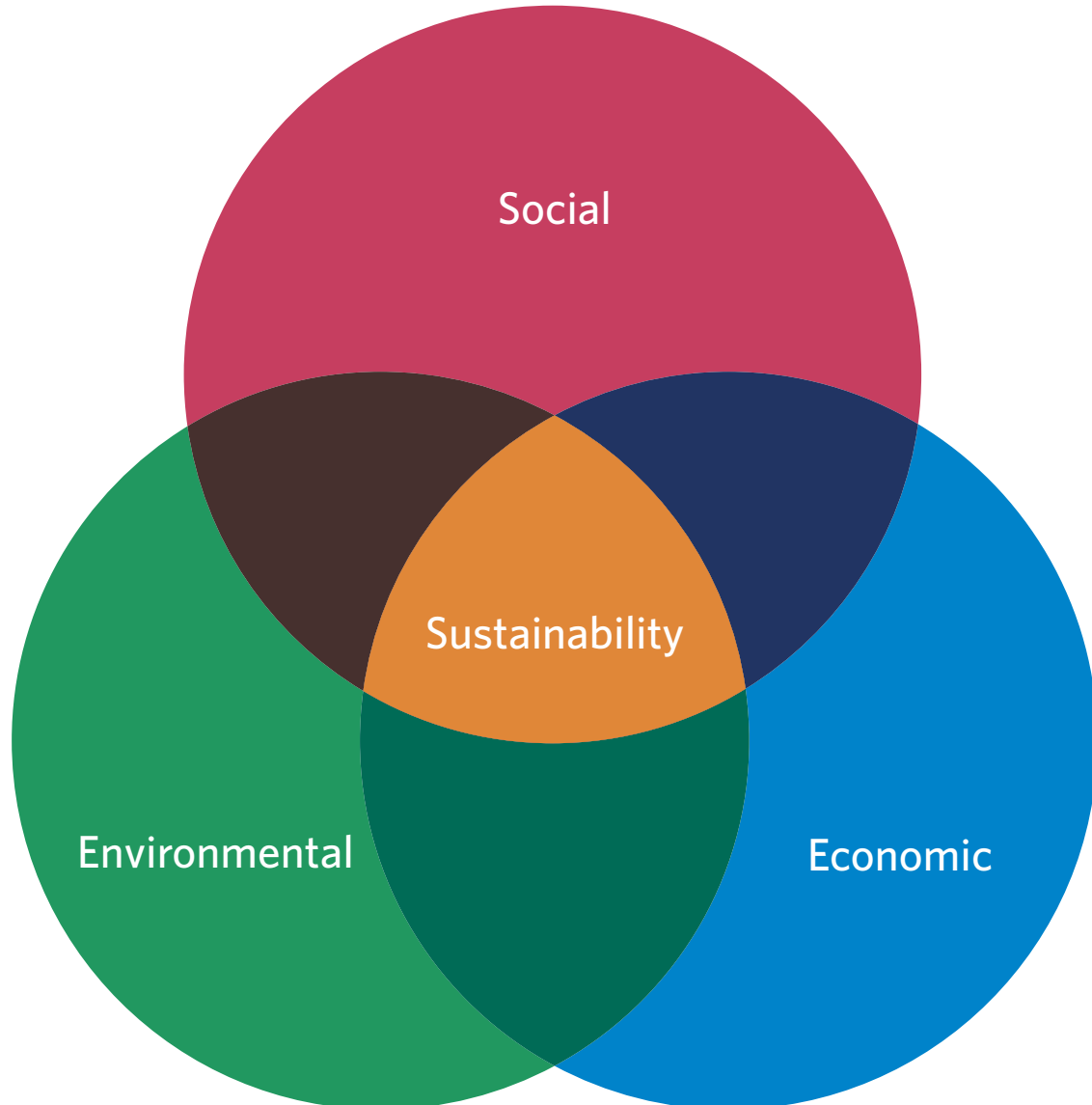
**ENVIRONMENTAL** Humans and other organisms depend upon the natural environment and the goods and services it provides, including clean air and water; **habitat**; **erosion** control; and food, timber, and other materials. Sustainable gardens protect and restore the land’s ability to provide these benefits for current and future generations.

**ECONOMIC** In designing sustainable gardens, we weigh decisions according to their long-term environmental and human health merits as well as financial costs and benefits. Any successful project must be economically feasible; however, profit should not always be the overriding factor. Placing economic gains or financial savings at the forefront of our decision making can lead to significant environmental and human health costs. We gain a better sense of the full cost of doing business when the impacts on people and the environment are included in our accounting, and in turn we are encouraged to act in a manner that is more socially and environmentally responsible. Sustainable gardens balance economic factors with equally important environmental and social factors.

**SOCIAL** The health and well-being of people are central to the concept of sustainability. Sustainable gardens create opportunities for people to interact with nature and improve their physical, psychological, and social well-being.

## The importance of creating sustainable gardens

Human populations have grown substantially over the past century. This continued and rapid growth has placed immense pressures on the Earth’s soil, water, and other **natural resources**. In order to protect our natural resources and the many benefits they provide, we need to become stewards of the land. **Stewardship** involves the protection of the environment and its natural resources by making sustainable changes in the way we approach the management of our immediate landscape.



*Sustainable practices recognize and attempt to balance the long-term impacts on environmental, economic, and social well-being.*

Sustainable gardens provide numerous and wide-ranging benefits such as the following:

**CLEAN AIR** Plants absorb pollutants from the air, sequester atmospheric carbon, and provide the oxygen we breathe. Sustainable gardens maintain healthy and established vegetation that can more effectively provide clean air benefits.

**CLEAN WATER** Plants and healthy soils capture and cleanse pollutants from **stormwater**. Stormwater **runoff** from developed land is the leading cause of water pollution in urban areas. As stormwater moves across roadways, roofs, driveways, and other **impervious surfaces**, it increases in temperature and accumulates pollutants that adversely affect



water quality. Sustainable gardens help slow water, allowing much of it to soak into the ground and replenish aquifers. Design features of sustainable gardens, such as bioswales or rain gardens, capture and cleanse water on site preventing the spread of water pollutants.

**STORE FRESH WATER** Healthy soil serves as a natural water reservoir, which can prevent flooding and sustain vegetation in times of drought. Over-compaction and low levels of organic matter are two common factors that limit the soil's ability to absorb and retain water. Sustainable gardens protect and restore the soil's ability to capture fresh water and support vibrant vegetation.

*Many good sources of organic matter are found in a home garden, including autumn leaves and garden and lawn clippings.*



DVORTYGRL/WIKIMEDIA COMMONS

**CONTROL EROSION AND SEDIMENT RUNOFF** Vegetation holds soil in place and decreases the likelihood of erosion and sediment runoff. Sedimentation is a major cause of polluted rivers and streams in the United States. Sustainable gardens use vegetation and mulch to protect soils from erosion and keep soil from entering water bodies.

**MAINTAIN SOIL HEALTH AND FERTILITY** Natural ecosystems often rely on decayed organic matter for healthy soils. Many good sources of organic matter are found in home gardens, including leaves and plant clippings. Each year, millions of tons of yard waste in the US end up in our landfills. Creating sustainable gardens can help minimize this waste by transforming plant trimmings into valuable and enriching resources such as **compost** or mulch.

**MITIGATE THE URBAN HEAT ISLAND EFFECT** Vegetated surfaces help to moderate air temperatures by providing shade and releasing moisture into the air. Urban development

replaces vegetation with dark surfaces such as roofs, roads, and buildings that absorb and trap heat, causing cities to have warmer temperatures than their rural surroundings. This phenomenon, known as the **urban heat island effect**, increases the demand for cooling energy in buildings and accelerates the formation of ground-level ozone and smog. Sustainable gardens favor vegetated surfaces, shading surfaces, and light-colored materials to mitigate urban heat island effects.

**PROVIDE HABITAT** Sustainable gardens can provide habitat for a variety of plants, animals, and **microorganisms**. For example, a single gram of soil can contain between 1,000 and 10,000 different species of bacteria and fungi that support the growth of associated plants species.

**SUPPORT HUMAN HEALTH AND WELL-BEING** Physical and visual access to natural settings can support many aspects of human health and well-being. Social scientists and psychologists have found that everyday encounters with nature, such as green views from

### Unsustainable vs. Sustainable Gardens: How They Compare OVERVIEW

| Unsustainable Gardens   | Sustainable Gardens  |
|---|--|
| <i>Requires regular application of potable water to sustain plants.</i>   | <i>Minimizes the use of potable water to support plants by using the following water sources:</i> <ul style="list-style-type: none"> <li>▪ <i>Local precipitation</i></li> <li>▪ <i>Harvested rainwater and/or air conditioner condensate</i></li> <li>▪ <i>Runoff directed from impervious surfaces to gardens</i></li> </ul> |
| <i>Plant trimmings are disposed of in the landfill.</i>   | <i>Plant trimmings are composted and used as mulch.</i>  |
| <i>Fertilizers are needed to support healthy plant growth.</i>  | <i>The natural soil food web, properly chosen plant species, and organic matter from on-site vegetation promote healthy plant growth.</i>  |
| <i>The reuse of site structures or materials at the end of the project life is not considered.</i>  | <i>Garden structures and features can be adapted and reused in place or easily deconstructed and reclaimed or recycled.</i>  |
| <i>More time, resources, and maintenance are needed because the layout and design does not incorporate local soils, vegetation, materials, and culture.</i> | <i>Design solutions fit the place and are representative of the local soils, vegetation, materials, and/or culture.</i>  |

an office window, a lunchtime stroll through a nearby park, or schoolyards with trees and other vegetation can restore our ability to concentrate, calm feelings of anxiety, and reduce aggression. Sustainable gardens seek to provide community and personal access to natural settings.

## Lesson 1

### Discussion

- *How are you a good steward of your home garden and the surrounding landscape?*
- *In what ways could you be better?*



*Recommend a short break while instructor prepares for Lesson 2: The Role of Soil in Sustainable Gardens*

## Resources: Sustainable Gardens

### Publications

#### **Bay-Friendly Landscape Guidelines: Sustainable Practices for the Landscape**

<http://www.stopwaste.org/>

*Guidelines written for the professional landscape industry to provide an integrated approach to environmentally friendly landscaping.*

#### **Sustainable Gardens**

Rob Cross and Roger Spencer  
Csiro Publishing (2009)

*Developed for amateur and professional horticulturist, this book illustrates how to make informed decisions when designing, constructing, and maintaining parks and landscapes for reduced environmental impacts.*

#### **Sustainable Sites Design: Integrated Design Strategies for Residential and Small Scale Sites**

Heather Venhaus  
John Wiley & Sons Inc. (2012)

*A sustainable landscape design guide that explores strategies for alleviating some of the most common and pressing environmental and human health issues. A detailed overview of each strategy is provided and includes design considerations, illustrations, and images to help readers determine the best options for their site. Case studies from public and private projects are provided throughout the book.*

#### **The Conscientious Gardener**

Sarah Reichard  
University of California Press (2011)

*This book explores the many benefits of sustainable gardening and provides straightforward, practical advice on topics such as pest control, water conservation, living with native animals, mulching, and controlling invasive species.*

#### **The New American Landscape: Leading Voices on the Future of Sustainable Gardening**

Thomas Christopher (ed.)  
Timber Press (2011)

*This book brings together the best thinkers on the topic of gardening sustainably, and asks them to describe the future of the sustainable landscape.*

#### **The Sustainable Sites Handbook: A Complete Guide to the Principles, Strategies, and Best Practices for Sustainable Landscapes**

Meg Calkins (ed.)  
John Wiley & Sons Inc. (2011)

*A technical guide, authored by many involved in the development of SITES, that contains information on principles, strategies, technologies, tools, and best practices sustainable site design for any type of landscape.*

**The Sustainable Sites Initiative: The Case for Sustainable Landscapes**

<http://www.sustainablesites.org/report/>

*A companion volume to the Sustainable Sites Initiative: Guidelines and Performance Benchmarks, 2009. This publication provides arguments—economic, environmental, and social—for the adoption of sustainable land practices.*

**Useful Websites****Designing Our Future: Sustainable Landscapes**

American Society of Landscape Architects

<http://www.asla.org/sustainablelandscapes/>

*This website provides educational resources and innovative design ideas on sustainable landscaping through a series of case studies from across the United States.*

**Fresh Landscape Design: Inspiring Places and People**

<http://www.freshlandscape.com.au>

*A case study featuring an impressive sustainably designed landscape in Australia.*

**Organic Land Care**

Rutgers New Jersey Agricultural Experiment Station

<http://njaes.rutgers.edu/organiclandcare/>

*This website provides information and resources in organic land care. In addition, information is offered on Rutgers' Land Care Certification Program, which provides landscape professionals with the tools needed to apply organic land care practices.*

**Sustainable Gardening Articles**

Brooklyn Botanic Garden

[http://www.bbg.org/gardening/category/sustainable\\_gardening](http://www.bbg.org/gardening/category/sustainable_gardening)

*This website provides articles on sustainable gardening topics such as sustainable garden design, gardening for wildlife, native flora, and urban gardening.*

**Sustainable Sites Initiative**

<http://www.sustainablesites.org/>

*This website provides guidelines for obtaining SITES certification and a series of example SITES-certified pilot projects. The publication "Sustainable Sites Initiative: The Case for Sustainable Landscapes" listed above, along with the updated version of the rating system and a project scorecard can be download on this website.*

\*Additional information on soil testing can be found through a local Cooperative Extension Office. A list of offices by state is provided in Appendix 2 of this manual.

# Lesson 2

## The Role of Soil in Sustainable Gardens



VITALIY PAKHNYUSHCHYI, BIGSTOCK

### Overview

**S**oil is critical to the success of sustainable gardens. Using sustainable gardening practices can help us restore the benefits our soils provide. Modern society has left much of Earth's soil eroded, exhausted, and polluted. Unsustainable gardening practices such as applying too much fertilizer or compacting soil has contributed to the problem. This lesson focuses on the role soils play in the sustainability of home gardens and surrounding landscapes. It will explore basic soil concepts, techniques, and resources that can be used to determine soil type.

## Soil and its role in sustainable gardens

**Soil** is a complex mixture of weathered rock and mineral particles; the living organisms of the soil food web; and the decaying remains of plants, animals, and microorganisms. It forms the foundation of sustainable gardens providing a variety of ecosystem services.

These services include the following:

- › Absorbs rainfall and mitigates flooding
- › Removes pollutants and cleanses water
- › Stores water for plants, wildlife, and people
- › Provides habitat for a wide range of organisms such as bacteria, fungi, insects, and earthworms
- › Stores carbon
- › Supports vegetation that provides a variety of ecosystem services

| <b>Unsustainable vs. Sustainable Gardens: How They Compare SOILS</b>   |  |
|--|--|
| <b>Unsustainable Gardens</b>   | <b>Sustainable Gardens</b>   |
| <i>Soils are over-compacted, which restricts the infiltration of rainwater and inhibits plant growth. Earthworms and other organisms that make up the soil food web are greatly reduced or nonexistent due to restricted air and water movement in the soil.</i> | <i>Soils are healthy, living ecosystems that provide the needed air and water flow to support plant growth and a diverse soil food web. Rainfall infiltrates and replenishes groundwater supplies.</i> |
| <i>Soils are exposed to sunlight, rain, and wind.</i>  | <i>Soils are protected by vegetation or mulch.</i>   |
| <i>Soils require frequent amending to support healthy vegetation.</i>  | <i>Vegetation is selected based on what can thrive in the existing soil type.</i>  |
| <i>Organic matter, such as leaves or grass clippings, is removed from the soil and disposed of offsite.</i>  | <i>Organic matter from these gardens are used to support the soil food web and healthy vegetation.</i>   |

## Examining the common characteristics of soil in the region

Soil scientists have identified more than 70,000 kinds of soil in the US that each contain different combinations of mineral particles—**sand**, **silt**, and **clay**—and various amounts of organic matter and nutrients. In addition to a number of natural factors that contribute to differences in soil type, development plays a large role in the high levels of variation, or heterogeneity, found in urban landscapes. Exploring the common characteristics of soils in the region can provide helpful insights into creating sustainably designed home gardens. A tool that is commonly used to explore differences in regional soil characteristic is the Natural Resources Conservation Service (NRCS) soil maps. Soil maps are compiled into

### Using soil maps to explore characteristics of soil in the region

#### Activity

*This activity will provide instruction on how to use the NRCS web soil survey tool to explore the common characteristics of regional soils. Prior to class, the instructor should make sure that the classroom has Internet access and a projector that can be connected to the instructor's computer.*

How to use the NRCS web soil survey:

1. Log on to the web soil survey by going to <http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm>.
2. Click the "Start WSS" button at the top of the page to begin learning about the regional soils.
3. Explore the "Area of Interest (AOI)" tab. This tab will allow you to zoom in on a specific study area using variables such as address, state and county, soil survey area, and geographic coordinates.
4. Before the data can be retrieved, you will need to define the AOI by using one of the mapping tools to draw a rectangle or polygon around the desired area.
5. Click the active "soil map" tab at the top of the screen to learn about the type and composition of soil in the selected area. Clicking on each of the underlined soils will provide a comprehensive description of the characteristics associated with each of the soil types.
6. The "soil data explorer" tab at the top of the screen can be used to learn about the suitability of each soil type for a particular land use. Exploring factors such as vegetative productivity may provide valuable insight when designing a home garden.



surveys that provide extensive interpretation of soil characteristics. These documents are published by county and can be searched by state at [http://soils.usda.gov/survey/printed\\_surveys/](http://soils.usda.gov/survey/printed_surveys/). In addition, the NRCS web soil survey is an interactive tool that can be used to populate data on a specified area. This tool can be found at <http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm>.

It is important to note the NRCS soil surveys tools are only meant to provide preliminary or background information. Reviewing these maps can be helpful in better understanding factors such as land use history, underlying soil properties, or topography associated with a particular area. Unfortunately, soil maps may not be available for some urban areas, soils may have been altered since the time of surveying, and/or maps may not provide enough resolution to adequately capture the heterogeneity across a small area, such as an individual's yard. Before designing a home garden, homeowners should test their soils to determine the exact soil type. The following sections discuss the methods for determining soil type.

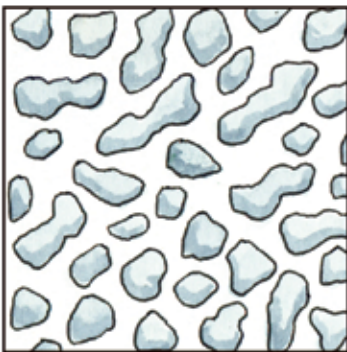
### Determining soil type

Gardeners must determine the **texture**, **structure**, and **pH** of a given soil to properly identify it. For demonstration purposes, instructors should show the class samples of different types of soil commonly found in the area along with samples of sand, silt, and clay.

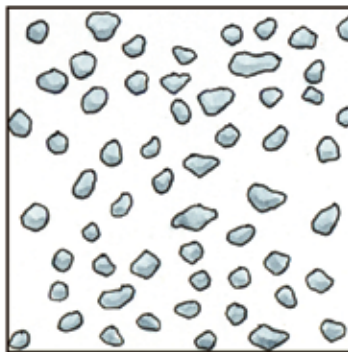
#### Soil Texture

Soil texture is described as the relative proportions of different size mineral particles in a soil. Sand, silt, and clay, the major mineral particles, are responsible for the size and

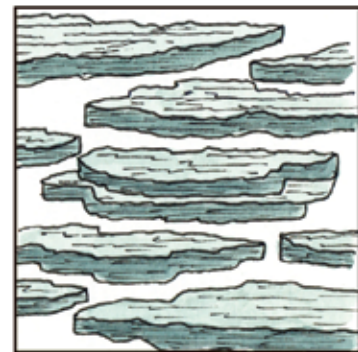
### The Structure of Healthy, Sandy, and Compacted Soils



*Healthy soil*



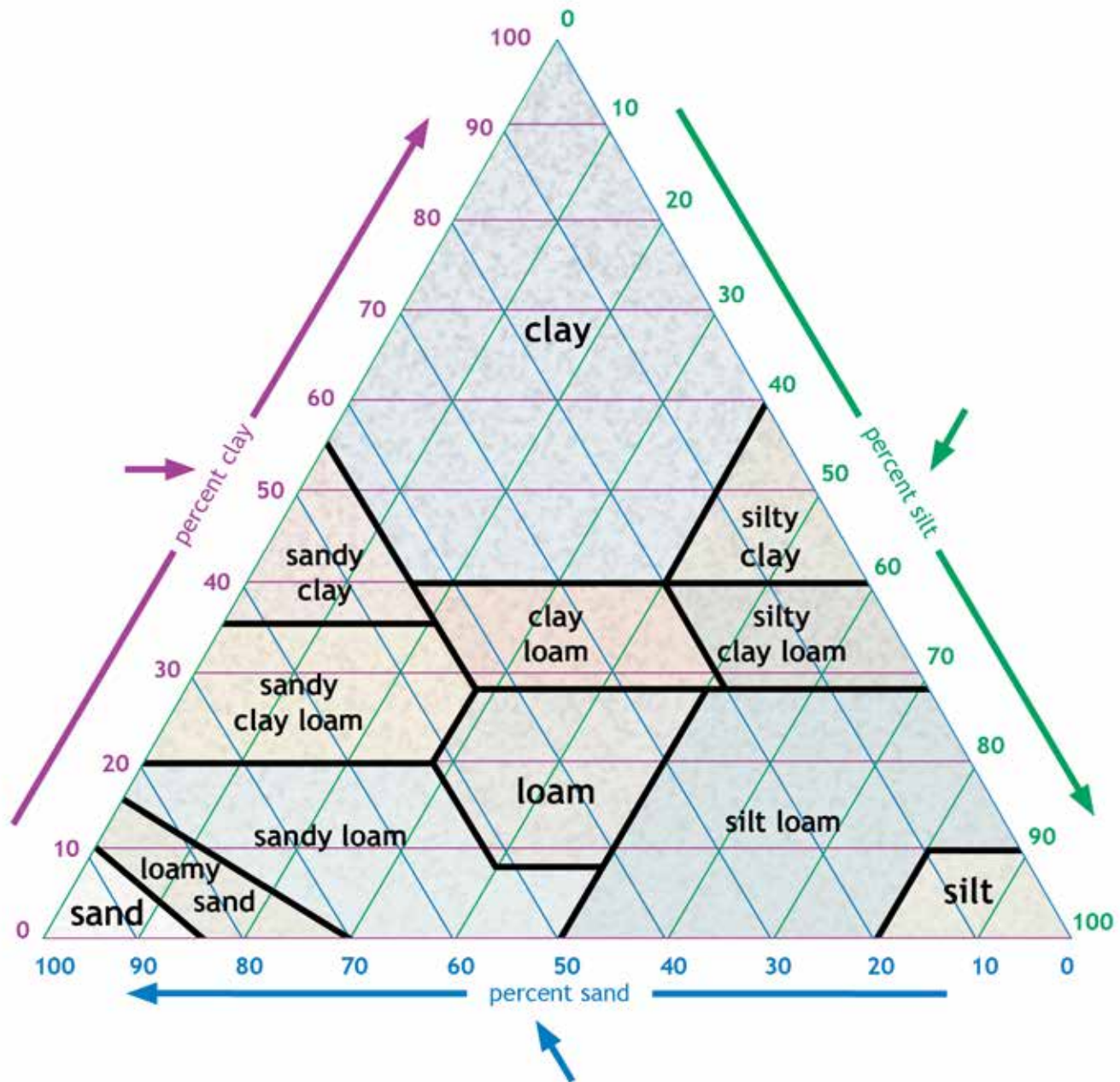
*Sandy soil*



*Compacted soil*

*Healthy soils (left) form visible soil aggregates that allow moisture and nutrient retention and proper aeration. Sandy soils (center) do not bind together to form aggregates. Compacted soils (right), often composed of mostly clay particles, form a platy structure with multiple layers of flat thin peds.*

## Soil Texture Triangle



Scientists divide soil into 12 textural classes. The soil texture triangle can help determine which class of soil you have.

- › After conducting the jar test to determine the percentages of sand, silt, and clay in your soil, locate the percentage of clay in your soil on the left side of the triangle and follow the purple (clay) line across.
- › Next, find the percentage of sand along the bottom of the triangle and follow the blue (sand) line up to where it intersects with the purple (clay) line you identified.
- › The green (silt) line at this intersection represents the percentage of the silt in your soil sample. The shaded area that contains the point where the lines intersect is your soil's textural class.

number of the soil's **pore spaces**. Soil pore space determines the amount of oxygen, the drainage rate, and capacity of soil to hold nutrients. Sand grains are the largest of these particles (2.00-0.05 mm) and create large pores. Sandy soils drain quickly and do not hold water and nutrients well. While sand can be seen by the naked eye, silt particles are microscopic (0.05-0.002 mm). Silt creates smaller pores in the soil, resulting in better water retention. Clay particles are the smallest in size (<0.002 mm), producing soils that have a tremendous capacity to hold water and nutrients, but tend to suffer from poor air circulation and slow drainage.

Soils are rarely pure sand, silt, or clay but rather a mixture of all three. Based on the relative proportions of these particles, they are grouped into 1 of 12 textural classes that compose the soil texture triangle (See Page 26 and Appendix 3). Sands and loamy sands, for example, are more than 70 percent sand and share the characteristics of sand. Clays, sandy clays, and silty clays are more than 40 percent clay and exhibit the characteristics of clay. **Loams**, commonly celebrated in gardening literature, share the attributes of several soil types—good aeration, drainage, moisture, and nutrient retention. Use the soil texture triangle to determine soil type.

**Testing Soil Texture**—Understanding and testing your soil texture is a critically important step in plant selection. Often we do not need to significantly alter or amend the soil if we match our plants to the existing soil texture. Sandy soils, which lose water and nutrients relatively quickly, will require plants that are more **adapted** to living in dry, nutrient-poor soils. Clay soils, which tend to retain water, often require plants that can withstand wet or flooded soil conditions. You can achieve a better understanding of your soil texture by performing a few simple tests at home. To gain a basic sense of soil texture, begin by feeling and squeezing a handful of moist soil in or near your garden. Soil dominated by sand will tend to feel gritty, falling apart when shaped into a ball. Silty soils are composed of slightly smaller particles than sand giving them a smooth, velvety feel. Clay soils contain small particles that group together readily, contributing to its sticky feel and ability to hold together when shaped into a ball. Depending on your needs, a jar test can help you achieve a more exact measurement of type of particles that compose the soil. Instructions for performing each of these tests can be found on page 28.

### **Soil Structure**

Soil structure is identified by how soil particles cling together to form different shaped and sized **aggregates**, called crumbs or **peds**. Soil structure determines how permeable a soil is, how well it retains moisture and nutrients, and how easily it allows plant roots to penetrate and grow.

The ideal soil structure may be different depending on the demands of the plant; however, most plants grow best when soil particles bind together to form loose, granular aggregates about the size of cookie crumbs. A loam, or relatively even concentrations of sand, silt, and clay particles, often forms loose granular, aggregates that are efficient at providing the right amount of moisture and nutrients for many garden plants. Soils that are composed of heavy clay or sand tend to be problematic for most plants, as this contributes to poor soil aggregation. Sandy soils do not bind together and tend to have the consistency of dry cake mix. Clay soils bind tightly and become very hard when dry. Compacted soils have a

## Determining soil texture and structure

### Activity

*In this activity you will learn different techniques to determine the texture and structure of garden soils.*

### I. The Jar Test

In the first activity, the instructor will demonstrate how to conduct the jar test. Instructors may choose to conduct the exercises indoors or out in the garden to avoid messy clean up. An example jar test should be completed the previous day to illustrate how the soil particles separate and can be measured to determine the percentage of sand, silt, and clay.

#### Supplies:

- Water**
- 2 cups of soil. Instructor should bring in different soil types for comparison purposes.**
- Wet paper towels or wash rag**
- Quart-sized jar with lid**
- 1 teaspoon of liquid dish soap**
- Example jar test completed the previous day**

#### How to conduct the jar test

After removing stones or debris, place 2 cups of garden soil in a quart-sized jar. Add 1 teaspoon of liquid dish soap. Fill the jar to the top with water and close the lid tightly. Gently turn the jar upside down right-side up for about a minute to mix. Let it sit for a day so the particles can settle out. Sand will have settled to the bottom, silt will comprise the middle layer, and clay the top. Place a ruler beside the jar and measure the thickness of each layer. Divide the thickness of each layer by the total thickness of all three layers. Multiply by 100. This will tell you the percentage of sand, silt, and clay in your soil.

### II. Additional Soil Tests

In this section of the class, instructors will lead students in conducting a variety of soil tests. Different soil types should be provided for comparison purposes.

**The Feel Test**—Rub a small amount of moist soil between your fingers. If it feels coarse and gritty, the soil is probably dominated by sand. If it feels smooth and

velvety, it is most likely a silt soil. If the soil clings together and feels sticky, it probably is largely composed of clay.

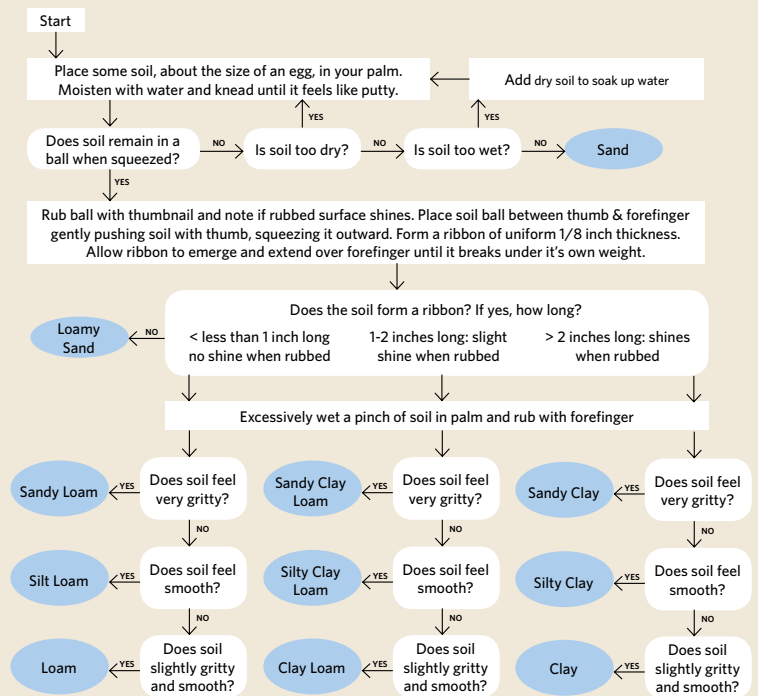
**The Squeeze Test**—Squeeze a moist soil sample in your hand and examine it closely. If soil clods resist crumbling and do not change shape when squeezed, you are likely working with a heavy clay soil. If clods break apart into individual particles, like cake mix, the soil probably is predominantly sand. Loam soils tend to stay together when squeezed, but unlike heavy clay soils, they change shape easily.

Soil structure can be related to other factors besides particle composition. For example, big clods may also be an indication of compaction, even in soils with relatively little clay. Sterile loam soils, in which natural microbial action has been impaired, are unable to form even small aggregates.

**The Ribbon Test**—Squeeze a moist ball of soil out between your thumb and fingers. If the ribbon that is formed easily breaks and is less than 1" you likely have a sandy soil. If the formed ribbon is between 1-2" your soil is likely composed of silt particles. Finally, if the ribbon holds together and is greater than 2" before breaking, your soil has a high concentration of fine-texture clay particles.

*The soil texture flow chart at right provides a series of questions that may guide you through the soil tests described above. The instructor may choose to provide students with a copy of the flow chart (Appendix 3) or simply use it to guide the course activities.*

### Soil Texture Triangle



*Recommend a short break before finishing the remainder of the course*

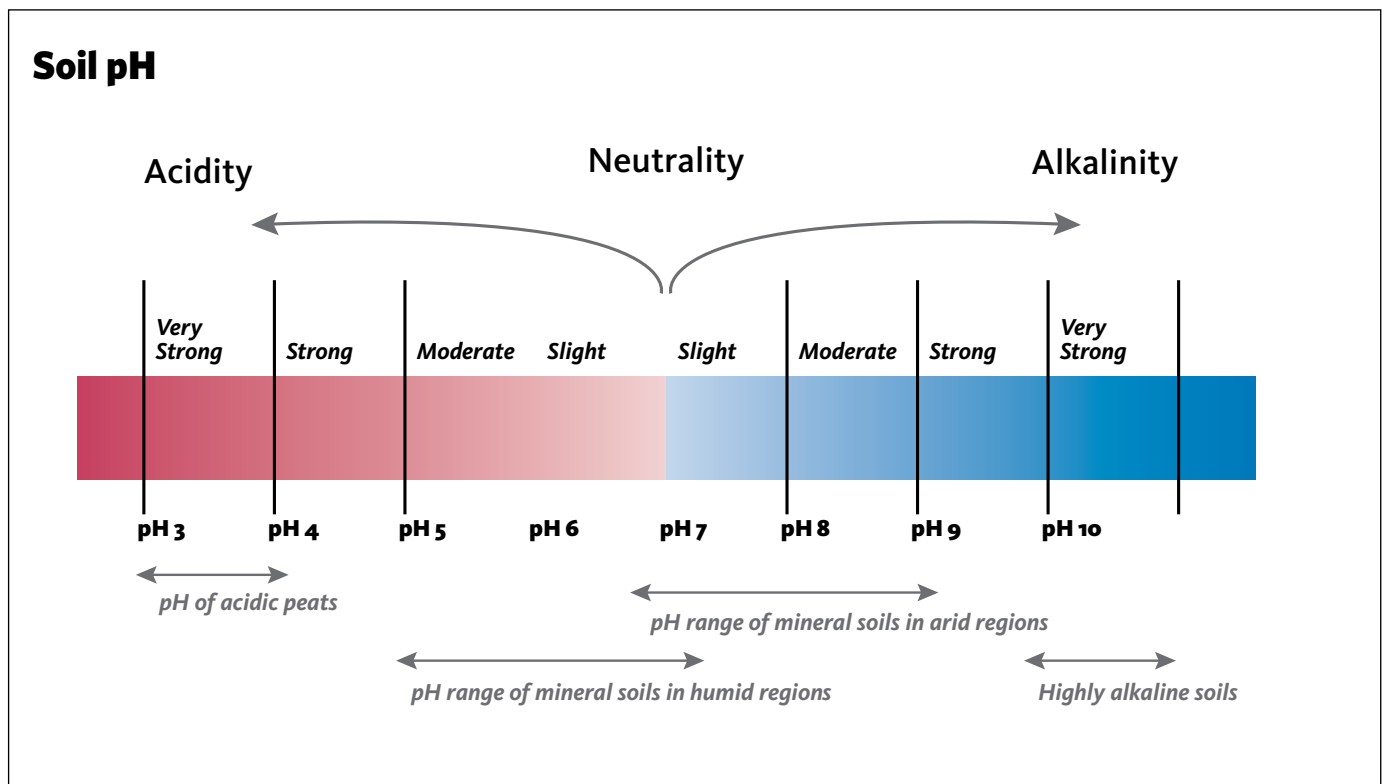
“platy” structure, with multiple layers of flat, thin peds. Weight bearing down on the soil can cause soil pores to collapse thereby restricting the movement of air and water and limiting the growth of plant roots. The key to improving or maintaining good soil structure is the presence of organic matter and thriving communities of soil organisms.

**Testing Soil Structure**—Soil texture or the proportion of sand, silt, and clay composing a soil often contributes to the overall structure. The tests mentioned in this manual can provide preliminary insights about the aggregation or structure of your soil. To gain a better understanding of you soil structure, you can begin by digging a hole about a foot deep. From the side of this hole remove a slice of soil. Lift the slice from the hole and place it on its side. Examine the soil, paying close attention to the size and shape of aggregates.

### Soil pH

**Soil pH** is a measure of soil **acidity** or **alkalinity**. The pH scale ranges from 0 to 14, with 7 representing neutral. From pH 0 to 7 the soil becomes less acidic, while from 7 to 14 it becomes increasingly alkaline.

Soil pH affects the availability of minerals and nutrients to plants. Before a nutrient can be used by a plant, it must be dissolved in the soil solution. Most plants prefer a slightly acidic to neutral soil, with a pH of 6 to 7, because that is the range in which most nutrients are readily available. In strongly acidic soils (pH 5.5 to 4), important nutrients



The figure above shows a common pH scale, ranging from 0-14. The pH ranges of various soil types displayed at the bottom of the chart provide a reference point.

such as phosphorus, potassium, calcium, and magnesium are typically less available. The availability of phosphorus, iron, copper, zinc, and manganese is reduced in slightly to moderately alkaline soil (pH 7 to 8).

Soil pH also affects the activity of microorganisms. Bacteria that decompose organic matter are inhibited in strongly acidic soils. This prevents organic matter from breaking down and ties up nutrients, particularly nitrogen. Strongly acidic or alkaline soils can increase the solubility of some nutrients and minerals to the point that they become **phytotoxic**. For example, in very alkaline soils, the levels of available calcium and magnesium are so high that they impede the availability of phosphorus.

**Testing Soil pH**—Having your soil pH tested is a highly beneficial and cost-effective gardening practice. University extension labs or commercial labs conduct standard soil tests for about \$25 to \$40 (See Appendix 2). Knowing your soil's pH can save you money on unnecessary fertilizer and plants that are not adapted to the natural soil conditions. A lab test can help avoid nutrient imbalances from excess fertilizer that can run off and pollute waterways. It will also help determine which plants are best suited to growing in the garden. Most soil labs will send a soil test kit that includes sampling instructions, a sample bag, and a survey form. Homeowners should be sure to fill out the survey in detail so the lab can make informed recommendations for their property.



LYNN BETTS

**Soil pH testing can be easily and affordably accomplished with at-home kits.**

Although they can vary somewhat by state, a standard soil test result typically includes the following measurements:

- › Soil pH
- › Levels of potassium, phosphorus, calcium, magnesium, and sulfur
- › Organic content
- › Lead contamination and what to do about it
- › Recommended nutrient or soil **amendments** (Recommendations are based on the needs of agricultural crops. Unless vegetables are being cultivated, nutrient recommendations may be much higher than what is needed to support garden plants.)

If they are not part of the standard test, levels of nitrogen and other nutrients, sodium, soil texture, and other factors can be tested for an extra charge, but must be specifically requested.

## Soil compaction

Weight from a single intense force or small repeated forces pushes soil particles together causing them to compact. Compacted soils have reduced macropores and micropores, resulting in limited air and water movement, restricted root growth, reduced infiltration rates, and decreased biological activity. Because of these factors, highly compacted soils greatly limit plant growth and the ability of the soils to absorb rainfall and filter pollutants.

Over-compaction is one of the most common characteristics of degraded soils, but simple changes in land use and maintenance practices can protect soils. Lesson 2 discusses the common causes and signs of compaction. Lesson 3: Successful Soil Practices covers restoration techniques for repairing compacted soils.

Common causes of soil compaction in urban landscapes include the following:

- › Operation of construction and maintenance equipment, such as using skid steer loaders to prepare a site for construction or using riding lawnmowers when the soil is wet
- › Parking or driving on portions of the site not designed for vehicular traffic
- › Repeated pedestrian and/or animal traffic
- › Repeated tillage
- › Walking on, compressing, or digging in the soil while it is wet
- › Rainfall on bare soils, particularly in areas where rainfall is intense and concentrated such as runoff from rooftops
- › Continually removing organic matter such as leaves or grass-clippings

Common signs of soil compaction can include the following:

- › Water ponding and/or the presence of very slow infiltration rates
- › Surface water runoff from both irrigation and rain
- › Soils that are bare and not supporting vegetation
- › Shallow tree rooting
- › Stunted vegetation
- › Soils that have a strong resistance to penetration when compared to surrounding soils

Gardeners can test the level of soil compaction by using a garden shovel or steel rod and applying weight evenly. It is helpful to begin by comparing areas of obvious compaction in different sections of the garden.



**Construction is a common cause of soil compaction. Limiting the area of disturbance and applying thick layers of mulch can minimize soil damage.**



## Lesson 2

### Discussion

- *What are the benefits and disadvantages of the NRCS soil survey maps?*
- *What information might they provide or not provide?*
- *Why is it still important to test your soils?*
- *Can you think of any past or present factors that may have affected soil type (texture, structure, or pH) of your garden?*
- *Are there any areas in your garden where soil type may vary? Please explain.*

## Site Assessment — Basemap & Soils

### Assignment

*Throughout the series, students will be asked to assess and record different aspects of their gardens. Participants will discuss students' findings and potential design scenarios during the last class.*

#### **Site Assessment—Basemap & Soils**

A site assessment evaluates the current conditions of the garden to determine the resources, constraints, and opportunities that should be considered in design. The site assessment assignment below includes two parts that focus first on creating a basemap and then on using this basemap as a tool to assess soil characteristics.

**Part 1: Create a basemap (See example on Page 35)**

Design a template for the site assessment and garden design by creating a basemap of your property. Using colored pencils and graph paper, draw the house and property to scale, allowing about a quarter inch per foot.

The basemap should include the following:

- › All paved surfaces, such as driveways, walks, and patios
- › The footprint of each building
- › Utility lines such as gas, sewer, and electric
- › North arrow
- › Scale of the basemap

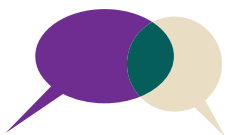
Once this basemap is complete students will need to make several copies and bring their basemaps and assessment findings with them to class each week.

**Part 2: Soil assessment (See example on Page 36)**

Using the soil tests discussed in the previous lesson, determine the texture, structure, and pH of your soils. Testing the pH should be conducted right away since it may take several weeks to receive the results. It is important to note that soils can vary across a garden and several tests may need to be conducted in different locations to gain a full understanding of soil conditions. Indications that soils may be different in an area are changes in color, texture, moisture, and compaction. Abrupt changes in vegetation type can also indicate varying soil conditions.

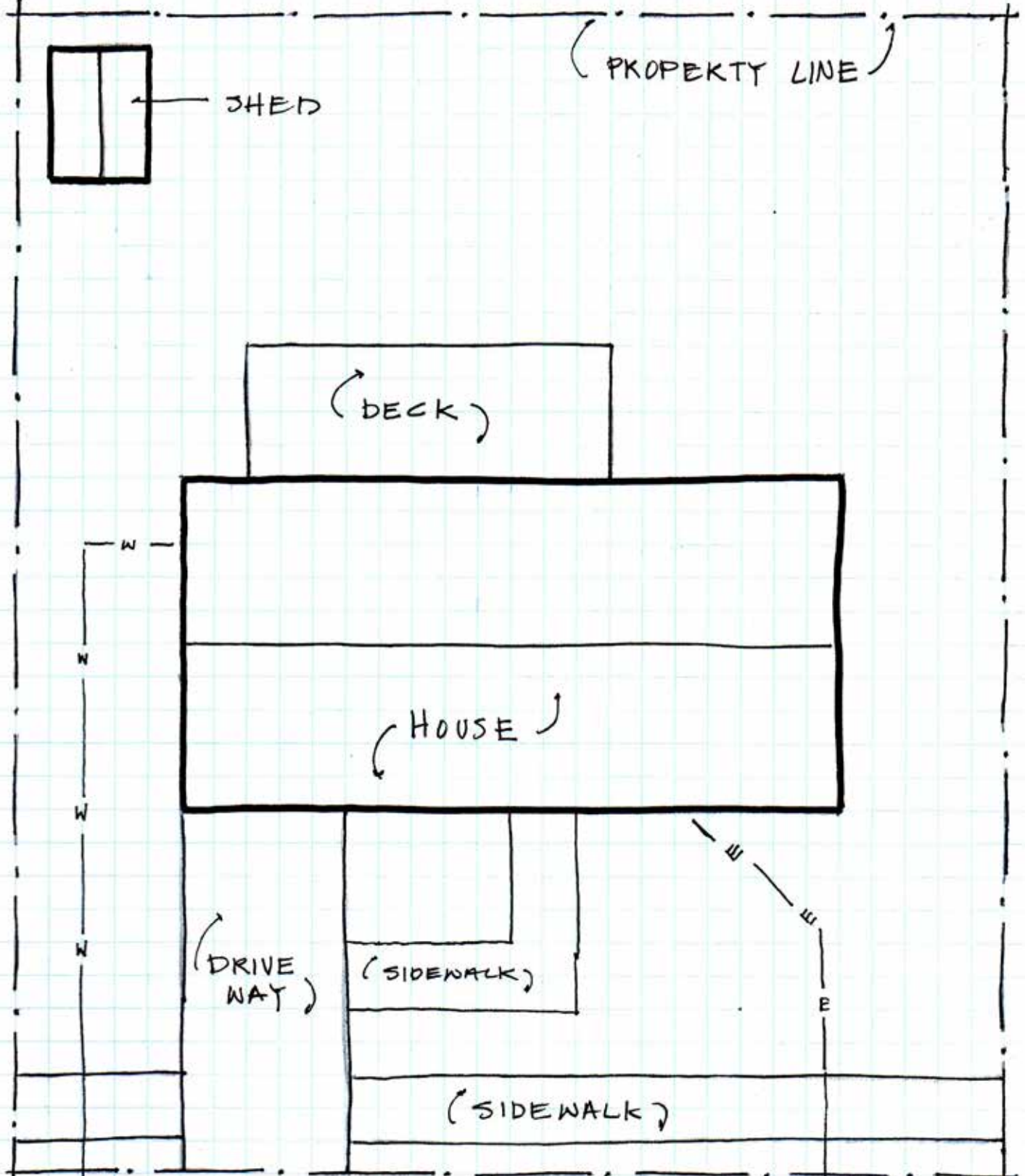
Using tracing paper over the basemap, outline the following characteristics:

- › Areas of erosion and compaction
- › Low areas that are commonly wet
- › Exposed rock
- › Shallow soils
- › Areas where the soil abruptly changes texture or structure

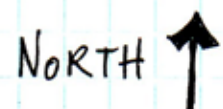


*Class Wrap-up: Closing Questions or Comments*

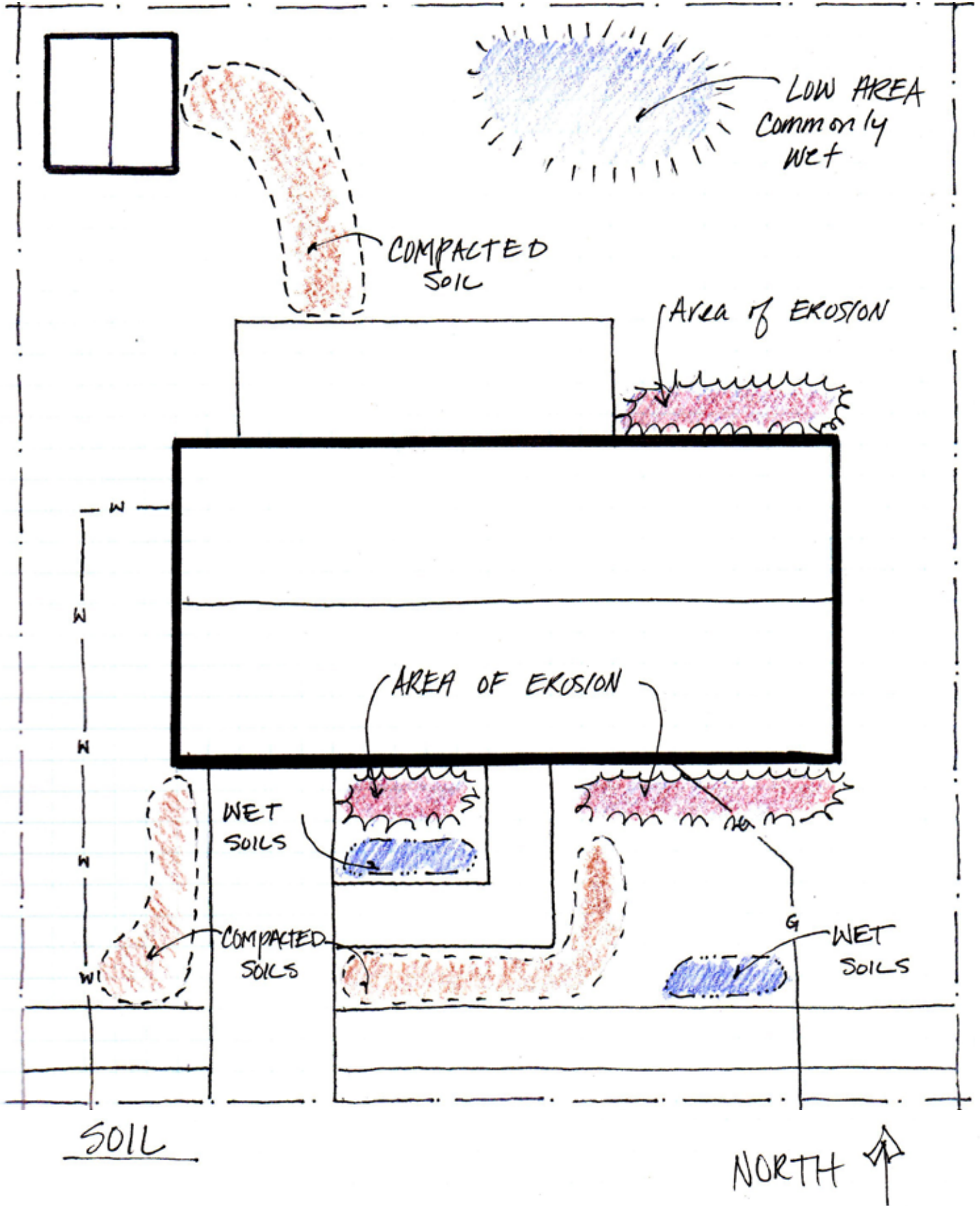
### Example: Basemap



PROPERTY BASEMAP



### Example: Soil Assessment



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# 2



HAWKEYE978, BIGSTOCK

## Class Preparation Checklist

- Prepare computer, projector, screen, and other necessary items required to lead the Class Two PowerPoint presentation
- Gather supplies for class demonstration: How to build a compost pile or vermicompost bin, page 52
- Research local freshwater source and the number of people who rely on the resource
- Research population projections for the area and be prepared to discuss how population growth will impact the local water supply

# Class 2

## Lesson 3: Successful Soil Practices

## Lesson 4: The Role of Water in Sustainable Gardens

**Learning objectives** *After completing this class students will be able to:*

### Lesson 3

- Describe how to work with soils to create successful gardens
- Explain techniques that can be employed to maintain soil fertility

### Lesson 4

- Explain why water conservation is important
- Compare the water use of sustainable and unsustainable gardens
- Identify gardening practices that contribute to water shortages and pollution

## Using the results of the jar test to determining soil texture

### Follow-up Activity

Before starting Lesson 3, review the results of the jar test activity introduced in Lesson 2, pg. 28. Refer to the information below to learn how a soil texture triangle can be used in conjunction with the results of the jar test to determine soil texture/structure.



### Using the Soil Texture Triangle

Scientists divide the soil texture triangle into 12 textural classes, based on the proportions of sand, silt, and clay. To use the soil texture triangle to determine textural class, calculate the percentages of sand, silt, and clay in the jar. The position of sand, silt, and clay are dependent on the size and weight of each of the particle types. Sand should sink to the bottom of the jar due to its relatively large size. In addition to its position, the sand layer is typically lighter in color than the silt or clay soil layers. Silt, being the middle-sized particle, is found between the sand and clay layer. The clay layer, with the smallest sized particles, is found at the very top of the soil layers.

After identifying each of the soil types in the jar, place a ruler against the outside to measure the 1) total amount of soil in the jar in centimeters and 2) the amount of each soil type in centimeters. The final percentage of sand, silt, and clay can be found by dividing each of the soil types by the total amount of soil in the jar and then multiplying by 100.

**Percent of sand** = (amount of sand in cm/ total amount of soil in cm) × 100

**Percent of silt** = (amount of silt in cm/ total amount of soil in cm) × 100

**Percent of clay** = (amount of clay in cm/ total amount of soil in cm) × 100

Compare each of these percentages to the soil texture triangle (page 26 and Appendix 3) to determine the texture class. First, locate the percentage of clay in their soil on the left side of the triangle and follow the purple line across. Next, find the percentage of sand along the bottom of the triangle and follow the blue line up to where it intersects with the purple line. The green line at this intersection represents the percentage of silt in the soil sample. The shaded area that contains the point where the lines intersect is the soil's textural class. As a class, briefly discuss the results of this activity.

If students have measurements from their own jar test(s), take some time to aid them in determining their soil texture. Otherwise, ask students to use the information presented above when they are at home to determine their soil texture. Students should record the results of their test(s) on the soil assessment map and bring this information to the next class.



# Lesson 3

## Successful Soil Practices



### Overview

In this second soil lesson, homeowners will learn how to work with their existing soil to create successful and sustainable gardens. The lesson discusses strategies for improving damaged soils along with stewardship practices that will support gardeners in maintaining soil health.

## Working with existing soil to create sustainable gardens



MRS. W.D. BRANSFORD

**California poppy**  
(*Eschscholzia californica*)

Too often, gardeners try to amend or modify their soils to fit the needs of poorly selected vegetation. Continually modifying soils and adding water, fertilizers, pesticides, and other elements can be wasteful, inefficient, and damaging to the environment. Sustainable gardens can save a homeowner resources, time, and money by incorporating plants that are well adapted to surviving in the sites existing soil conditions.

### Sandy Soils

Plant roots can grow with ease in sandy soils, but water drains quickly and nutrient ions do not readily bind to sand particles. As a result, sandy soils can lack moisture and nutrients.

Strategies for working with sandy soil:

- ▶ Grow drought-tolerant plants that are **native** to sandy soils or can adapt well to these conditions. In California, for example, good choices include lavenders (*Lavandula*), California lilac (*Ceanothus*), and California poppy (*Eschscholzia californica*).
- ▶ Incorporate organic matter into the soil to improve water retention. Organic matter decomposes relatively quickly in sandy soils; to address this issue, add a mix of materials in various stages of **decomposition** such as **humus**, straw, or shredded bark.
- ▶ Mulch planting beds to retain water.
- ▶ Frequently provide plants with small amounts of water, to give plant roots the moisture they need while minimizing the leaching of nutrients.
- ▶ Grow **green manures**, such as clover, to add organic matter and nitrogen.



SHAW NATURE PRESERVE

**Purple coneflower**  
(*Echinacea purpurea*)

### Clay Soils

Soils with heavy clay content typically lack good drainage and aeration. Clay soils are prone to compaction and when dry can become very hard. However, clay soils can hold on to nutrients and are generally quite fertile.

Strategies for working with clay soil:

- ▶ Grow plants adapted to heavy soils. In the Midwest and Southern Plains, for example, good choices include purple coneflower (*Echinacea purpurea*), prairie blazing star (*Liatris pycnostachya*), and lanceleaf coreopsis (*Coreopsis lanceolata*).
- ▶ Improve aeration and drainage by working organic matter into the soil.
- ▶ Use a fork rather than a shovel when cultivating the soil.
- ▶ Work the soil only when it is moist, not dry or wet, to avoid compacting. Let large clods air dry before breaking them up with a rake.
- ▶ Apply mulch to maintain organic matter. Mulch also helps minimize compaction from rain and shields the soil from the sun.
- ▶ Install pathways in the garden to minimize compaction from foot traffic.
- ▶ Irrigate the soil slowly to avoid waterlogging.



SALLY AND ANDY WASOWSKI

**River birch**  
(*Betula nigra*)

### Wet Soils

In wet or poorly drained soils, pore spaces are **waterlogged** and aeration is poor. Plants not adapted to continually wet soils will suffer from disease, decline, and eventual death.

Strategies for working with wet soil:

- ▶ Grow plants adapted to wet soils. In the eastern states, for example, good choices include river birch (*Betula nigra*), summersweet (*Clethra alnifolia*), and goatsbeard (*Aruncus divicus*).
- ▶ Create raised beds.
- ▶ Divert rainwater from the waterlogged area using practices such as rainwater harvesting or bioswales.



SALLY AND ANDY WASOWSKI

**Orange azalea**  
(*Rhododendron austrinum*)

### Acid Soils

Acid or “sour” soils are often found in areas where rainwater leaches calcium and magnesium from the soil. **Acid rain** and fertilizers can also acidify the soil. Most garden plants do best in slightly acidic soil, with a pH of 6.2 to 6.8, but typically can tolerate levels as low as 5.5.

Strategies for working with acid soil:

- ▶ Grow plants adapted to acidic soils. In the east, for example, good choices include azaleas and rhododendrons (*Rhododendron spp.*), hydrangeas (*Hydrangea spp.*), and bayberries (*Myrica spp.*).
- ▶ Certain animal manures, leguminous **cover crops**, or compost to help raise a soil’s pH. Mix in 1 to 3 inches of compost, then mulch with the same amount every year.



SALLY AND ANDY WASOWSKI

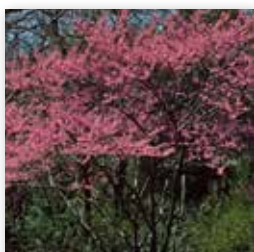
**Eastern persimmon**  
(*Diospyros virginiana*)

### Alkaline Soils

Alkaline or “sweet” soils have a pH higher than neutral, or 7. These soils are common in arid regions like the southwestern US, where **evaporation** exceeds precipitation and calcium and magnesium accumulate in the soil. Nitrate-based fertilizers can also raise soil pH. When soil pH is higher than 8, the solubility and ultimate availability of nutrients to plants is significantly reduced.

Strategies for working with alkaline soil:

- ▶ Grow plants adapted to alkaline soils. In the Midwest, for example, good choices include eastern persimmon (*Diospyros virginiana*) and redbud (*Cercis canadensis*).
- ▶ Use compost made from oak leaves, sawdust, or other wood products that can gradually lower soil pH.
- ▶ Grow vegetables and herbs in raised beds that contain compost-rich soil.
- ▶ Mulch with pine needles or shredded pine bark, which help acidify the soil over time.



SALLY AND ANDY WASOWSKI

**Eastern redbud**  
(*Cercis Canadensis*)

### Saline Soils

Saline soils are often found in arid, poorly drained, and coastal regions. In arid areas with a high **water table**, dissolved salts are pulled up from the groundwater by **capillary action**. In coastal areas, wind-blown salt from the ocean builds up in the soil. Fertilizers can also

increase salinity, and in some areas the use of salt on roads can contribute to the problem. Soil tests such as those conducted to determine pH can also establish the salinity of soils.

Strategies for working with saline soil:



**Alpine Aster**  
(*Aster alpinus*)

- ▶ Grow plants adapted to saline soils. In the eastern US, for example, good choices include redbuds (*Cercis spp.*), summersweet (*Clethra alnifolia*), common lilac (*Syringa vulgaris*), and phlox (*Phlox spp.*).
- ▶ In arid areas, use mulch to lessen salt accumulation by reducing evaporation at the soil surface. Avoid mulching with animal manures or other organic materials that are high in salt or those, such as wood ash, that can raise soil pH.
- ▶ Incorporate compost or other organic materials that are low in salt, if soil drainage is poor.

### Shallow Soils

Shallow soils constrict plant roots, may be nutrient-deficient, and tend to dry out quickly. They typically consist of a thin layer of soil on top of a dense, clay subsoil or bedrock. Shallow soils can also be caused when builders scrape away the topsoil at a construction site.

Strategies for working with shallow soil:

- ▶ If topsoil is naturally thin, grow shallow-rooted, drought-tolerant plants adapted to rocky habitats. In the Pacific Northwest, for example, good choices include alpine aster (*Aster alpinus*), harebell (*Campanula rotundifolia*), and meadow pink (*Dianthus deltoides*).
- ▶ Garden in raised planting beds.
- ▶ To repair soils around recently constructed homes, incorporate compost and green manures, and mulch with shredded leaves, bark, or other organic material.

### Compacted Soils

Healthy soil typically has more than 40 percent pore space, ranging from large pores, which promote drainage, to small pores, which help store water. This combination enables air and water to penetrate, promotes good drainage, and allows soil organisms to flourish and plant roots to grow. Compaction by machinery, foot traffic, and pounding rain makes sustaining life in the soil difficult. Compacted soils can flood and also be droughty, since water runs off rather than infiltrating. Repair compacted soils by rebuilding its spongy structure.

Strategies for working with overly compacted soils:

- ▶ Top-dress planting beds with several inches of compost to improve lightly compacted soils. Earthworms and other soil **fauna** will gradually pull the compost down into the soil, loosening the soil and improving water-holding capacity. A 2- or 3-inch layer of shredded leaf mulch or wood chips will provide similar benefits.
- ▶ Cultivate the soil lightly, taking caution to avoid large plant roots. Incorporating compost into the soil can speed up the healing process.
- ▶ Use more extreme physical aeration techniques to repair highly compacted soils. Be

cautious when working under and around existing vegetation to avoid damaging the root system. Tree experts can provide guidance on the most appropriate methods, which may include air-excavating tools, **vertical mulching**, or **radial trenching**.

- › Protect the soil from re-compaction. Create pathways and use garden walls, fences, or mulches to keep foot traffic off the soil.

Strategies for protecting garden soils from compaction:

- › Avoid working garden soils when wet.
- › Avoid leaving soils bare. Cover soils with either vegetation or mulch.
- › Create pathways and designated areas for walking and driving.
- › Use walls, fences, and mulch to protect gardens from foot and vehicular traffic.

### **Special considerations for gardens that are being newly developed or redeveloped**

The development of a property can have a profound effect on soil quality. The increase in heavy equipment and overall traffic during this process can easily lead to the compaction of soils. By reducing air and water movement, soil compaction greatly inhibits the growth and vitality of plants and soil microorganisms. Toxic chemicals from materials used during the construction process can leach into the soil, further degrading quality. In areas that are undergoing development, it is important to establish a strategy for protecting soils.

Strategies for protecting soils from development:

- › Prior to development, conduct a site analysis, mapping areas of healthy soils and minimal, moderate, and severe compaction. To the greatest extent practicable, avoid **grading**, vegetation removal, or other disturbances to healthy soils. Have site features that require soil disturbance and compaction, such as driveways, building foundations, and patios constructed in areas where soil is degraded.
- › Work with the building and landscape practitioners to develop a soil preservation plan. The plan should clearly outline the areas that are not to be disturbed. Areas to be preserved should be fenced off and preservation directives should be clearly communicated to construction personnel.
- › During construction, enforce tight limits on disturbance by defining perimeters around constructed features. As a general guideline, SITES recommends that disturbance be limited to 40 feet (12m) beyond the building perimeter; 10 feet (3m) beyond surface walkways, patios, parking, and utilities that are less than 12 inches (30cm) in diameter; 15 feet (6m) beyond primary roadways curbs and main utility branch trenches; and 25 feet (8m) beyond constructed areas with permeable surfaces, such as stormwater detention facilities and recreational fields.
- › Work with the building and landscape practitioners to designate areas for on-site parking and equipment/ material storage. Prioritize the use of areas that are already degraded or will be compacted in order to support a future use, such as patio, driveway,

or building site. Explore options to use existing roads or parking areas adjacent to the property for access and storage.

- › In areas where compaction cannot be avoided, carefully harvest and store the topsoil for reuse.
- › During the construction process, spread thick layers of mulch over areas of soil that may receive occasional traffic. Sheets of plywood can be added on top of the mulch to help spread the weight in areas of repeated traffic.
- › Use the lightest equipment possible to complete the job.

## Soil fertility

### Essential Macronutrients

The elements essential to plant health are classified as **macronutrients**, which are needed in large quantities and micronutrients, which are required in minute amounts. Both are necessary for healthy plants. The primary macronutrients are nitrogen (N), phosphorus (P), and potassium (K). The relative proportions of these nutrients are listed as N-P-K on fertilizer labels. Fertilizers may be either natural or synthetic. There are advantages and disadvantages to the use of both types. Although natural fertilizers can cost significantly more, take longer to apply, and see the results than synthetic, they can offer a number of benefits.

Benefits of using natural over synthetic fertilizer:

- › They are made from natural sources that use lower amounts of **fossil fuels** during the production process, potentially leading to the release of less **greenhouse gas** into the atmosphere.
- › When compared to some quick-release synthetic fertilizers, they are released more slowly, helping to reduce the runoff of nutrients into nearby waterways.
- › Nutrients are released only when soil is warm and moist, coinciding with times when need is greatest.
- › Over time they can improve quality of soil by promoting microbial populations that support nutrient holding capacity, proper soil structure, and **pathogen** suppression.

**NITROGEN (N)** Nitrogen is necessary for **photosynthesis** and energy production. It promotes the uptake of other nutrients and depending on environmental conditions it either stimulates plant top (leaves and shoots) or root growth. Plants deficient in nitrogen tend to be **chlorotic**, or pale yellowish green, and stunted with thin, spindly stems. Most nitrogen is derived from the decomposition of organic matter and **nitrogen fixation** by bacteria. To maintain nitrogen levels in fertile soils, gardeners should mimic natural processes by mulching with compost or other organic matter. Blood meal, other natural fertilizers, or nitrogen-fixing green manures can increase the nitrogen levels of infertile

soils.

**PHOSPHORUS (P)** Phosphorus is essential for energy utilization, nitrogen fixation, flowering, fruiting, and seed production. It also encourages root development. Symptoms of phosphorus deficiency include delayed flowering or fruit set and a purplish cast on leaves and stems. Bone meal is a natural fertilizer high in phosphorous that also contains calcium. It is commonly used early in the season during planting. Bone meal is a slow-acting and long-lasting fertilizer. Because bone meal may attract animals, it is commonly mixed with compost and added to the soil.

**POTASSIUM (K)** Potassium is known to activate 80 enzymes responsible for basic plant processes such as photosynthesis and carbohydrate metabolism. It is critical to reducing the loss of water from leaves and increases the ability of the roots to take up water. Adequate soil potassium is linked to improved **drought tolerance**, improved winter **hardiness**, better resistance to some fungal disease, and greater tolerance of insect pests. When plants suffer from potassium deficiency, the tips and edges of the oldest leaves become scorched, chlorotic, and may eventually die back. Compost can help maintain good potassium levels in fertile soil, while kelp meal can help raise potassium levels in deficient soils. Composted wood ash is another source of potassium, but should be used only on acidic soils.

### **Micronutrients**

Other nutrients are considered secondary because they are typically found in sufficient quantities in the soil and no amendments are required. Secondary nutrients include calcium, magnesium, and sulfur. Micronutrients or trace elements include iron, boron, copper, manganese, zinc, chlorine, and molybdenum. With the exception of calcium and magnesium, micronutrient deficiencies are generally uncommon, and a balanced supply can be maintained with regular applications of organic matter.

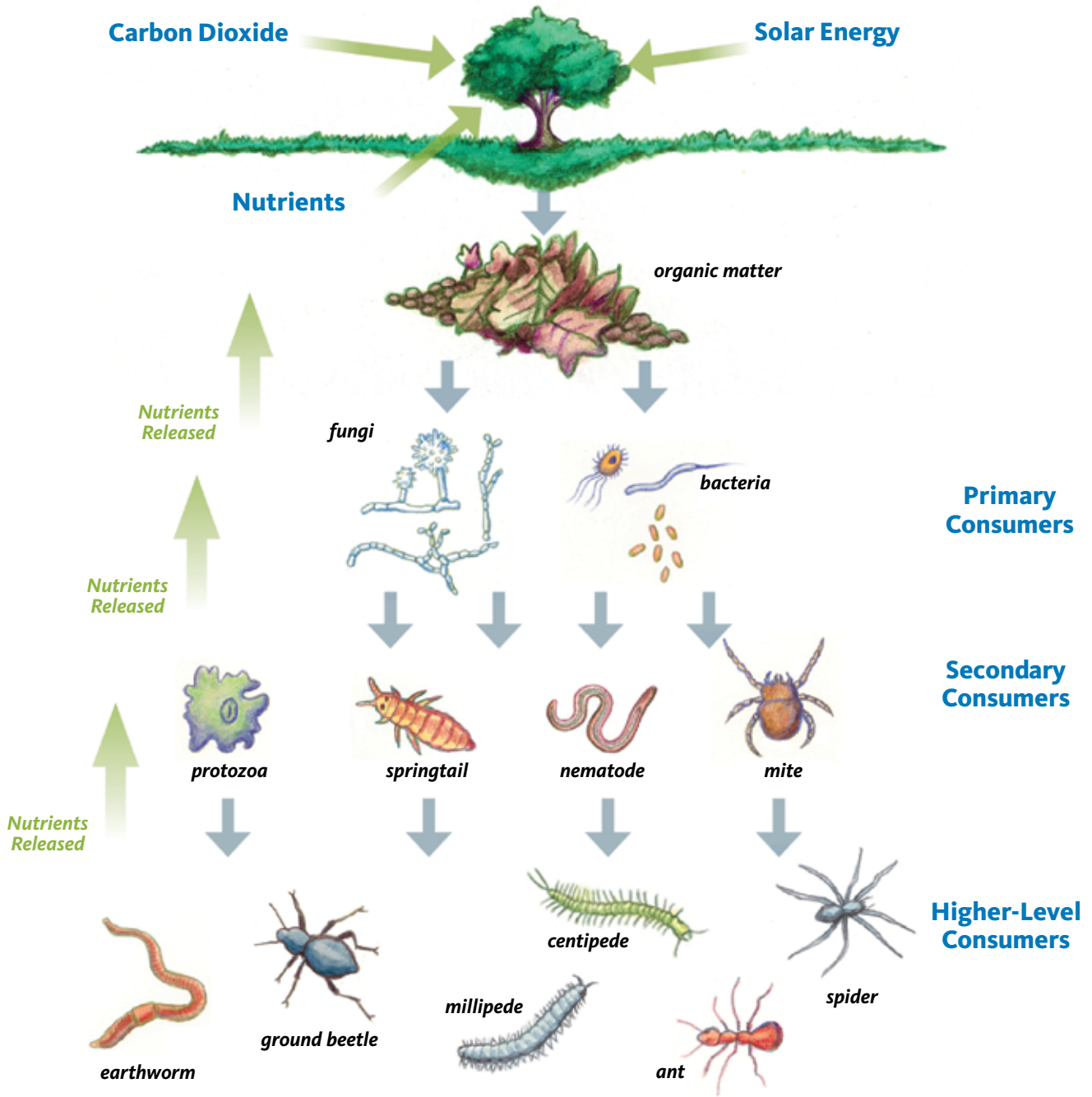
Most often calcium and magnesium deficiency appears as an imbalance between the two micronutrients. This is especially common when dolomitic lime is used repetitively to increase magnesium relative to calcium. Calcium levels are ideally twice that of magnesium or 2:1. While there may be adequate calcium in the soil, if the ratio to magnesium decreases, it can become deficient in plants. To remedy this, use calcitic lime for low pH soils or gypsum ( $\text{CaSO}_4$ ) if soil pH is in the desired range.

## **Tips to maintaining soil fertility**

### **Establishing a Diverse Community of Soil Organisms**

The **soil food web** is the key to fertile soil. This diverse community of organisms making up the soil food web can be organized into functional groups depending on how they obtain energy. Plants are producers—they use the sun's energy to convert water and carbon dioxide into food (carbohydrates) via photosynthesis. **Primary consumers**

### Soil Food Web



The soil food web is the key to fertile soil. It is made up of primary, secondary, and higher-level consumers that support each other in producing healthy, nutrient-rich soils.



included herbivores (mainly animals) and **decomposers** (mainly fungi and bacteria) and are capable of obtaining energy by digesting leaves and other plant matter. Secondary consumers feed on primary consumers, then release nutrients that can be absorbed directly by plants, as well as undigested remains that become part of the organic soil matter. Higher-level consumers feed on **secondary consumers**. Their fecal pellets and undigested remains also return nutrients to soil.

The production and breakdown of organic matter by organisms maintains soil fertility and in turn aids in healthy plant growth, nutrient cycling, pollutant removal, and improved soil structure. In order to maintain these ecosystem services, we need to support the basic needs of soil organisms by providing air, water, nutrients, and a hospitable soil environment.

Strategies for protecting and encouraging soil organisms:

- › Limit soil disturbance and tillage.
- › Restore overly compacted soils to allow air and water movement.
- › Avoid leaving soils bare by covering soils with plants or mulch. Regularly apply layers of compost or organic mulch to the top of the soil.
- › Avoid pesticide use that may harm soil biota.
- › Plant a diverse garden to provide a variety of food sources.
- › Grasscycle—use a lawn mower that returns mulched lawn clippings to the soil.
- › Allow leaves and other plant materials to decompose throughout the garden.

### **Convert greenwaste into compost**

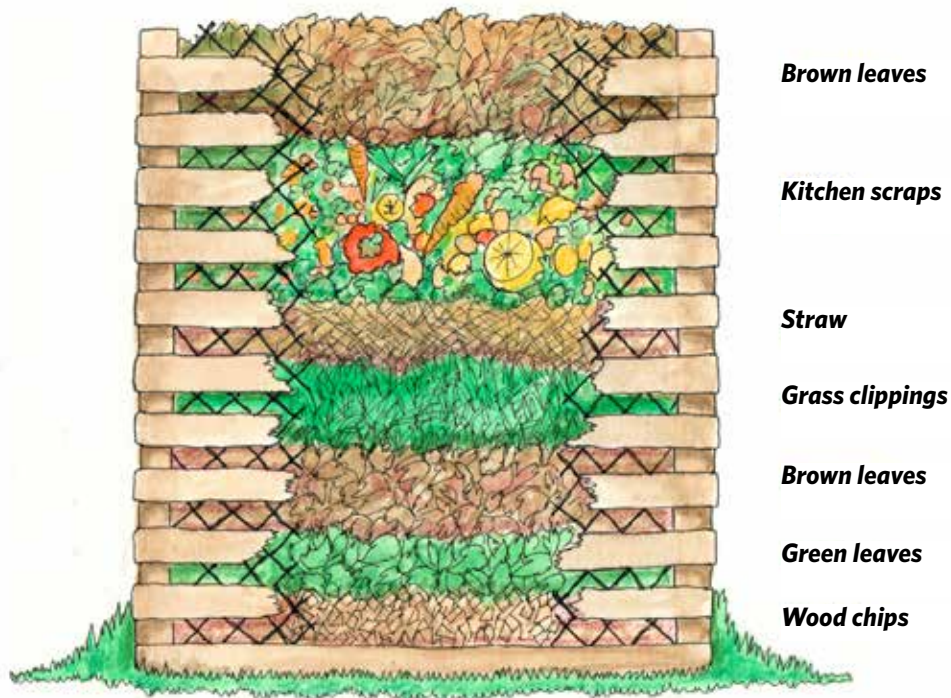
**Compost Piles**—By converting our **greenwaste** into compost, we can help add nutrients to the soil by making use of the same natural recycling that occurs every day in nature. This process, called decomposition, can take years; however, when you create a compost pile, you can speed the process by providing fungi, bacteria, and other decomposers with the materials they need to recycle much faster. A one-inch-thick topdressing of compost on planting beds is generally all that is needed to maintain healthy soils and provide plants with a balanced source of nutrients. Also, composting keeps valuable organic materials out of landfills.

### **How to Build a Compost Pile—**

- › **DETERMINE APPROPRIATE LOCATION** Locate compost pile in a well-drained spot that is shaded from the hot afternoon sun.
- › **PURCHASE OR BUILD BIN** Purchase or build a compost bin to keep organic material in and wildlife out. The bin should be about 4 feet in diameter and 3 feet high.

- › **FILL BIN WITH NUTRIENTS TO SUPPORT DECOMPOSERS** Fungi, bacteria, and other decomposers need a balanced diet of carbon (C) and nitrogen (N). Fill the bin with alternating layers of high-carbon “brown” materials, such as leaves, newspaper, and chipped woody trimmings and nitrogen-rich “green” materials, such as grass clippings and other green garden trimmings and kitchen scraps. This will provide the support a C:N ratio of 30:1, conserving the most nitrogen and carbon in the finished compost.
- › **PROVIDE MOISTURE** Nature’s recyclers also need moisture. Turn the pile with a garden fork as often as necessary to keep the materials damp to the touch. If the materials are wet, turn the pile to increase aeration. However, too much air will dry out the pile and slow decomposition. If it feels dry, add water as you turn over the pile.
- › **MAXIMIZE AIRFLOW** Maximize airflow by shredding materials before adding them to the pile and by building the compost pile on a foundation of wood chips or other coarse organic material.
- › **ESTABLISH A SECOND BIN FOR NEW MATERIAL** It’s a good idea to have two

### Layers of a Compost Pile



*A healthy compost pile has alternating layers of high-carbon “brown” materials, such as dry leaves, straw, and woody trimmings; nitrogen-rich “green” materials, such as fresh grass clippings; and “wet” or green garden trimmings and kitchen scraps. To encourage air flow, it’s a good idea to build your compost pile on a foundation of wood chips or other coarse organic matter.*

compost piles—a full pile that is “finishing” and another for adding new material.

- › **DETERMINE IF COMPOST IS READY FOR USE** Finished compost is dark in color and smells earthy, like soil. Usually, it’s difficult to recognize any of the original ingredients. But there’s no single point at which compost is finished—it depends on how you want to use it. For most garden applications, it’s fine to use compost that still has a few recognizable bits of leaves or twigs, which will finish rotting in the soil. If gardeners plan to use compost in seed-starting mixes, it is better to use highly finished compost.

**Vermicomposting—Composting with Worms—**Vermicomposting, or composting with earthworms, is an excellent way to turn food scraps into a garden resource in an apartment building or other setting where space is limited.



SHENAGENZLUK

**Worms from a  
compost pile**

The most common types of earthworms used for vermicomposting are redworms or “red wigglers” (*Eisenia fetida*)—not to be confused with the common earthworm (*Allolobophora caliginosa* and other species) found in garden soil. Worms for vermicomposting can be purchased from online vendors or garden stores.

Redworms break down food waste and other organic residues into nutrient-rich compost, which often has nutrient levels higher than traditional compost. It is estimated that two pounds of earthworms can recycle one pound of food waste in a 24-hour period. When finished, vermicompost has a rich, earthy smell and can be mixed with potting soils or directly applied to benefit lawns or gardens.

Gardeners should take care to contain worms that are not native to the area. Like other non-native species, worms can cause damage when introduced to new environments.

### **How to Make Vermicompost—**

- › **MAKE A WORM BIN** A variety of untreated wood or plastic containers can be used to make a worm bin. When using recycled containers, ensure that it is clean and has never stored pesticides or other toxic materials. It is recommended that the bins be opaque and no more than 8 to 12 inches deep. The appropriate size of the bin depends on the amount of food waste generated. On average, two people produce approximately 4 pounds of food waste each week. As a general rule, approximately one square foot of surface area is required per pound of waste.
- › **DRILL HOLES** Drill air and drainage holes approximately ¼ to ½ inch diameter in the sides and bottom of the bin. Slightly raise the bin with bricks or blocks and provide a tray to catch excess water, which can be used as a liquid fertilizer.
- › **ADD BEDDING MATERIAL** Bedding serves as both habitat and food for the worms. A variety of materials such as shredded non-glossy newspapers, cardboard, leaves, aged straw, or hay can be used. Approximately two pounds (dry weight) of bedding material is needed for each square foot of bin. Two handfuls of soil or sand will supply the worms

with roughage. Bedding material should be moistened to the point where it is wet but not dripping and spread evenly across the bin. Because the worms consume the bedding, additional materials will need to be added periodically with food waste.

- › **ADD WORMS ON TOP OF THE BEDDING** Exposing the worms to light will encourage them to bury themselves in the bedding.
- › **ADD FOOD WASTE** Earthworms eat all kinds of food and yard waste including coffee grounds, tea bags, vegetable/fruit scraps, and pulverized egg shells. As with compost, add citrus sparingly and avoid introducing bones, dairy products, or meats. Because worm can feed as little as once a week, burying food scraps every couple of days in different areas of the bin should be sufficient.
- › **COVER BIN** Cover the bin to conserve moisture and exclude sunlight. Outdoor bins should be protected from freezing weather, extreme heat, and rain.
- › **HARVEST** After about 6 weeks you will begin to see worm castings. The average bin will need emptying every 3 to 4 months. Worm castings can be gathered by placing small piles of the compost in the sun. After several minutes, the worms will move towards the bottom of the pile to avoid the sunlight, allowing you to harvest the

## How to build a compost pile or vermicompost bin

### Activity

*After reviewing the composting instruction in the classroom, instructors may choose to go outdoors for a demonstration.*

#### Supplies:

##### Compost pile

- Compost bin
- Brown materials such as leaves, newspapers or chipped wood trimmings
- Green materials such grass clippings, fresh garden clippings, or kitchen scraps
- Garden fork or shovel
- Water
- Example of finished compost

##### Vermicompost

- Worm bin
- Bedding material such as shredded newspaper or cardboard, leaves, or straw
- Two cups of garden soil
- Water
- Food scraps
- Red worms
- Worm castings to serve as an example of the finished product

compost from the top of the pile. Another option for separating the worms from the compost is to sift the materials through a small screen to separate them. Complete this process by sifting out and discarding the large particles from the rest of the gathered compost.

### Apply Organic Mulches

When we apply mulch to a garden, we mimic one of nature's fundamental processes. Many plant communities naturally generate healthy layers of organic litter. Consider what happens in a **deciduous** forest, one of nature's champion mulchers. The leaves shed in autumn are transformed by the soil's natural food web into plant food and the rich organic matter called **humus**. In addition to helping to maintain soil fertility, the blanket of organic matter protects plant roots from extremes of temperature, limits soil erosion, and conserves soil moisture that otherwise would evaporate.

The benefits of applying mulch are many and wide ranging:

- › Conserves water by shading the soil and reducing evaporation.
- › Insulates roots by moderating soil temperatures.
- › Cushions the impact of downpours and helps prevent soil compaction, allowing water to penetrate and plant roots to breathe.
- › Decomposes and adds nutrients and organic matter to the soil, improving water retention and nurturing the soil fauna that promote fertility.
- › Creates the conditions that help plants thrive, making them less vulnerable to pests and diseases.
- › Suppresses weeds, reducing the need for regular cultivation.

Inorganic mulches, such as crushed stone and recycled rubber chips are appropriate for rock gardens, driveways, and paths. In most **climates** and situations, organic mulches are preferable for planting beds because they eventually break down and enrich the soil.

Bagged mulches are commercially available, but you can save money and reduce the carbon footprint of the garden by mulching fallen leaves and other organic materials. Recycling them in the yard also keeps them out of the local landfill.

#### Tips for Applying Mulch—

- › **DETERMINE MULCH THICKNESS** For best results, most mulches should be about 3 inches deep. The optimum mulch depth also depends on the soil type. Sandy soil, which loses moisture rapidly benefits from a thicker mulch than clay soil, which tends to retain water.
- › **REMOVE EXISTING WEEDS** Before applying mulch, pull any existing weeds or smother

them with a layer of newspaper.

- › **AVOID PLACING MULCH NEXT TO BASE OF PLANTS** To avoid diseases, place mulch an inch or two back from the base of plants.
- › **DECIDE WHEN TO MULCH** The best time to spread mulch around heat-loving vegetables like peppers and tomatoes is after the soil has warmed, usually mid or late spring. Cabbages, greens, and other cool-weather crops can be mulched earlier. Mulches around shrubs and perennials will offer the best protection against winter cold if laid down in early winter, when the soil has cooled but not frozen hard. Mulch can be applied anytime in herbaceous perennial beds and around trees and shrubs. Recycled holiday trees and trimmings are great for this purpose.
- › **MULCH AFTER SEEDLINGS HAVE ESTABLISHED** Don't mulch seedlings planted in very moist soils because excessive wetness is an invitation for **damping-off**, an often fatal fungal disease. Once seedlings are established, it is safe to mulch.
- › **DETERMINE WHEN MULCH NEEDS TO BE REAPPLIED** Because organic mulches eventually break down and become part of the soil, they need to be renewed every two

*Homeowners can create their own mulch or compost from yard trimmings such as branches, leaves, and grass clippings.*



*Mulch can be created from a variety of materials including pecan hulls, as shown in the picture to the right.*



HEATHER VENHAUS

or three years, depending on the climate and the type used.

#### **Some Recommended Organic Mulches—**

- › **LEAVES** Leaves make a great and inexpensive organic mulch. Apply a layer 2 to 3 inches thick. Partially shredded leaves are less likely to mat and shed water than whole leaves; homeowners can run leaves through a shredder or pass the lawn mower over them a few times before mulching to produce a better mulch. Leaves with a lot of **cellulose**, such as oak leaves, are very slow to break down so composting them with some grass clippings for a week or two will improve mulch quality.
- › **BARK** Bark mulches should be applied 3 to 4 inches deep. Because it is a byproduct of the lumber industry, bark is preferable to wood chips, which may be made from trees felled solely for the manufacture of mulch. Look for products expressly labeled “bark mulch,” not just wood or hardwood mulch. Avoid dyed mulches.
- › **WOOD CHIPS** when obtained from local arborists who create them from their daily prunings, wood chips are a good choice and may even be available for free. Three to four inches is the proper application depth. There is some evidence that freshly chipped

wood can rob nitrogen from soil. To address this issue, homeowners can compost them first, or let them “season” in a pile for a few weeks, especially if the wood chips will be used in a vegetable garden.

- › **PINE NEEDLES** Pine needles are light and don’t get compacted, so water penetrates easily. Apply a layer 4 to 6 inches thick. Because they tend to lower soil pH, they’re best used around acid-loving plants.
- › **NUTSHELLS** If nutshells are an agricultural byproduct in the area, they are a good choice. Apply them about 2 inches deep. Shells tend to look a bit more formal than other mulches. Beware of cocoa hulls, a by-product of chocolate processing, which contain compounds toxic to dogs.
- › **STRAW** Straw is an effective mulch when applied 6 to 8 inches deep; however, be sure you to purchase straw and not hay, which can be full of weed seeds.
- › **COMPOST** Annually topdressing planting beds with an inch of compost will provide most plants with a balanced source of nutrients.

### **Plant Green Manure Cover Crops**

Growing green manures, grains, and legumes as cover crops, is a good way to increase the amount of organic matter and nutrients in soil. Cover crops reduce the need for fertilizer. They also help suppress weeds, aerate the soil, increase its capacity to conserve moisture, and protect it from being compacted by rain and eroded by water or wind. Grains such as wheat and oats are especially good at increasing soil organic matter. In addition to adding organic matter, leguminous cover crops, like alfalfa, clovers, or cow peas, which contain nitrogen-fixing bacteria in their root nodules, remove nitrogen from the atmosphere and make it available in soil. Some gardeners use green manures to cover bare vegetable beds in winter months.

Strategies for growing cover crops:

- › For multiple benefits, grow grains and legumes together.
- › Plant winter cover crops at least four weeks before the expected first hard frost date to get them off to a good start.
- › Plant cover crops with large seeds, like peas, in shallow, closely spaced furrows. **Broadcast** those with small seeds and then rake lightly to cover.
- › If the weather is dry, water to keep the soil slightly moist until the cover crop is established.
- › **Till** cover crops into the soil in spring, just before flowering, or about three weeks before planting to give the organic matter time to start breaking down.
- › Avoid cover crops that are **invasive** in your region.



### Appropriate Fertilizer Use

The goal of applying fertilizer is to provide just enough to supply the needs of the plant. Too much fertilizer can run off into nearby waters, leach into groundwater, or lead to weed problems. A plant's health should be the guide. If plants suffer from a lack of vigor, retarded growth, sparse foliage, or leaf discoloration, they may be nutrient deficient, although improper drainage or inadequate aeration are also likely causes.

#### Strategies for Appropriate Fertilizer Use—

- › **DON'T APPLY FERTILIZER WITHOUT TESTING YOUR SOIL** Test soil to determine whether there is a nutrient deficiency.
- › **CHOOSE A NATURAL FERTILIZER** If supplemental nutrients are necessary, choose a renewable natural fertilizer, preferably produced locally, over synthetic (petrochemical-based) fertilizer or mined products, such as rock phosphate. Synthetic fertilizers require much more energy to produce than natural options, such as blood meal, bone meal, fish meal or emulsion, and kelp meal.
- › **USE SINGLE NUTRIENT FERTILIZERS** Whenever appropriate, use single-nutrient fertilizers instead of complete fertilizers that contain nitrogen, phosphorus, and potassium. For example, if soil is low in nitrogen but not in phosphorus and potassium, use blood meal, fish emulsion, or other high-nitrogen natural fertilizer. Better yet, grow green manure.
- › **ONLY ADD THE RECOMMENDED AMOUNT** Add only the amount of fertilizer recommended in the soil test, no more. Follow the guidelines on the fertilizer label.
- › **APPLY ONLY TO SOIL** Avoid contributing to water pollution by applying fertilizer only to the soil—not to paved areas—and by sweeping stray particles into the planting bed. Do not use fertilizer near streams or drainage ways.

### Lesson 3

#### Discussion

- *What strategies do you use to maintain soil fertility?*
- *Is there anything that we have not discussed during this lesson that you can add to the list?*
- *What type of organic mulch is available in this area?*
- *Where do you obtain these resources?*



*Recommend a short break while instructor prepares for Lesson 4: The Role of Water in Sustainable Gardens*

## Resources: Soil

### Publications

#### **Interpreting Soil Test Results: What do all the Numbers Mean?**

Pam Hazelton and Brian Murphy  
CSIRO Publishing (2007)

*A guide that explains important soil properties and how to interpret the results of soil laboratory tests.*

#### **Let it Rot!: The Gardener's Guide to Composting**

Stu Campbell  
Story Publishing, LLC (1998)

*A guide to the basic principles of starting and maintaining a composting system.*

#### **Selecting and Using a Soil Testing Laboratory**

University of Maryland Cooperative Extension (revised 2005)  
<http://hgic.umd.edu/documents/SelectingSoilTestLabandSoilTestChart.pdf>

*General information on selecting and using soil testing labs.*

#### **Soil Design Protocols for Landscape Architects and Contractors**

Timothy Craul and Phillip Craul  
John Wiley & Sons, Inc. (2006)

*Provides step-by-step technical skill sets for implementing productive planting soils.*

#### **Teaming with Microbes: The Organic Gardener's Guide to the Soil Food Web, Revised Edition**

Jeff Lowenfels and Wayne Lewis  
Timber Press, Inc. (2010)

*A publication about using organic gardening techniques to strengthen the soil food web and create healthy soils.*

### Useful Websites

#### **A Free Directory of Composting Facilities throughout North America**

Biocycle  
<http://www.findacomposter.com/index.php>

*A searchable webpage that provides lists of local facilities that accept organic waste for composting and/or sell compost.*

#### **Composting for Facilities**

US EPA  
<http://www.epa.gov/compost/>

*This website provides composting and compost application information for compost facilities, businesses, industry, and local governments.*

**Cornell Soil Health**

Cornell University College of Agriculture and Life Science

<http://soilhealth.cals.cornell.edu>

*Information about testing and improving soil health.*

**Soil Texture Calculator**

USDA NRCS

<http://soils.usda.gov/technical/aids/investigations/texture/>

*A web-based calculator that can help determine soil texture.*

**Web Soil Survey**

USDA NRCS

<http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm>

*The National Cooperative Web Soil Survey produced by the USDA Natural Resources Conservation Service (NRCS) provides soil maps and data for most of the United States. In addition, a web soil survey app formatted for mobile devices, allows for real-time access to soil survey data. This app can be downloaded for free at <https://play.google.com/store/apps/details?id=casoilresource.apps.soilweb&hl=en>.*

\*Additional information on soil testing can be found through a local Cooperative Extension Office. A list of offices by state is provided in Appendix 2 of this manual.

# Lesson 4

## The Role of Water in Sustainable Gardens



ED CASTRO LANDSCAPES

### Overview

**C**lean water shortages are quickly becoming one of the most pressing environmental challenges facing humanity. Americans apply more than 7 billion gallons of water a day outdoors. Furthermore, stormwater runoff from gardens and lawns is a major source of water pollution. However, residential properties can be part of the solution. This lesson focuses on water and the important role it plays in garden sustainability. It discusses the Earth's water supplies and explores gardening practices that contribute to freshwater water shortages.

## The Earth's water supply

Much of the earth is covered with water, contributing to it being termed the “water planet.” About 97 percent of the water is ocean saltwater. Most freshwater is locked up in the polar icecaps. Only 0.003 percent of the earth's water is available for human consumption.

Water supports our environment and sustains our lives. It is required for producing food, clothing, and electronics, transporting our waste, and supporting the natural environment. Unfortunately, this already limited resource is becoming even scarcer due to continued pollution and inefficient use. In the US, 36 of the 50 states anticipate freshwater shortages in the next 10 years. We often use **potable water** or drinking water in our gardens without realizing the costs of treating and pumping this water source. Instead of capturing and using stormwater in our gardens, we've created an entire infrastructure of gutters, downspouts, and sewers to rapidly transport it offsite. The resulting runoff can contaminate local waterways with fertilizers, pesticides, and other pollutants. Strategies for successfully reusing stormwater in your home garden will be discussed in the next lesson.

## Garden practices that contribute to water shortages

In regions around the world fresh water is in chronically short supply. Water scarcity has been cited as one of the most pressing issues of the 21st century. In the US, the inefficient use of water resources is a major contributor to the threat of freshwater shortages. Landscape irrigation alone consumes more than 7 billion gallons of freshwater each day. Other unsustainable garden practices further degrade our limited supply of this valuable resource.

Unsustainable garden practices contributing to water shortages:

- › Planting vegetation not suited to local precipitation patterns
- › Employing wasteful irrigation practices
- › Employing practices that degrade soils and limit their infiltration and water-holding capabilities
- › Using impervious building materials that prevent water from infiltrating into the soil and recharging groundwater supplies
- › Treating stormwater as waste and allowing it to runoff the site before it has an opportunity to benefit the garden

### Unsustainable vs. Sustainable Gardens: How They Compare WATER

| Unsustainable Gardens   | Sustainable Gardens  |
|---|--|
| <i>Treats stormwater runoff as a waste product that is quickly removed from the site.</i> | <i>Manages stormwater onsite. Uses stormwater as a resource to sustain the garden.</i>   |
| <i>Uses municipal drinking water for irrigation.</i>                                      | <i>Minimizes the use of potable water. Supplements water in the garden with onsite alternatives such as harvested rainwater or air conditioner condensate.</i> |

### Practices that contribute to water pollution

In healthy gardens soil and vegetation store and clean water. In developed areas, however, much of the land has been paved over, and the soil itself is often too compacted to absorb precipitation or stormwater. Rainfall flows from our roofs to gutters and downspouts, over compacted lawns and driveways into roads, and down storm drains, picking up pollutants along the way. Researchers have found runoff from developed land to be the leading cause of water pollution in urban areas. In many older cities stormwater can overwhelm sanitary sewers, sending raw sewage as well as runoff into nearby waterways.

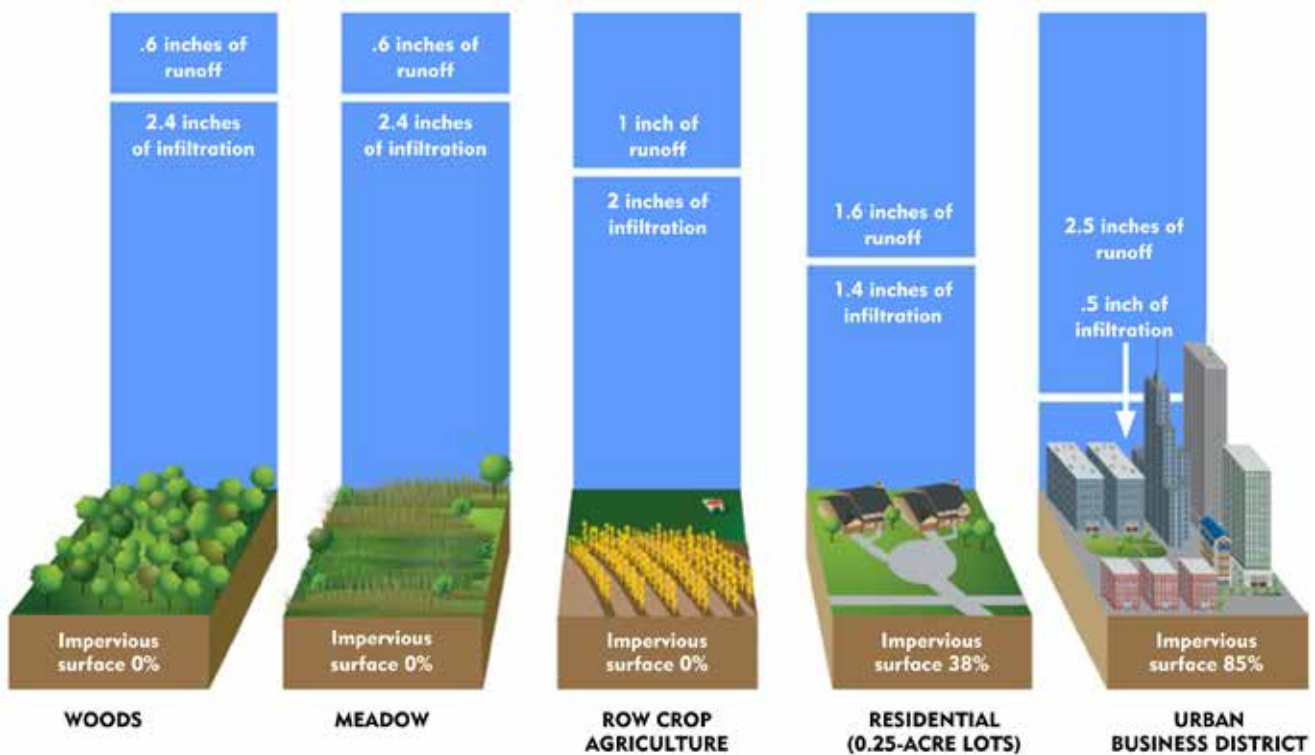
Common sources of stormwater pollution:

- › Fertilizers, herbicides, and insecticides
- › Animal waste
- › Road salt
- › Fluids and particles from automobiles such as oil and gas, brake linings, and tire and engine wear
- › Sediment from improperly managed landscapes
- › Building materials such as copper and zinc roofs or gutters, galvanized materials, and treated lumber
- › Coal tar sealants used on paved roads



**Stormwater overflow from sewers can cause pollution of nearby waterways.**

## Runoff and Infiltration Rates as a Function of Impervious Surface



The illustration above shows the percentage of impervious surface and the amount of infiltration and runoff following a 3-inch rainstorm for each landscape type. Increased development and the associated impervious surfaces significantly reduce the soil's ability to absorb stormwater. The resulting runoff transfers pollutants and damages nearby ecosystems.

### Lesson 4

#### Discussion

To lead this discussion, instructors will need to conduct outside research prior to beginning this lesson.

- What is the local freshwater source?
- How many people rely upon the resource?
- What are the population projections for the area?
- How will this impact the water supply?

## Site Assessment — Water

### Assignment

*Throughout the series, students will be asked to assess and record the conditions of their landscape. During the last class, students' findings and potential design scenarios will be discussed.*

#### **Site Assessment — Water (See example on page 65)**

The assignment for this lesson is to investigate water use, runoff, and aquatic features of landscapes. On the site analysis base map created in the previous lesson, locate any existing water features such as wetlands, shorelines, ponds, streams, or other waterways on or adjacent to your property.

Using trace paper over the basemap, outline the following:

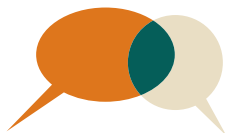
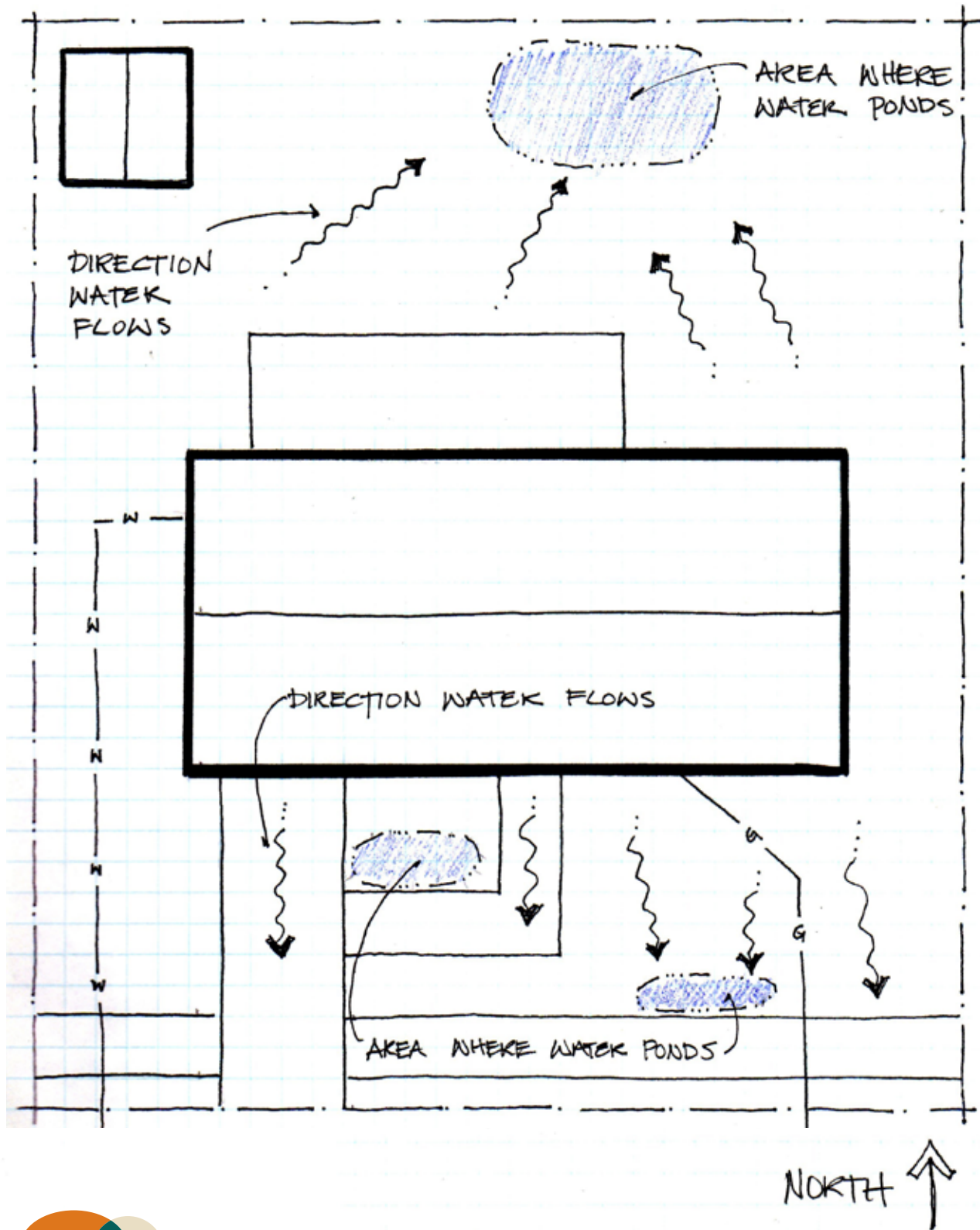
- ▶ Direction water flows across the garden and areas where water pools during storm events.
- ▶ Locations where stormwater runoff is concentrated and eventually leaves the site (e.g., driveways, drainage pipes, storm gutters, etc.).

On a separate sheet of paper, calculate the following:

- ▶ Area of each impervious surface, along with the material type. For example, 2,000 ft<sup>2</sup> shingle roof, 200 ft<sup>2</sup> concrete driveway, 500 ft<sup>2</sup> gravel patio.
- ▶ Amount of water used on the garden. Municipal water bills typically indicate all potable water usage of a property. To calculate the irrigation use, compare municipal water bills between months of heavy irrigation and months where irrigation was not needed or was minimal. The difference between the two is the estimated average garden water use per month.



### Example: Water Assessment



Class Wrap-up: Closing Questions or Comments

# 3



EPA

## Class Preparation Checklist

- Prepare the computer, projector, screen, and other equipment required to lead the Class Three PowerPoint presentation.
- Research the average monthly rainfall that occurs in the local area. Use this information to prepare a chart that illustrates the amount of rainwater that can be harvested from a 2,000 ft<sup>2</sup> house. See page 72 for an example.
- Determine whether greywater reuse and rainwater harvesting are allowed by local water laws. What are the standards and requirements?
- Prepare an example for the class activity: Determine the size of the rain garden needed to capture rainwater runoff from your home, page 78.
- Research the following questions: 1) What did this area look like prior to development? 2) What were the major characteristics of the landscape? 3) What were the dominant native plant communities? See page 86 for an example of the Edwards Plateau region of Texas.
- Determine the local hardiness zone, page 87
- Prepare for the class field trip, "Identifying plants commonly grown in the area," page 89.

# Class 3

## Lesson 5: Successful Water Practices

## Lesson 6: The Role of Plants in Sustainable Gardens

**Learning objectives** *After completing this class students will be able to:*

### Lesson 5

- Explain basic strategies for conserving water in home gardens
- Select and describe specific design techniques used for cleansing and conserving stormwater resources
- Determine how much stormwater can be collected from home gardens

### Lesson 6

- Provide examples of the benefits vegetation can provide to homeowners and the surrounding community
- Explain how gardens and the larger ecoregion interact
- Identify site conditions, including hardiness zones and macroclimates that should be considered in plant selection

# Lesson 5

## Successful Water Practices



LEWIS GINTER BOTANIC GARDEN

### Overview

In this lesson, homeowners will learn how to minimize water waste and create sustainable gardens that benefit not only their family but the surrounding community. The lesson includes information on basic water conservation strategies and specific design techniques that can be used to effectively cleanse and capture stormwater to be used onsite.

## Select plants adapted to local site conditions

Growing plants adapted to the site conditions is one of the basic principles of sustainable gardening. In the upcoming lesson, vegetation that is well-suited to the local climate will be discussed in more detail.

The following are important tips for plant selection and maintenance:

- › **PRESERVE ESTABLISHED VEGETATION** Established plants generally require less water than newly-planted vegetation that has not yet developed deep root systems. When purchasing new plants, select regional natives that are adapted to the local climate and well-suited to the growing conditions of the site.
- › **PLANT AT THE RECOMMENDED TIME** To speed establishment and minimize water use, plant at the recommended time of the year for a particular species.
- › **MINIMIZE LAWN SIZE AND/OR SELECT GRASS SPECIES THAT REQUIRE LESS WATER** Lawn size and type can have a huge impact on the amount of irrigation a garden requires. To minimize water use, choose grass species that require minimal irrigation or look for ways to minimize unnecessary lawn.

## Use water-thrifty irrigation practices

Conventional irrigation practices waste significant amounts of water. Irrigating with traditional sprinklers or when it is hot or windy leads to water loss through evaporation. Watering too quickly or in excess can lead to runoff and water waste.

The following are strategies for creating water-thrifty gardens:

- › **IRRIGATE ONLY WHEN PLANTS NEED WATER** How often to water depends on a number of factors, including soil, vegetation type and stage of establishment, season, climate, and weather conditions. Homeowners should avoid irrigating on a fixed schedule that does not reflect the needs of the vegetation. Frequent, shallow watering tends to lead to weak, shallow-rooted plants. Less frequent, deep watering encourages roots to grow deep, where the soil stays moist longer. Applying water slowly will encourage infiltration and reduce runoff.
- › **CHOOSE THE BEST TIME OF DAY TO IRRIGATE** Sunny or windy conditions increase evaporation and water loss. The most favorable time for irrigation is typically in the early morning hours.
- › **USE A RAIN GAUGE AND/OR SOIL MOISTURE PROBE** A variety of relatively simple tools can help gardeners determine when to water. The simplest and most inexpensive tool is a rain gauge. Soil moisture probes employing different technologies are commercially available at varying prices. They measure the moisture level of soil, giving a more precise indication of how much water plants require.

Rain gauges and soil moisture probes should be used in conjunction with a basic understanding of a plant's water requirements. For example, vegetables generally need more water than established woody plants. And even edible plants require less water when it is overcast and relatively cool than when it is sunny and hot.

- › **HAND WATER** Watering with a hand-held hose has been shown to conserve more water than other irrigation methods. If in-ground systems are required, consider installing a drip irrigation system, as it uses the least amount of any automatic system. In-ground spray systems consume 35 percent more water than hand watering, and an automatic spray system used 47 percent more.
- › **USE "SMART" IRRIGATION TECHNOLOGY** To maximize efficiency, install climate-based controllers that prevent the irrigation system from turning on during and immediately after rainfall. Even better are sensors that activate irrigation only when soil moisture drops below a pre-determined level. So-called "smart" or weather-based irrigation controllers take into account a range of factors, including temperature, rainfall, humidity, solar radiation, and soil moisture levels to determine when supplemental water is necessary. As with all technologies, water conserving irrigation systems and devices must be installed and operated correctly in order to be effective and reduce water use.
- › **CLOSELY MONITOR THE IRRIGATION SYSTEM** Regularly check irrigation equipment for leaks or breaks. Adjust irrigation equipment and schedules to address changes in the garden and seasons. Monitoring the amount of water used by the irrigation system will help flag any leaks or breaks within the system and will encourage conservation efforts.

**Terraces acting as mini-check dams slow the flow of water and encourage infiltration.**





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***A rain barrel (left) and rainwater cistern (right) are manufactured in various shapes and sizes and can easily be integrated into the design of the garden. Rain barrels generally hold around 50 gallons, while cisterns can be used to store larger amounts of water.***

## **Water reuse and conservation strategies**

With a little ingenuity, gardeners can utilize non-potable water from a variety of indoor and outdoor sources to irrigate their garden. Non-potable water is not safe for drinking, but can be a great resource for watering vegetation. On-site alternative water resources, such as rainwater runoff, air-conditioner condensate, and greywater, are typically considered waste products in unsustainable gardens and quickly removed from the site. Sustainable gardens capture this water. Doing so protects nearby ecosystems from pollutants commonly carried in stormwater. In addition, the volume of water going to storm sewer systems is reduced, lessening the likelihood of flooding and combined sewer overflows.

### **Rainwater Collection**

Rainwater collection has been used for centuries to support households and grow beautiful, productive gardens. The practice typically falls into two categories, passive and active.

**Passive Rainwater Harvesting**—diverts water overland to vegetated areas for immediate use. Roads, driveways, and sidewalks are designed to direct water to vegetated areas instead of storm drains. Design features such as shallow bioswales or **terraces** can be integrated into the garden and used to slowly convey and disperse the water throughout the garden

**Active Rainwater Harvesting**—captures water in a barrel or cistern where it is held for reuse. The containers are manufactured in a variety of shapes and sizes and connected to the downspouts of the roof gutter system. **Rain barrels** generally hold around 50 gallons of water and come with a screened cover and an overflow spout. Cisterns are used to store larger volumes of water and may be buried below ground or integrated into

the garden as a freestanding structure. Active rainwater harvesting is prohibited in some areas. Homeowners should check and understand local water laws prior to designing a rainwater collection system.

The amount of rainwater available for reuse varies with precipitation patterns and should be estimated for each month. Approximately 600 gallons (2,271 L) of water can

## Determine how much rainwater can be harvested from a house and driveway each month

### Activity

Based on the site analysis from the previous lesson, determine the approximate amount of water that can be harvested from their roof and driveway annually.

Monthly rainwater available gallons (liters) = catchment area in ft<sup>2</sup> (m<sup>2</sup>) × in (cm) of rain × 600 gal (2,271 L) per in (2.54 cm) / 1,000 ft<sup>2</sup> (93 m<sup>2</sup>)

**Table 1:** Example of the potential for rainwater harvesting off of a 2000 ft<sup>2</sup> house in Boston, MA. Instructors should prepare a chart for local area.

| MONTH        | RAINFALL (in) | RAINFALL (cm) | RAINWATER AVAILABLE (gal) | RAINWATER AVAILABLE (L)* |
|--------------|---------------|---------------|---------------------------|--------------------------|
| January      | 3.9           | 9.9           | 4,680                     | 17,716                   |
| February     | 3.3           | 8.4           | 3,960                     | 14,990                   |
| March        | 3.9           | 9.9           | 4,680                     | 17,716                   |
| April        | 3.6           | 9.1           | 4,320                     | 16,353                   |
| May          | 3.2           | 8.1           | 3,840                     | 14,536                   |
| June         | 3.2           | 8.1           | 3,840                     | 14,536                   |
| July         | 3             | 7.6           | 3,600                     | 13,627                   |
| August       | 3.4           | 8.6           | 4,080                     | 15,444                   |
| September    | 3.5           | 8.9           | 4,200                     | 15,899                   |
| October      | 3.8           | 9.7           | 4,560                     | 17,261                   |
| November     | 3.9           | 9.9           | 4,680                     | 17,716                   |
| December     | 3.8           | 9.7           | 4,560                     | 17,261                   |
| <b>Total</b> | <b>42.5</b>   | <b>108</b>    | <b>51,000</b>             | <b>193,055</b>           |

\*Metric answers are based on unrounded conversions.



be collected for each inch (2.54 cm) of rain falling on a 1,000 ft<sup>2</sup> (93 m<sup>2</sup>) of impervious catchment surface. It is important to note that all of the rain that falls on a surface will not be collected. Different surface materials and collection systems generate varying amounts of runoff. For example, metal roofs typically generate more runoff than asphalt shingles, and some rain will overshoot the gutters during heavy rain events. When designing for rain water collection, materials and system components should be carefully selected to minimize waste.

### **Air Conditioner Condensate**

**Air conditioner condensate** is produced when warm, moisture-laden air passes over the coils of an air conditioning system. Collecting condensate is an attractive irrigation option because, unlike rain, which is sporadic and unpredictable, condensate is produced regularly during the hottest months, when the need for irrigation is greatest.

To collect and reuse condensate, the water is simply piped and gravity fed or pumped to a storage cistern, from which it can be drawn for irrigation or other garden purposes. Air conditioner condensate is essentially distilled water that does not contain chlorine, minerals, or other additives, making it a high quality water source for irrigation. Rainwater harvesting and condensate recovery systems use similar tanks for storage and can be combined to create a more efficient system. The average single-family home in the US produces 5 to 10 gallons of condensate per day. Condensate recovery systems are best suited to hot and humid climates.

### **Greywater Collection**

**Greywater** is wastewater produced by a variety of appliances and fixtures, including bathtubs, showers, bathrooms sinks, washing machines, dishwashers, and kitchen/utility sinks. An estimated 50 to 80 percent of residential wastewater is greywater, with a typical US household generating an average of 35 gallons per person/day. Many people find greywater to be an attractive irrigation option because it provides a steady, year-round water source and saves potable water resources. Greywater can be safely used to grow beautiful gardens; however, due to the soaps, detergents, skins cells, and other organic substances commonly found in the greywater, direct human contact or the watering of food plants should be avoided.

Some garden characteristics may prevent the use of greywater:

- › Areas prone to water ponding or flooding
- › High water tables
- › Shallow soils
- › Steep slopes that may lead to runoff or seepage

Greywater systems vary greatly in complexity and cost. Systems can be designed to convey greywater directly from the source to the garden or plumbed to capture, treat, and

temporarily store greywater for later reuse. The simplest way to collect greywater is to plug the drain and employ a bucket to transport bath or shower water for use outdoors. Another common practice (but illegal in some locations) is to drain the washing machine directly onto outside vegetation. Sophisticated systems involve separate plumbing for greywater as well as settling tanks and sand filters to remove solids and pathogens.

The quality of greywater depends on the source of the water and how it has been used. The alkalinity of the soil can be increased by sodium, potassium, and calcium salts commonly found in greywater. High salinity can damage soil structure and limit the ability of roots to absorb water. Applying greywater over a broad area will help avoid the buildup of harmful substances. Rain and freshwater irrigation can help flush the soil and reduce the concentration of salt and other chemicals. Garden-friendly detergents and other cleaning agents are commonly used in households with greywater systems to minimize any negative impacts.

Plants that grow in acidic soils, such as rhododendrons, hydrangeas, or camellias, typically do poorly when irrigated with greywater due to the water's high pH. If irrigating with greywater, select plants that grow well in alkaline soils and are not overly sensitive to elevated salt concentrations. In general, seedlings and young plants tend to be more sensitive to elevated salinity than well-established vegetation. Plants that are especially sensitive to high levels of salts include crape myrtle, redwoods, star jasmine, and hollies. Plants that commonly do well when irrigated with greywater include oleander, bougainvillea, rosemary, oaks, agapanthus, and juniper.

### **Note on State and Local Regulations**

States and local governments regulate greywater differently. Some prohibit the collection of greywater entirely. Prior to installing a greywater system, investigate what qualifies as greywater and whether any restrictions apply in your area. A list of some states and municipalities with greywater policies can be found at [www.oasisdesign.net/greywater/law/index.htm](http://www.oasisdesign.net/greywater/law/index.htm).

### **Water pollution: Common sources and preventative measures**

Developed areas have significantly higher amounts of impervious surfaces than natural systems. Concrete, asphalt, pavers, and other impervious surfaces prevent the infiltration and ultimate cleansing of water by soil. The rapid downstream transfer of polluted runoff by impervious surfaces is the leading cause of water pollution in urban areas in the United States.

Pollutants carried by stormwater come from many common sources:

› **FERTILIZERS, HERBICIDES, AND INSECTICIDES** Excess nutrients from overuse and runoff of fertilizer can cause algal blooms. When algae die, they sink to the bottom and decompose in a process that removes oxygen from the water. Fish and other aquatic organisms have difficulty surviving in water with low dissolved-oxygen levels. Insecticides and herbicides present in stormwater can poison aquatic life.

Land animals and people can become sick from eating contaminated fish or drinking pesticide-contaminated water. Homeowners can reduce the risk of these pollutants by minimizing the use of fertilizers and pesticides. Any excess fertilizer spread on driveways, sidewalks, streets, or other impervious surfaces should be collected and properly disposed of before it has an opportunity to pollute stormwater.

› **ANIMAL WASTE** Feces contains bacteria and other nutrients that can pollute our waterways and harm human health. Animal waste should be removed from vegetative buffers surrounding waterways or other areas where it may contaminate stormwater runoff.

› **ROAD SALT** Rock salt can leach into the soil, changing its chemical composition, and flow into local waterways, where it can poison fish and aquatic organisms. It can also harm sensitive plants. Salt is highly corrosive to paved surfaces, buildings, and metal. Alternatives to rock salt include materials that increase traction, such as kitty litter and sand. For situations where a product that melts ice is required, look for rock salt substitutes, such as those made with beet juice extracts, a byproduct of beet sugar production. Magnesium chloride, which is safer to use near plants than rock salt but not as effective in very cold conditions, is another possibility.

› **PARTICLES AND FLUIDS FROM VEHICLES, SUCH AS OIL AND GAS, BRAKE LININGS, TIRE, AND ENGINE WEAR** Cars, trucks, and other vehicles deposit pollutants onto paved surfaces. The pollutants are washed off during rain events and transported to storm sewers, where they often end up in local waterways. Gardens that capture and reuse stormwater minimize the spread of pollutants and provide a valuable water source to the garden.

› **SEDIMENT FROM IMPROPERLY MANAGED LANDSCAPES** Sediment can cloud waterways and carry attached pollutants. Gardens can minimize sediment pollution by preventing erosion and capturing stormwater on site.

› **CONVENTIONAL BUILDING MATERIALS INCLUDING GALVANIZED METAL, CONCRETE, PAINTS, AND EXPOSED/ PRESSURE TREATED WOOD** The aging and weathering of conventional building materials can release a number of pollutants, including heavy metals, polycyclic aromatic hydrocarbons (PAHs), lead and zinc, contributing to significant ecological damage. When replacing conventional roofing or other building materials, homeowners should consider less toxic alternatives such as wood shingles, slate, or baked enamel painted metal products that typically release fewer pollutants. Greenroofs, or roofs that are fully or partially covered with vegetation, are an attractive option for buildings that can support the additional weight. While

significantly limiting the leaching of harmful pollutants, greenroofs provide a variety of additional benefits including stormwater absorption, insulation from cold temperatures, mitigation of urban heat island effects, and habitat for wildlife.

- › **COAL TAR SEALANTS USED ON PAVED ROADS** Coal tar sealants, better known as blacktop, are high in PAHs, which contribute to the pollution of many of the nation's water bodies. PAHs are toxic to aquatic life and several are suspected carcinogens. Blacktop is also impermeable. Sustainable gardens use less toxic materials, such as crushed seashells, rocks, or gravel.

### **Incorporating and designing garden features that can reduce water pollution**

One of the most effective ways to prevent the runoff of polluted stormwater from a home garden is to create biofiltration gardens. Also known as rain gardens or bioswales, the gardens use plants, soils, mulch, and microbes to slow and treat stormwater runoff. The management practice is modeled after natural ecosystems and has been shown to effectively reduce heavy metals, bacteria, other pollutants, and water temperatures. Like the rest of your ornamental garden, biofiltration areas can be easily integrated into the garden and composed of a variety of beautiful plants. The gardens hold standing water temporarily and typically drain within 24 to 48 hours. Because water is held only for short periods of time, biofiltration gardens are typically not habitat for mosquitoes.

Besides reducing the transfer of polluted stormwater, rain gardens, and bioswales provide a variety of additional benefits:

- › Reduce the likelihood of downstream flooding
- › Increase the amount of water a garden receives
- › Replenish groundwater supplies.

### **Rain gardens**

A rain garden is a strategically located low area where water can naturally soak into the soil. Rain gardens can be any size or shape and easily integrated into the home garden.

#### **Where to Build a Rain Garden**

Homeowners should build rain gardens in areas where rainwater runoff naturally flows and can be easily collected. This may be near the house to capture roof runoff from the downspouts, or in the garden where water from the roof, lawn, and other impervious surfaces can be captured.



***Bioswales and raingardens at the High Point development in Seattle, WA receive runoff from the surrounding rooftops and streets.***

Factors to consider when selecting a location for a rain garden:

- › Locate underground service lines or utilities prior to digging
- › Keep the rain garden at least 10 feet from the house to prevent moisture problems
- › Place the garden at least 25 feet from septic systems
- › Avoid placing the garden directly under trees to prevent conflicts with roots
- › Avoid placing the garden on a slope that has an elevation change greater than 1 foot every 12 feet
- › Avoid placing the garden in areas where water currently ponds. Standing water is an indication that the soil is slow to absorb water
- › Consider where water from the garden will overflow during periods of heavy rainfall

### **Creating a Rain Garden**

A typical residential rain garden ranges from 100 to 300 square feet. The size and shape can be adjusted to fit the amount of water being captured and the overall size of the garden. In situations where large volumes of water need to be managed, it is typically easier to construct several small rain gardens rather than one large one.

Steps to creating a rain garden:

- › **DETERMINE THE DRAINAGE AREA** Calculate the area draining to the rain garden in square feet. A general rule is to make the rain garden 30 percent of the size of the drainage area.
- › **CONDUCT A DRAINAGE TEST** Dig 1 or 2 test holes approximately 8 inches wide by 8 inches deep in the proposed garden area. Fill the hole completely with water and observe how long it takes the hole to drain. Homeowners should avoid constructing rain gardens in areas where the test holes do not fully drain within a 24-hour period.
- › **DETERMINE THE GARDEN DEPTH** The depth of the garden depends on the soil type and how quickly water can be absorbed. Clay soils absorb water more slowly than



sandy soils. To avoid drowning plants in clay soils, the garden depth should not exceed 6 inches. Heavy clay soils can be amended with compost to speed drainage. Rain gardens located in more sandy soils can be up to 8 to 12 inches deep.

- › **DIG THE GARDEN** Rain gardens can be excavated with standard garden tools. Regardless of the depth, the goal is to keep the bottom of the garden level. A low berm should be created around the downhill sides of the garden to contain the water. Rainwater runoff can be directed from one part of the garden to another by bioswales or pipes.
- › **PLANT THE GARDEN** A rain garden is typically comprised of three wetness zones. In the lowest zone, plant species should be able to tolerate wetter conditions that include short periods of standing water. In the middle zone, vegetation will need to tolerate both wet and dry conditions. And in the upper zone, along the outer edges of the berm, plants should be selected that prefer dryer conditions. After planting, apply a 2- to 3-inch layer of organic mulch to reduce weeds and to protect and enrich the soil.

## Bioswales

Bioswales are shallow vegetated channels that slowly convey and absorb stormwater runoff. They can be used to direct surface runoff to rain gardens or other areas of the garden where the water can be absorbed. Bioswales can be easily incorporated into the garden and vegetated with a variety of trees, shrubs, and perennial plants. The longitudinal slope of a bioswale typically ranges from one to six percent. Decorative rocks, check dams, and vegetation can be used to control and slow the velocity of water moving through the channel. Similar to rain gardens, bioswales typically have three wetness

### Determine the size of a rain garden needed to capture rainwater runoff from a home

#### Activity

Based on the site analysis from the previous lesson, determine the general size and depth a rain garden would need to be in order to manage runoff. Depending on the quantity of stormwater, several rain gardens located near the various rain gutters may be needed.

To calculate the rain garden size, use the following formula:

Rain garden area in square feet (square meters) = collection area in ft<sup>2</sup> (m<sup>2</sup>) × 30 percent



**Vegetated bioswale**

zones. In the lowest zone, plant species should be able to tolerate wetter conditions that include short periods of standing water. In the middle zone, vegetation will need to tolerate both wet and dry conditions. And in the upper zone, along the outer edges of the bioswale, plants should be suited to drier conditions.

### **Limit impervious surfaces**

Impervious surfaces are typically constructed surfaces—rooftops, sidewalks, driveways, roads—covered by impenetrable materials such as concrete, blacktop, and mortared brick or stone. Urban and suburban soils, which are often compacted by intense foot traffic or construction equipment, can also be highly impermeable. As urbanization increases, so does the amount of impervious surface. Studies have shown that the quality of many urban watersheds is negatively correlated with the amount of impervious cover in the watershed. Impervious surfaces are a primary cause of elevated

stormwater runoff because they prevent precipitation from being absorbed into the soil. During heavy rainfall events, large areas of impervious surfaces allow runoff to gather volume, speed, and pollutants leading to excessive flooding and the damage of nearby ecosystems.

**Porous paving reduces stormwater runoff and mitigates the urban heat island effect.**



Homeowners can use a variety of strategies to reduce impervious surfaces:

- › Construct two-track driveways and service roads that maintain a center strip of vegetation or other permeable surface.
- › Use stepping stones surrounded by creeping groundcovers instead of continuous impermeable pathways.
- › Opt for “dry laid” instead of “wet laid” or mortared patios and walkways. Set in sand, these allow some stormwater to infiltrate into the soil, unlike the impervious cement products typically used as mortar.
- › Allow green spaces between patios, pathways, and other impermeable spaces.
- › Restore the ability of soils to absorb rainfall and take steps to prevent soil compaction elsewhere in the garden. See page 44 for more information.
- › Consider various types of permeable paving, such as concrete products with a porous structure that allows water to pass directly through the surface.

### **Protect and restore vegetated buffers along waterways and wetlands**

In undisturbed natural areas, waterways and wetlands are protected by adjacent vegetation. Grassland, woodland, and wetland plant communities naturally absorb and cleanse stormwater. Buffers along waterways and wetlands can also improve wildlife and fish habitat by providing food, shelter, and shade. When vegetation is replaced by impervious surfaces, stormwater runoff volumes increase. Stormwater often carries pollutants including nutrients from fertilizers, pet waste, and sediment into natural water bodies. Pollutants reduce the water quality and negatively affect wildlife habitat. In residential areas, turf grass often extends down to the water, polluting it with fertilizers and pesticides routinely used in lawn care.

In developed areas, vegetated buffers can fulfill the same important ecological functions as undisturbed waterside vegetation. As the name suggests, these are thickly vegetated strips of land that protect waterways and wetlands from polluted runoff and erosion. They also provide year-round habitat for a variety of wildlife, including “stopover habitat” for migrating birds in spring and fall.

Research shows that ecological benefits are positively correlated with the width of a vegetated buffer. Buffers less than 50 feet wide offer minimal benefits while those 200 to 300 feet in width offer a wide range, including soil stabilization, stream shading, water quality protection, flood prevention, and wildlife habitat. Vegetated buffers more than 300 feet wide can function as wildlife corridors and even harbor imperiled and sensitive species.



Strategies for creating a successful vegetative buffer:

- › Create a thickly vegetated buffer at least 50 feet wide. Because riparian and coastal zones are often regulated, property owners should contact local and regional government agencies for information on appropriate vegetation buffers in their area.
- › Avoid using pesticides or fertilizers—even natural fertilizers including compost—in a vegetated buffer.
- › Undisturbed buffers provide the best protection. If access to the water is needed, create an elevated walkway made from untreated wood to protect vegetation.

## Lesson 5

### Discussion

- *What should be your first steps in creating a more sustainable, water-friendly garden?*
- *For this geographic area or your specific garden, what types of water harvesting methods would be the best or most practical? Please explain.*



*Recommend a short break while instructor prepares for Lesson 6: The Role of Plants in Sustainable Gardens*

## Resources: Water

### Publications

#### Create an Oasis with Greywater

Art Ludwig

Oasis Design (2009)

*A step-by-step guide to greywater harvesting and reuse in residential settings.*

#### Rain Gardens: A How to Manual for Homeowners

Roger Bannerman and Ellen Considine

Wisconsin Department of Natural Resources and University of Wisconsin-Extension (2003)

<http://learningstore.uwex.edu/assets/pdfs/GWQ037.pdf>

*This manual contains comprehensive, step-by-step instructions on all aspects of creating a rain garden. It includes a number of rain garden planting designs and plant lists for varying sun and soil conditions that are especially appropriate for the Midwest.*

#### Rain Gardens: Managing Water Sustainably in the Garden and Designed Landscape

Nigel Dunnett and Andy Clayden

Timber Press (2007)

*Drawing on examples from around the world, this book explores the ways in which landscapes can harvest and reuse stormwater to make beautiful gardens.*

#### The Texas Manual on Rainwater Harvesting

Texas Water Development Board (2005)

[http://www.twdb.state.tx.us/publications/reports/rainwaterharvestingmanual\\_3rdedition.pdf](http://www.twdb.state.tx.us/publications/reports/rainwaterharvestingmanual_3rdedition.pdf)

*Detailed manual providing information on how to harvest, treat, and reuse rainwater.*

### Useful Websites

#### Depave

<http://depave.org/>

*This organization promotes the removal of unnecessary pavement from urban areas to create community green spaces and mitigate stormwater runoff.*

#### Lake Shoreland Protection Resources

US EPA

<http://water.epa.gov/type/lakes/shoreland.cfm>

*This website provides information and resources about lakeshore protection and restoration.*

#### Low Impact Development (LID)

US EPA

<http://water.epa.gov/polwaste/green/#info>

*This website provides factsheets, reports, design and guidance manuals, informational resources, and videos and other multimedia on low impact development. Low impact development is*

*an approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible. Free downloadable videos on this topic are available at <http://water.epa.gov/polwaste/green/video.cfm>.*

**Water Environment Research Foundation (WERF)**

<http://www.werf.org/>

*Clearinghouse for stormwater best management practices.*

**Water Sense**

US EPA

<http://www.epa.gov/watersense/>

*This website includes water efficiency tips, water usage calculators, and resources for rebates.*

**Watershed Academy Webcast Seminars**

US EPA

[http://water.epa.gov/learn/training/wacademy/webcasts\\_index.cfm](http://water.epa.gov/learn/training/wacademy/webcasts_index.cfm)

*Provides monthly webcast seminars on implementing best watershed practices. Archives of previous webcasts are available on this website.*

**Water Use in the United States**

USGS

<http://water.usgs.gov/watuse/>

*Provides water use data for county, state, and national level.*

**Water Use it Wisely**

<http://wateruseitwisely.com/links-and-resources/#regional>

*Provides a comprehensive list of water conservation related websites, along with an interactive database of water-use authorities by state.*

**Where Does your Water Come From?**

All Hands on Earth

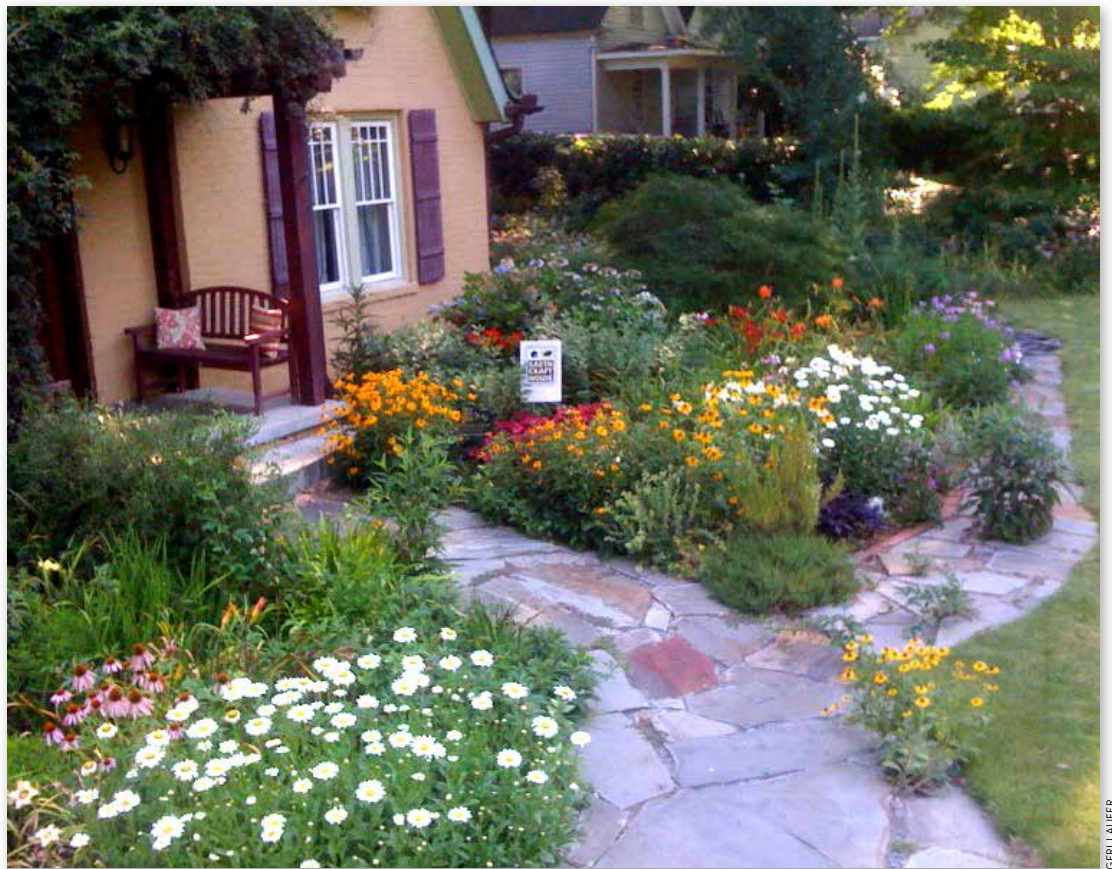
<http://www.nature.org/all-hands-on-earth/where-does-your-water-come-from-3.xml>

*An interactive map of water sources throughout the United States.*

\*Information on water testing can be found through a local Cooperative Extension Office. A list of offices by state is provided in Appendix 2 of this manual.

# Lesson 6

## The Role of Plants in Sustainable Gardens



GERI LAUFER

### Overview

**V**egetation is a key component of sustainable gardens. The environmental benefits that plants offer, including clean air and water, temperature regulation, and erosion control, are essential to the functioning of both healthy home gardens and surrounding landscape. Additionally, plants can provide a variety of economic and social benefits, including reduced energy use/ costs and increased wellness through the creation of restful settings. This lesson focuses on the important role plants play in garden sustainability. It discusses how to select vegetation for the home garden in a way that enhances the environmental, economic, and social benefits for not only the homeowner, but also the surrounding community.

## The role of plants in sustainable gardens and surrounding landscapes

Plants play an integral role in providing the ecosystem services that are required for the functioning of home gardens and surrounding landscapes. Homeowners can enhance ecosystem services and the overall function of their garden by using sustainable plant selection and design practices.

Some ecosystem services provided by vegetation:

- › **MITIGATE THE URBAN HEAT ISLAND** Plants cool the air by providing shade and evaporating soil moisture.
- › **REDUCE ENERGY USE AND COSTS** Properly placed vegetation can reduce energy use and costs by shading a house during summer and providing insulation during cold winter months.
- › **CLEANSE AIR AND WATER** Vegetation removes pollutants from air and water.
- › **PROVIDE OXYGEN** Through the process of photosynthesis, vegetation sequesters CO<sup>2</sup> and releases oxygen.
- › **CONTROL EROSION** Plants reduce the intensity of rainfall hitting the ground, increase the absorption of water into the soil, and help hold soil together.
- › **PROVIDE HABITAT** Vegetation provides refuge, breeding, and nursery habitat for wildlife both above and below the ground.

### Unsustainable vs. Sustainable Gardens: How They Compare PLANTS

| Unsustainable Gardens   | Sustainable Gardens   |
|---|---|
| <i>Often includes invasive plants that threaten natural ecosystems.</i>                 | <i>Vegetation is carefully selected to avoid the use of invasive species. Existing invasive species are removed from the garden.</i>    |
| <i>Often requires potable water, fertilizers, and pesticides to sustain vegetation.</i> | <i>Includes plants that are adapted to the conditions of the site and can thrive without potable water, fertilizers, or pesticides.</i> |
| <i>Often has low diversity and minimal wildlife habitat.</i>                            | <i>Includes plants that are both beautiful and useful as food or refuge for wildlife.</i>   |
| <i>Not designed to improve home energy efficiency.</i>                                  | <i>Uses vegetation to reduce the heating and cooling requirements of the home and surrounding buildings.</i>                            |
| <i>Provides minimal long-term savings.</i>  | <i>Can save homeowners money over the long run by cutting water, heating, and cooling bills.</i>  |

- › **PRODUCE FOOD AND RENEWABLE NON-FOOD PRODUCTS** Plants provide resources such as wood, cloth fibers, oils, fruits, and vegetables.
- › **CREATE RESTFUL AND PEACEFUL SETTINGS** Trees and other vegetation create settings that allow us to refresh our minds, relax, and better manage stress.

## Selecting plants

When selecting vegetation for sustainable gardens, homeowners should work with nature and select plants that are adapted to the conditions of the site. Vegetation that is well suited to the growing conditions of the garden will maximize benefits and minimize the need for fertilizers, pesticides, and irrigation. Exploring the **ecoregion** in which a garden is located can provide valuable insight about the environmental characteristics of the site and the basic type of plants or plant communities that may have adapted to survive in a particular area. To address environmental changes and/or irregularities that can occur across a garden, homeowners should consider the regional climate and **microclimatic**, including **hardiness zone** and sun/shade requirements, before selecting vegetation. Additionally, a careful review the soil, water, and remaining plant lessons should be completed before a homeowner incorporates new vegetation into their garden.

### Ecoregion

Ecoregions denote areas with general ecosystem similarities and the type, quality, and quantity of environmental resources. Learning about your ecoregion can support a deeper understanding of the environmental characteristics of your garden and what types of vegetative communities these characteristics tend to support. The EPA has developed level IV ecoregion maps for most of the US. The maps can be found at <http://www.epa.gov/wed/pages/ecoregions/ecoregions.htm>. Additional resources include the local branch of the EPA, local parks and wildlife agencies, The Nature Conservancy, and land grant universities.

Below is an example for the Edwards Plateau region of Texas:

**ELEVATION** Measurements range from 600 feet above sea level in the eastern canyons to 3,000 feet above sea level in the ridges of the central and western regions.

**PRECIPITATION** Levels vary from 23 to 35 inches per year.

**TOPOGRAPHY** The features are round, often with rolling hills. It is thought of as a southern extension of the Great Plains.

**SOILS** Most of the Edwards Plateau contains mottled yellowish clay or clay loam surface soil with rocky clay or solid limestone rock layers underneath. Erosion has left much of the region with top soils of less than 10 inches.

**VEGETATION DESCRIPTION** The Edwards Plateau is characterized by a combination of tall, medium, and short grasses, including little bluestem, sideoats grama, switchgrass, Indiangrass, Texas wintergrass, and three-awn often intermixed into a woodland setting with hardwood trees such as escarpment live oak, Texas oak, honey mesquite, and with coniferous Ashe juniper. Protective canyons, especially on the eastern and southern portions of the plateau, provide for a great diversity of other hardwood species, such as Texas madrone, escarpment black cherry, Texas mountain-laurel, Mexican plum, Carolina basswood, lacey oak, and bigtooth maple. Springs and creeks found in these canyons are typically lined with bald cypress, sycamore, and black willow.

**IMPACTS OF FIRE** Prior to heavy settlement, fire played a major role in shaping the vegetation on the Edwards Plateau. Fire occurred on much of the land every 2-10 years. During this interval, Ashe juniper was kept out of most uplands by fire and dense grass competition. Other trees such as escarpment live oak and honey mesquite were kept more isolated among the grasses. Concentrated livestock grazing reduced the cover of grasses which suppressed wildfire and allowed trees to begin moving into the grasslands. Protected canyons and moist, north-facing slopes reduced the number and intensity of damaging fires, allowing many trees to persist prior to human settlement.

**HISTORICAL INFORMATION** Bison were known to frequent the Edwards Plateau. Their migration in great numbers undoubtedly affected the landscape, plant communities, and the cultures of early human inhabitants. Later settlement brought primarily German farming communities and the adventurous livestock ranchers which have since been identified with Texas.

Ecoregion maps and descriptions should only serve as background or preliminary information. Additional environmental information and/or testing should be gathered before selecting vegetation. The next two sections will provide plant selection strategies based on regional climate and garden-level microclimate.

### **Regional Climate**

The climatic conditions of a region are largely determined by geographic factors including latitude, terrain, distance from bodies of water, prevailing winds, and elevation. The regional climate takes into account long-term temperature and precipitation patterns and has a significant impact on the types of plants a particular area can support. Hardiness zone classifications are tools that were created to help map geographic climate bands. They provide gardeners with an easy way to determine their regional climate and select appropriate vegetation.

**Hardiness Zone**—Most plants available for sale at nurseries or through online suppliers have been assigned a hardiness zone that correlates with a hardiness zone map. These are among the most basic tools have been used by gardeners for decades to determine if a particular plant can survive winter in their area. Probably the most widely-used map in the eastern two-thirds of the country is produced by the US Department of Agriculture (USDA). The most recent USDA map, [www.planthardiness.ars.usda.gov](http://www.planthardiness.ars.usda.gov) published in

2012, divides the country into 13 color-coded bands or zones. Each successive zone represents a 10-degree Fahrenheit difference in average annual minimum temperature; higher zone numbers correspond to warmer gardening temperatures.

In 2006, using the same basic zone structure as the USDA, the National Arbor Day Foundation produced a map ([www.arborday.org/media/zones.cfm](http://www.arborday.org/media/zones.cfm)) for the US that is also useful.

Gardeners in the West generally use the system of 24 climate zones first published by the Sunset Publishing Corporation in the *Western Garden Book*. The Sunset zone maps factor in not only minimum winter temperatures but also summer highs, growing season length, humidity, and rainfall patterns. The zones correlate to a series of regional maps of the West. Zone 1 represents the harshest growing conditions, zone 24 the mildest.

In 1997, Sunset published its first national garden book. Applying the same range of climatic criteria to areas of the United States and Canada east of the Continental Divide, it added 21 new climate zones (zones 25 to 45). Most gardeners in these regions, however, continue to use the USDA map.

### **Local Microclimate**

It is important to recognize that every garden is influenced by not only the regional climate but also microclimates, which are formed when the prevailing climate of a region interacts with objects in the garden. For example, planting beds located on the south side of a house or garden wall receive more sunlight and are typically warmer than those on the north side. Low areas of the garden may be cooler at night due to pockets of cold air pooling in the depressions. When the cold air drops below freezing, frost pockets will form and can cause damage to plants. Homeowners should select plants that are best suited to each particular microclimate within the site.

**Sun and Shade Conditions**—Plants need sunlight to photosynthesize and make their food, and only some can tolerate low light levels. Conversely, those that have evolved for shady conditions will often fail if planted in full sun. Plant labels, nursery catalogs, or gardening books typically identify the needs of many plants commonly expressed in degrees of sun or shade.

Definition of common terms:

- › **FULL SUN** Six to eight hours of direct sunlight a day.
- › **PARTIAL SUN OR LIGHT SHADE** Generally refers to an area that gets full sun for all but a few hours of the day.
- › **PARTIAL** Also known as medium shade, it is an area that gets sunshine for roughly half of the day and shade for the other half.
- › **FULL SHADE** The sun is obstructed for most of the day.
- › **DENSE SHADE** Near-total shade, which is too dark for all but the most shade-tolerant species.



## Identifying plants commonly grown in the area

### Field Trip/ Activity

The field trip is intended to help with the plant identification class assignment. Instructors will lead students on a walking tour of the surrounding area and point out vegetation that is commonly grown in the area and may be found in home gardens. The following class will include a discussion of native and invasive vegetation along with plants best suited for the area, so the instructor need not cover that information in this walkabout. Students should be encouraged to point out any plants currently found in their garden.

When the class is being held in a location where common garden plants cannot be found within walking distance, the instructor may decide to schedule a field trip and/or provide a PowerPoint presentation of plants commonly found in the area.

## Lesson 6

### Discussion

- *Prior to this class, have you thought about how to incorporate plants in your garden in a way that maximizes environmental, social, or economic benefits? If so, can you share any interesting or unique design techniques that you have used or are planning on using?*
- *What is the hardiness zone for this area? Can you think of any benefits or limitations of the different hardiness maps discussed in this lesson? When might you choose one map of the other?*

## Site Assessment — Plants

### Assignment

*Throughout the series, students will be asked to assess and record the conditions of their landscape. During the last class, student's findings and potential design scenarios will be discussed.*

#### **Site Assessment — Plants (See example on page 90)**


The assignment for this lesson is to map and identify the plants in the homeowners' garden. On a copy of the site analysis base map, locate large trees, shrubs, lawn, and other significant vegetation. The canopy area of each plant should be outlined along with the name, general size, and health of the plant. Encourage students to bring in photos or samples of vegetation they cannot identify.

On a separate sheet of trace paper, outline the sun and shade patterns of the site. Note areas that receive sun all day, areas that receive morning, midday, or afternoon sun only, and areas that are shaded all day.

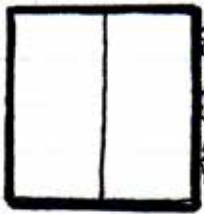


*Class Wrap-up: Closing Questions or Comments*

### Example: Plants Assessment

SCALE  $\frac{1}{4}'' = 1'$   
NORTH 

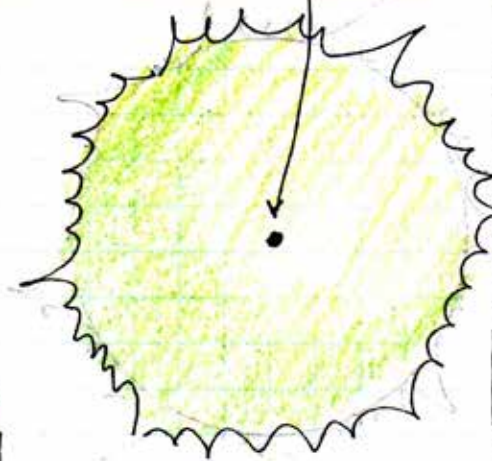
LIVE OAK



GRAPE MYRTLE



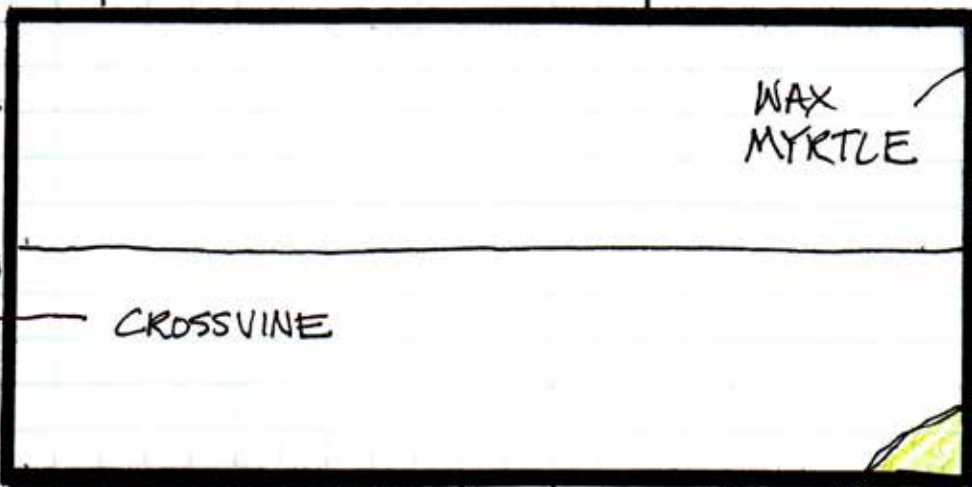
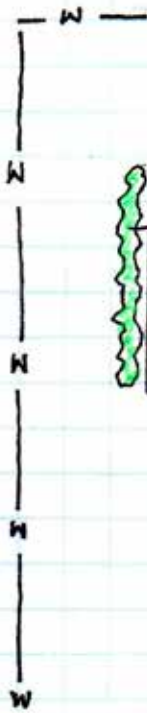
TURF GRASS  
LAWN



CEDAR ELM



CENIZO



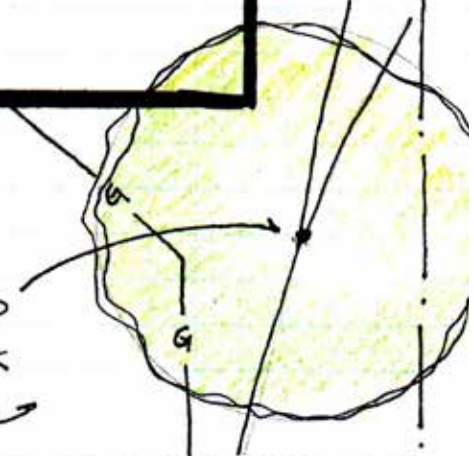
WAX  
MYRTLE



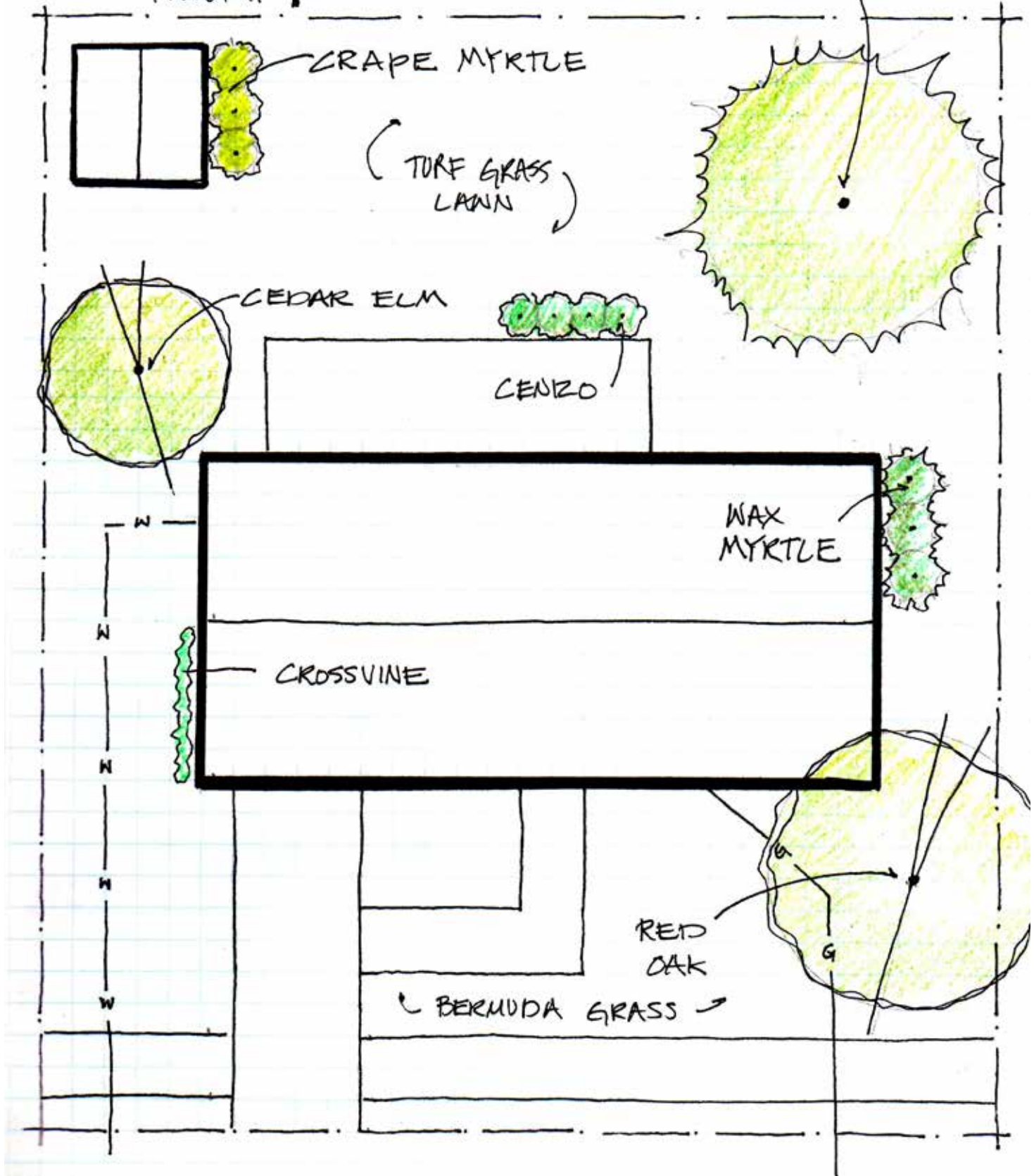
CROSSVINE



RED  
OAK



BERMUDA GRASS



# 4



GRACE DESIGN ASSOCIATES

## Class Preparation Checklist

- Prepare computer, projector, screen, and other necessary items required to lead the Class Four PowerPoint presentation
- Prepare a walking tour, field trip, or PowerPoint presentation of native and adaptive plants, page 97
- Compile a diverse list of plants that are native to the area, attractive in garden settings, and can be purchased at local nurseries, page 97
- Identify and research invasive plants commonly found in the area. Provide a general overview, removal guidelines, and photos, page 100
- Compile a diverse list of non-invasive adapted plants that are attractive in garden settings and can be purchased at local nurseries, page 97

# Class 4

## Lesson 7: Successful Plant Practices

## Lesson 8: Selecting Materials for Sustainability

**Learning objectives** *After completing this class students will be able to:*

### Lesson 7

- List vegetation that is well suited to the site conditions
- Explain the benefits of using native plants in the garden
- Explain why it is important to remove and stop the spread of invasive species
- Identify invasive species common to the area
- Describe garden features that are beneficial to wildlife
- Demonstrate how to use plants to increase the energy efficiency of a home

### Lesson 8

- List strategies for reducing material use in the garden

# Lesson 7

## Successful Plant Practices



### Overview

**W**hile incorporating the right vegetation into your garden can provide a wide-array of benefits, planting the wrong vegetation may cause significant economic and environmental damage. In this lesson, homeowners will learn how to stop the spread of invasive species, as well as select adapted vegetation that optimizes benefits such as attracting desirable wildlife and increasing the energy use efficiency of their home.

## Plants gardeners should include in their garden

### Native Plants

**Native plants** are species that exist in a region without human introduction. About 20,000 native plant species grow in the United States from the tropical rainforests of Hawaii to the deserts of Arizona. Unfortunately, native plants are disappearing at an alarming rate. Botanists are concerned about the survival of one in every five of this country's native plants, which provide critical habitat for countless other creatures. To help prevent the further loss of these plants, many can be attractively incorporated into our home gardens.

Native plants can add beauty to a garden, just as they do in natural areas. The great variety of regional natives provides gardeners with options that can support any garden design. In addition to enhancing a garden's aesthetic appeal, native plants also do much more.

Some benefits of using native plants:

- ▶ Native plants that are well suited to the site conditions do not require soil modifications or fertilizers and, once established, can thrive without regular watering. Ultimately, they reduce maintenance costs associated with **irrigation**, fertilizers, and pesticides.
- ▶ Native plants are the foundation of the ecological **biodiversity**. For example, they can nurture important pollinators like bees, butterflies, and hummingbirds.
- ▶ Native plants create a distinctive sense of place, preserving the natural character of a region.

Growing natives can be as simple as adding a regionally native shrub or wildflower to an existing flowerbed or border. Larger projects may include protecting an area of native habitat—a **fragment** of prairie or forest, for example. Homeowners may also choose to restore or recreate the native habitat that once existed on their sites. Even a tiny yard can be restored to include a small native patch of meadow or a woodland glade.

Native plants can provide a variety of benefits to homeowners and the surrounding area, but in order to be successful, they must be well suited to the growing conditions of the site. As with all plants, gardeners should consider the soil type, pH, sun and shade requirements, and watering needs of native vegetation before planting.

### Non-native Appropriate Plants

Appropriate plants can be thought of as plants that are not native to a region, but can adapt well to site conditions. They do not possess invasive qualities (e.g., abundance of seed or dense rhizomatous roots) and can be sustainably maintained without the addition of regular input or resources



HOLLAND YATES

*Meadow designed using yarrow and grasses*



## Identifying native and non-native appropriate plants

### Field Trip/Activity

*When preparing for this section, instructors will need to compile a diverse list of native and non-native appropriate plants that are attractive in the garden settings and can be purchased at local nurseries.*

This list can be used to guide a walking tour of native plants and non-native appropriate plants in the surrounding area. Local botanic gardens, other gardens, or nurseries may provide good sites for a tour. If a walking tour is not possible, the instructor may choose to prepare a PowerPoint presentation. The tour and/or presentation should include different plant types (trees, shrubs, and perennials) that grow in different settings (sun, shade, wet, dry) to give the homeowner a variety of options. This section of the class is not meant to be a complete plant identification course but should offer students a starting point when considering native and non-native appropriate plants.

## Plants gardeners should avoid

### Invasive Species

An **invasive species** is a non-native plant or animal species that causes or is likely to cause economic or environmental harm. Studies have shown that at least half of the invasive plants in the US were introduced for horticultural use. Invasive plants are often able to outcompete and displace native vegetation when the natural checks and balances that existed in their native range are no longer present in the new environment.

Most invasive plants are habitat **generalists** and able to survive in a wide range of conditions. However, they are more likely to invade ecosystems that have been disturbed or are degraded. Over time they can further degrade or change the characteristics of an ecosystem, altering important natural processes like hydrology, fire, and nutrient flow.

Many invasive plants are still being sold for garden use, despite their documented ability to degrade natural areas. No system is yet in place to effectively screen plants for their potential invasiveness, and new plants from around the world are constantly being introduced.

Certain traits are associated with invasive plant species and should be approached with caution when developing a home garden. For example, rhizomatous roots, large quantities of seed, or fleshy fruits aid many invasive plants in rapid dispersal. Non-native plants bearing these traits should be carefully selected and monitored. It is also recommended

that homeowners avoid planting any species found escaping into vacant lots or roadsides, even if they cannot be found on any official invasive species list.

The most prudent prevention measure is to select regionally native plants. Homeowners who grow plants that are native to their region are helping to prevent the spread of invasive species, preserving the natural character of the region, and supporting the complex interrelationships that have coevolved between native plants, and the insects, birds, and myriad of other creatures belonging to the area.

### **Examples of Invasive Species Introduced for Horticultural Purposes**

#### **Purple Loosestrife (*Lythrum salicaria* L.)**

Purple loosestrife is an ornamental herbaceous perennial that is native throughout Eurasia. It was first introduced to the northeastern US and Canada in the 1800s for ornamental and medicinal purposes. Loosestrife tends to invade natural and disturbed wetlands, forming dense, homogeneous stands or monocultures. These stands displace native wetland plant species, reducing habitat of several federally endangered orchids and waterfowl species in the US. Loosestrife now occurs in 48 states across the US and has an estimated cost of \$45 million per year in control and forage losses.



STEVE DEWEY

**Purple loosestrife (*Lythrum salicaria* L.)**

**Salt Cedar (*Tamarix* spp.)**

Salt cedar is a large ornamental shrub native to Eurasia. It was introduced to the US in the 1800s for its attractive flower, low maintenance requirements, and ability to prevent stream bank erosion. Despite these advantages, this invasive shrub can significantly degrade or alter an ecosystem by absorbing large quantities of water, restricting river access, and changing the chemical profile of the soil by depositing salt above and below ground. These salt deposits can inhibit other plants from growing and displaces native habitat. By 1998 salt cedar had successfully invaded nearly every drainage system in the southwestern US to occupy over 1 million acres. Efforts to remove salt cedar and restore native habitat can be quite costly. For example, direct costs for restoring areas along the Middle Pecos River, New Mexico were estimated at around \$2.2 to \$6.4 million.



**Salt cedar (*Tamarix* spp.)**

## Identifying and controlling common invasive species found in your area

### Activity

To prepare for this section, instructors will need to identify and research the invasive plants that are commonly found in their community. Instructors should provide a general overview of the invasive plant along with removal guidance and photos to help students with identification. The example below can be used as a guideline to help structure this discussion.

Resources for learning more about the invasive species in your region include [www.naeppc.org](http://www.naeppc.org), [www.invasiveplantatlas.org](http://www.invasiveplantatlas.org), the USDA Natural Resources Conservation Service, the Center for Plant Conservation, The Nature Conservancy, state natural resources departments, state conservation departments, and state forestry departments.

Below is an example of the information an instructor would provide to help students identify and control invasive species in the local area:

#### **Japanese Honeysuckle (*Lonicera japonica*)**

**GENERAL DESCRIPTION** Japanese honeysuckle is a showy vine with fragrant white or pale yellow flowers. The **evergreen** to **semi-evergreen** vine was introduced to the US in the early 1800s as an ornamental plant, for erosion control and as wildlife forage. It has been found to compete with native vegetation for light and nutrients and has few natural enemies in North America. These traits have allowed Japanese honeysuckle to thrive and spread widely.

**POTENTIAL ENVIRONMENTAL DAMAGE** Japanese honeysuckle can invade fields, forests, wetlands, and a variety of disturbed areas. It kills shrubs and young trees by girdling the vascular system within the stem and eventually cutting off the flow of water. This can contribute to the malformation and stunted growth of both trees and shrubs. With its abundant seeds and rhizomatous roots, this plant spreads rapidly and significantly alters the surrounding ecosystem.

**HOW TO CONTROL** Management and control of small infestations can be performed by carefully hand pulling the vines and roots. To avoid spreading seeds, homeowners should burn or bag the pulled vegetation and carefully dispose of the materials. Larger infestations can be successfully controlled through **prescribed burning**. When prescribed burning is not an option, Japanese honeysuckle can be treated with a **systemic herbicide**, such as glyphosate. The herbicide is largely immobile in the soil and degrades in about three months. Glyphosate is nonselective and can kill surrounding vegetation. When using pesticides, always follow the label instructions carefully.

**ALTERNATIVE PLANTS FOR THE AUSTIN, TEXAS AREA** Trumpet creeper (*Campsis radicans*); Coral honeysuckle (*Lonicera sempervirens*)



**Japanese Honeysuckle**  
(*Lonicera japonica*)

### **Gardening for wildlife**

As wilderness areas become more fragmented and urban landscapes expand, butterflies, songbirds, and other creatures are left without **habitat** or the places and resources needed to live. New development continues to consume 2 million acres of quality wildlife habitat each year—an amount equivalent to the size of Yellowstone National Park. Invasive plants, the overuse of polluting fertilizers and pesticides, and other unsustainable gardening/agricultural practices further threaten wildlife habitat.

Creating sustainable residential gardens can help offset the loss of critical wildlife habitat. The first step in creating sustainable gardens for wildlife is to determine the priority species. Next, gardeners should identify habitat needs including food, water, and shelter for each species. Below is an overview of habitat essentials.

#### **Food**

The best food source is often a diverse selection of native plants. For the vast majority of native wildlife, most of the non-native plants that have been incorporated in our gardens for more than a century do not provide sufficient food. When you plant native trees, shrubs, and herbaceous plants, you provide wildlife with the nectar, pollen, fruits, leaves,

seeds, and nuts—and associated insects—that have nourished them for millennia.

### Water

All wildlife needs water for drinking, bathing, and regulating body temperature. Water can be scarce in arid areas and in cities. Nature provides water to wildlife in a multitude of ways that the homeowner can replicate such as a shallow in-ground pool or pond, a water-barrel, or a birdbath. Homeowners should work to ensure that water is clean, accessible to wildlife, and does not serve as a breeding ground for mosquitoes.

### Cover

Native trees, shrubs, thickets, grasses, brush piles, and artificial wildlife houses provide cover or places for wildlife to hide, rest, and nest. For birds, all trees and shrubs provide cover, but none are better than evergreens. The seeds in **conifer** cones are an important source of food for many avian species. Regionally native pines and other conifers are more



*Since space is limited in most home gardens, it makes sense to select native plants that support the greatest wildlife diversity possible. In Doug Tallamy's book *Bringing Nature Home: How Native Plants Sustain Wildlife in Our Gardens*, native oaks are found to be one of the best plants in supporting wildlife diversity, providing habitat for more than 534 species of butterflies and moths alone. These trees also provide food and shelter for many birds, mammals, and reptiles.*



WIKIMEDIA COMMONS

**To enhance wildlife biodiversity, use natural areas as a model in recreating vertical layers of vegetation in the home garden.**

vertical plant layers. However, these layers tend to be more distinct in forested regions. The canopy, the tallest layer of a forest, is composed of mature trees. Canopy trees typically reach heights between 30 and 100 feet. The next layer down, or the understory, is composed of saplings of canopy tree species as well as smaller flowering trees such as dogwoods and redbuds. The understory layer extends from about 12 to 30 feet above the ground. The shrub layer is the lowest layer of woody vegetation occupying the height between 3 and 12 feet. The lowest aboveground layer of a forest, below 3 feet, is called the ground layer. In this layer, wildflowers, ferns, grasses, and sedges grow in often spectacular combinations. Plants in the ground layer also partition their environment vertically. Spring ephemeral wildflowers bloom first, typically raising their foliage only a few inches above the leaf litter. When they go dormant, taller ferns and wildflowers overtop them.

Prairies and other communities dominated by herbaceous plants also have distinct vertical layers. The earliest plants to emerge in spring are low to the ground. Each successive emerging plant overtops the next, culminating with the tallest grasses and late-blooming asters and other composites that end the growing season. The layers also extend below the ground, from fibrous-rooted grasses to wildflowers with deep taproots. In general, the more vertical layers there are, the more complex the vegetative structure and the more habitat is created for a wider array of animal life.

### **Using vegetation to increase the energy efficiency of your home**

Collectively, US households consume around 22 percent of the country's total energy. About half of this is devoted to heating and cooling. A properly designed garden can make a home significantly more energy efficient by utilizing trees, shrubs, groundcovers, and vines to provide cooling shade in the summer and insulation against heat loss in winter. An energy-efficient garden also provides a variety of other benefits, which includes cutting heating and cooling bills by as much as 40 percent and adding significant aesthetic value to a home. A windbreak, for example, can define the space in a yard or patio and provide

likely to host the native insects upon which birds depend.

Homeowners should avoid the use of pesticides, which can harm birds and other wildlife directly or contaminate the flowers or vegetation that serves as an important food source. To provide habitat **niches** for the widest array of wildlife, it helps to recreate various vertical layers of vegetation—trees, shrubs, flowers, and grasses—found in nearby natural areas.

All native plant communities consist of

privacy while blocking blustery winds. Using plants as living air conditioners or insulating blankets, homeowners can soften a house's architectural edges with foliage and flowers while improving its energy performance.

## Basic energy efficiency strategies by climatic region

Basic energy-saving strategies for buildings are in large part determined by geographic location. The US Department of Energy had divided the US into four climate regions—cool, temperate, hot and arid, and hot and humid—and has recommended the following landscaping strategies for each zone.

### Cool

The cool climate region is characterized by very cold winters and hot summers. Temperatures throughout the year are known to vary widely, ranging from about -30 degrees F to 100 degrees F during hot summer months. During the winter, days are short and the sun is low, limiting the amount of solar radiation available for warming. Prevailing winds tend to blow from the northwest to the southwest.

Energy conservation strategies for the cool climatic region:

- › Use windbreaks to protect buildings from cold winter winds.
- › Avoid planting tall vegetation on the south side of the house that may prevent the sunlight from reaching walls or windows.
- › Shade south and west windows and walls from the direct summer sun if summer overheating is a problem. Deciduous plants can be used to provide shade while still allowing low-angle sunlight of winter to warm your home during the coldest months.

### Temperate

The temperate climate region is also known to have distinct cool and hot seasons. However, temperatures are less extreme than in the cool region. Winds tend to blow from the northwest to the south. Temperate regions are known for having high levels of rainfall and humidity, making summers particularly unbearable.

Energy conservation strategies for the temperate climatic region:

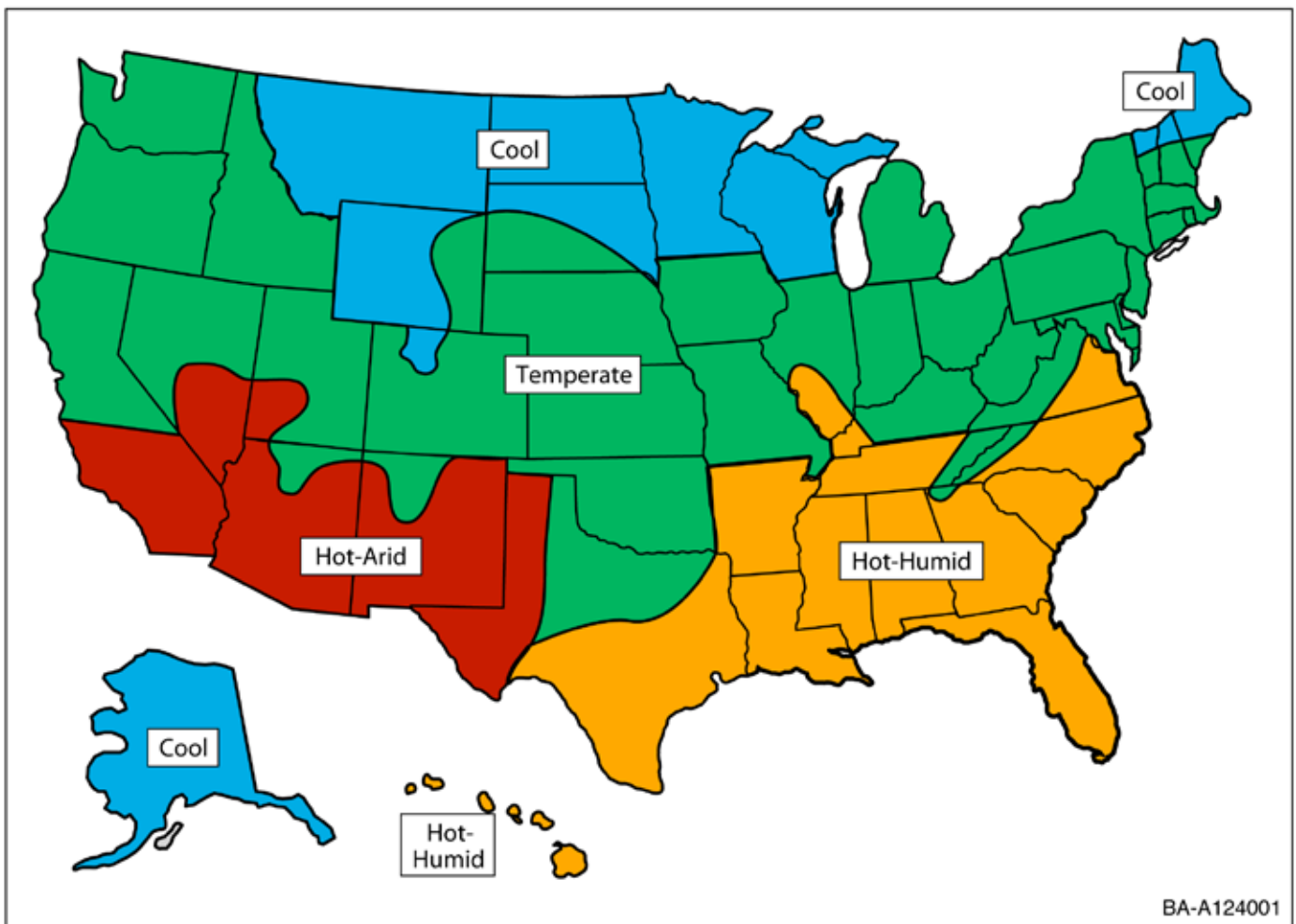
- › Locate vegetation and use deciduous trees so plants do not block the winter sun
- › In summer months, shade the roof and the south- and west-facing walls
- › Deflect winter winds away from the house
- › Funnel summer breezes toward the house



### Hot and Arid

The hot and arid climate region has long summers that are characterized as being dry and hot. Nighttime temperatures drop dramatically. Winds vary between night and day, but tend to blow from east to west.

- › Energy conservation strategies for the hot and arid climatic region:
- › In summer months, provide shade to cool roofs, walls, and windows
- › Plant around your home so that it is cooled by evapotranspiration, the release of water vapor from the soil and plant surfaces into the atmosphere
- › Funnel summer breezes toward your home if it is cooled naturally and does not rely upon an air-conditioner unit
- › Deflect wind away from houses that are air-conditioned



*As outlined by the Department of Energy, the US is composed of four distinct climatic regions. The climate region in which you live should affect the landscaping strategies you select.*

### Hot and Humid

The hot and humid climate zone is characterized by being warm and wet for most of the year. Winds are variable and can blow from any direction.

Energy conservation strategies for the hot and humid climatic region:

- › Direct summer breezes toward the house
- › Make the most of summer shade with trees that still allow low-angle winter sunlight to warm the home
- › Avoid locating planting beds close to the house if they require frequent watering

### Strategies for using vegetation to reduce energy consumption during the summer

Warm summer temperatures can increase the need for cooling and significantly raise a household's energy use. This is especially true in urban areas where temperature is already elevated by buildings, asphalt, sidewalks, and other built surfaces that absorb and slowly release heat. Properly placed vegetation in a home garden can significantly reduce energy use by shading buildings, appliances, and other structures that absorb and/or emit high levels of solar radiation.

- › **SHADE A/C UNITS** An easy way to get quick results is to shade the air conditioner. According to the US Department of Energy, this can increase a unit's efficiency by as much as 10 percent. Be sure that shrubs or vines planted near the compressor do not obstruct the airflow or impede access for repairs.
- › **SHADE ALL WINDOWS THAT RECEIVE DIRECT SUNLIGHT** A building gains substantially more heat through windows than insulated walls, making the shading of windows a priority in the summer.
- › **SHADE WALLS AND PARTS OF ROOF THAT RECEIVE THE MOST SUN** In the northern hemisphere, the location of the sun is shifted slightly to the north in the summer, making the building surfaces that receive the most sunlight the roof and east- and west-facing walls. Overheating early in the day can be prevented by shading east and southeast building surfaces, whereas shade on the west and southwest walls and roof can significantly reduce peak indoor air temperatures and accelerate cooling in the afternoon and evening hours. In the southern hemisphere, the location of the sun is shifted slightly to the south in the summer, the building surfaces that receive the most sunlight are still the roof and east- and west-facing walls. Overheating early in the day can be prevented however by shading east and northeast building surfaces, whereas shade on the west and northwest walls and roof can significantly reduce peak indoor air temperatures and accelerate cooling in the afternoon and evening hours.
- › **SHADE DARK-COLORED DRIVEWAYS, ROADWAYS OR PATIOS** Dark paving and roofing materials, such as asphalt roads, roofs, and driveways, absorb and radiate



ED CASTRO LANDSCAPE

***Vines can help shade a home, while adding aesthetic appeal.***

significant amounts of heat. The resulting warm air can influence the inside temperature of a home and the comfort of people who utilize the garden. Shading these surfaces, particularly during summer months is an important strategy for mitigating the urban heat island that will benefit not only the site but also the surrounding area.

### **Selecting Vegetation to Increase Shade and Improve Energy Efficiency**

**Vines**—Because trees often grow slowly, homeowners can more efficiently moderate solar radiation by planting fast-growing vines on strategically placed trellises. Permanent structures like trellises are most appropriate in hot climates, where blocking solar heat gain in winter is not counterproductive. Where wetness and humidity are a problem, keep the trellis at least a foot away from the house to allow for air circulation. In these areas, air should be allowed to flow around the home, keeping the structure and surrounding soil dry to prevent mildew and rot. Arbors or pergolas are a better choice in temperate regions because they allow winter sun to penetrate the windows and warm the house.

Annual vines grow quickly and can cover a large area by mid to late summer. Homeowners can make shading devices twice as functional by growing vines that provide not only shade but also fruits or vegetables. Edible vines, such as scarlet runner beans, winter squashes, and luffa squashes are both vigorous and fast growing. Ornamental vines are also good candidates. For example, cypress vine and scarlet creeper provide nectar for hummingbirds, while moonflower attracts moths. At the same time, homeowners can plant perennial vines, which may take two or more years to cover an arbor or trellis as tall as the home's walls. Avoid planting these in cooler climates where solar heat gain is desirable during the cold months unless they don't block the sun in winter or can be cut back drastically at the end of the season.

**Trees and Shrubs**—Large trees and shrubs take longer to fill in but provide the best cooling shade. The air temperature can be as much as 25 degrees F cooler under trees than around nearby asphalt lots. As is true for vines, in cool and temperate climates the placement of trees is more complicated than it would first appear. Trees can reduce summer temperatures significantly, especially when they are located on the south and west sides of the house. Large specimens that shade the roof and walls from the afternoon sun can reduce indoor temperatures by as much as 8 to 10 degrees F. Trees should be located close enough to the house to cast shade but far enough away (typically about 15 feet) that their roots will not damage the foundation. Homeowners should also consider how wide the trees will become when mature, and space them accordingly.

On small city or suburban lots, the optimum location for a shade tree may be in a neighboring yard. Homeowners should work with neighbors to create a larger garden



PROJECT LIVING PROOF

*Trees planted near a home should accommodate shade as well as spacing needs, when possible.*

plan that enhances energy conservation and lowers costs for everyone. If this is not an option, homeowners can use shrubs and vines to shade the walls, windows, and air conditioners. Deciduous trees provide shade in summer and then drop their leaves in autumn, allowing the sun to warm the home during the winter. Tall trees with broad leaves and a high, spreading crown (e.g., maples) are ideal for this purpose. As few as two or three properly spaced trees with wide crowns may suffice, depending on the size of the house. Prune lower branches for maximum heating of walls and roof by the low winter sun. A 6- to 8-foot deciduous tree planted near a home will typically begin shading windows the first year. Shading the roof of a home will typically take between five and ten years depending on the tree species and the height of the home. Smaller trees and shrubs can also play a role in helping to conserve energy. Species with branches lower to the ground can be planted closer to the house than tall shade trees and used for shading east and west facing walls and windows from the lower morning and afternoon sun. For the greatest ecological benefit, select species native to the region

that offer food and shelter for pollinators and other wildlife. Shrubs planted close to the house can fill in rapidly and shade walls and windows relatively quickly in wet and humid areas. Avoid planting them right up against the house so air can circulate freely.

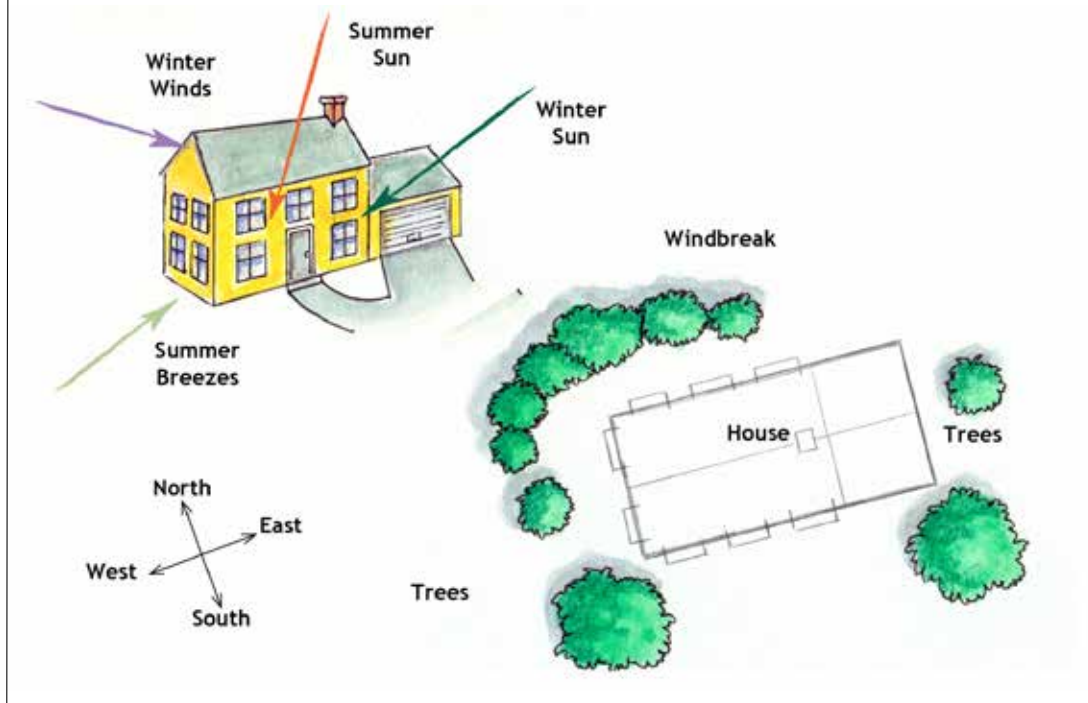
### **Using Vegetation to Reduce Energy Consumption During the Winter**

Winds make winter cold significantly worse, however it is possible to keep a house warmer in winter by blocking the chilling effect of wind. The most effective way is to plant a windbreak perpendicular to the prevailing winds. If a property is small, homeowners can plant evergreen shrubs next to the house to create a dead air space that can help insulate the home. Evergreen shrubs can also be strategically located near the house to help shelter doors exposed to the wind.

**Creating an Effective Windbreak**—To be most effective, a windbreak should meet certain height and length requirements. For the greatest protection, homeowners should plant windbreaks at a distance from their house of about two to five times the height of the mature trees. That means that if the trees being planted grow to 40 feet, homeowners should plant them at least 80 feet upwind from the house. Windbreaks should be located so that it does not prevent sunlight from reaching the house, particularly on the south facing walls between the hours of 9 am and 3 pm.

A good windbreak provides protection in more than one direction. A study in South Dakota found that placing windbreaks on at least three sides of the home (i.e., west, north, and east) can cut fuel consumption by an average of 40 percent. Houses with windbreaks planted only on the windward side—the side of the prevailing winds—only averaged 25 percent less fuel consumption when compared to unprotected homes.

## Garden Plan to Enhance Home Energy Efficiency



*A simple garden plan can help you devise the most effective strategies for an energy-conserving garden. Note which areas of your home are affected by the sun and wind (upper left) to determine the best placement of plantings (lower right). The plan above is for a home in the eastern states, where winds generally come from the north and west.*

The best windbreaks block the wind close to the ground as well as up high, so homeowners should be sure to include species that have low crowns, such as spruces and firs. Evergreen and deciduous trees and shrubs can also be combined with a wall, fence, or berm to lift the winds up and over the house. Some air should be able to pass through the windbreak. Impenetrable barriers create a strong vacuum on the protected or leeward side, causing some of the wind to hit the house instead of lofting over it. Windbreaks composed of trees and shrubs allow some of the wind to penetrate, making them a more effective option.



*A standard multiple row windbreak consists of an upwind row of dense conifer trees and shrubs, interior rows of tall broadleaf trees, and downwind rows of shrubs or conifers. How far apart the trees and shrubs should be planted depends upon the size and shape of the species when they reach maturity, but there should be no gaps between the plants when they are fully grown.*

## Lesson 7

## Discussion

- *Do you have any favorite native plants that you have utilized in your home garden?*
- *Besides being aesthetically appealing, have these plants helped you accomplish any specific design goals or provided any additional benefits?*
- *Do you have any desirable wildlife that utilizes your garden? What are their habitat requirements?*
- *Are there any features that you can incorporate into your home garden to accommodate these wildlife species? Please describe.*

## Site Assessment — Energy Efficiency

## Assignment

**Site Assessment—Energy Efficiency**

*Throughout this series, students will be asked to assess and record the conditions of their garden. During the last class, students' findings and potential design scenarios will be discussed.*

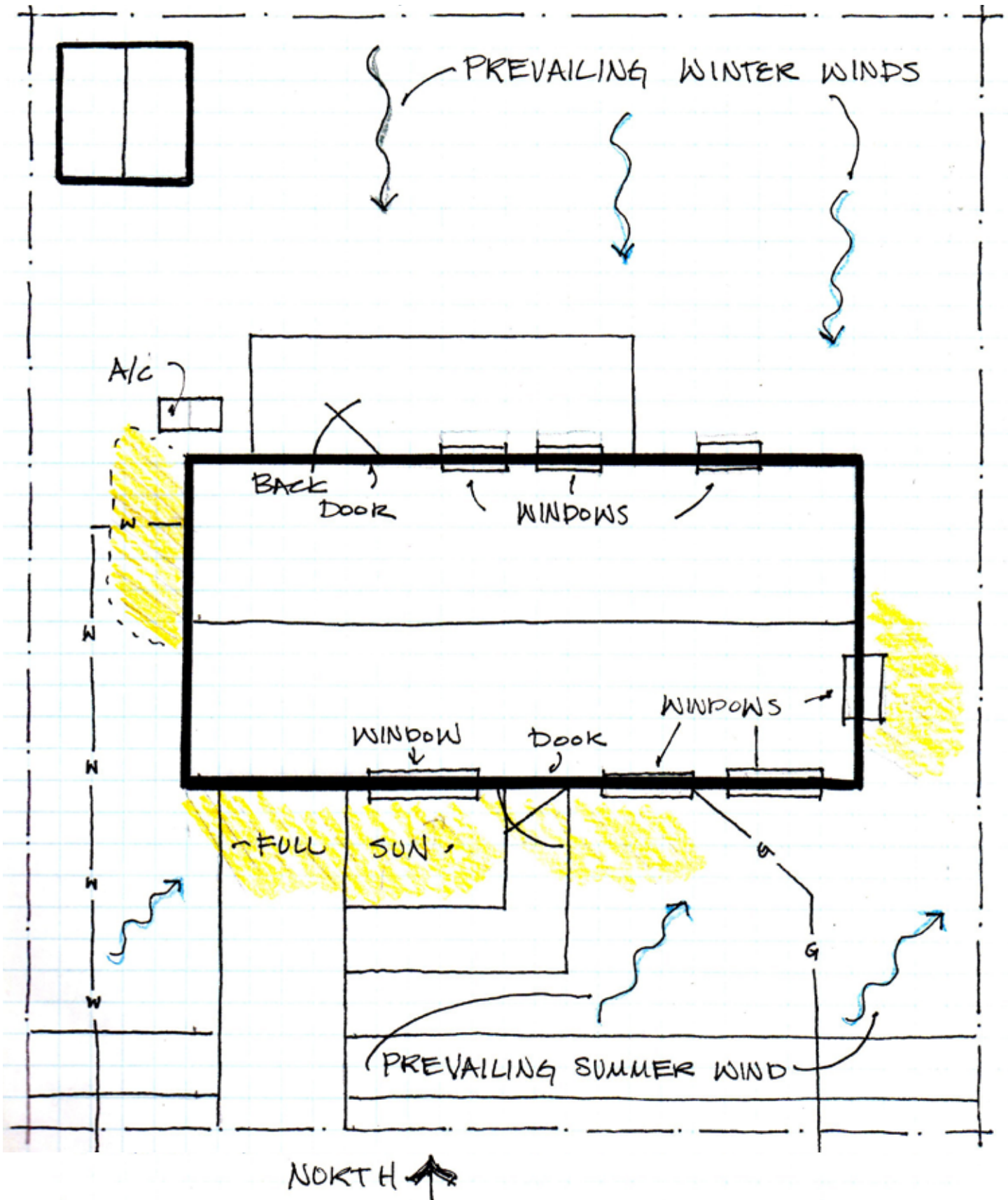
This assignment focuses on investigating the site conditions that impact a home's energy efficiency. On the site analysis base map, locate the following:

- › All windows, doors, and skylights in the house
- › A/C units
- › Solar collectors or photovoltaic arrays
- › On a separate sheet of trace paper, note the following:
  - › Direction of prevailing winds in the winter and summer
  - › Portions of the home that receive sunlight in the morning, afternoon, and evening during the summer and winter



*Recommend a short break while instructor prepares for Lesson 8: Selecting Materials for Sustainability*

### Example: Energy Efficiency Assessment



## Resources: Plants

### Publications

#### **Bringing Nature Home: How You Can Sustain Wildlife with Native Plants**

Douglas Tallamy  
Timber Press, Inc. (2007)

*A book about using native plants to create habitat for local wildlife.*

#### **Edible Estates: Attack on the Front Lawn, Expanded 2nd Edition**

Fritz Haeg  
Metropolis Books (2010)

*A well-illustrated book that showcases edible gardens across the US.*

#### **Energy-Wise Landscape Design: A New Approach for your Home and Garden**

Sue Reed  
New Society Publishers (2010)

*This book demonstrates how homeowners can use plants and other standard landscape materials to reduce energy use.*

#### **Native Alternatives to Invasive Plants**

C. Colston Burrell  
Brooklyn Botanic Garden (2011)

*This handbook provides recommendations for a variety of beautiful, regionally native, trees, shrubs, vines, herbaceous plants, and grasses that can replace commonly planted invasive species.*

#### **Trees in the Urban Landscape: Site Assessment, Design, and Installation**

Peter Trowbridge and Nina Bassuk  
John Wiley and Sons, Inc. (2003)

*A well-illustrated guide to successful planting in urban landscapes, from design conceptualization to daily maintenance.*

### Useful Websites

#### **ACTrees**

Alliance for Community Trees  
<http://actrees.org/what-we-do/>

*This organization provides resources geared at creating healthy urban and community forests.*

#### **Casey Trees**

<http://caseytrees.org/>

*This organization provides information on how to install, select, and care for trees in urban areas.*

#### **Celebrating Wildflowers: Gardening for Pollinators**

US Forest Service  
<http://www.fs.fed.us/wildflowers/pollinators/gardening.shtml>



*This website provides basic tips and a list of additional resources about using wildflowers to attract pollinators.*

### **Growing Green Lawns**

Community IPM Network

[www.growinggreenlawns.org/](http://www.growinggreenlawns.org/)

*A resource that provides integrated best management practices for residential landscapes, lawns, gardens, and home pests.*

### **Invasive and Exotic Species of North America**

Center for Invasive Species and Ecosystem Health

[www.invasive.org/](http://www.invasive.org/)

*A comprehensive resource for invasive species identification and control.*

### **Least Wanted: Alien Plant Invaders of Natural Areas**

Plant Conservation Alliance's Alien Plant Work Group (PCA)

<http://www.nps.gov/plants/alien/factmain.htm>

*Illustrated, easy-to-read fact sheets on invasive alien plants with native ranges, plant descriptions, ecological threats, US distributions and habitats, background of introductions, plant reproduction and dispersal, management approaches, alternative native plants, and other useful information.*

### **National Tree Benefit Calculator**

Casey Trees and Davey Tree Expert Co.

<http://www.treebenefits.com/calculator/>

*Calculates the environmental and economic value trees provide on an annual basis.*

### **Native Plant Information Network (NPIN)**

Lady Bird Johnson Wildflower Center, the University of Texas at Austin

<http://www.wildflower.org/plants/>

*The largest native plant database in North America.*

### **North American Native Plant Society**

<http://www.nanps.org/>

*This organization provides information and resources on the cultivation and conservation of native plants.*

### **PLANTS Database**

Natural Resource Conservation Service (NRCS)

<http://plants.usda.gov/java/>

*This database provides standardized information about vascular plants, mosses, liverworts, hornworts, and lichens of the US and its territories. It includes names, plant symbols, checklists, distributional data, species abstracts, characteristics, images, crop information, automated tools, and references.*

**Pollinator Friendly Plant Guides**

Pollinator Partnership

<http://www.pollinator.org/>

*This website provides ecoregional native planting guides focused on selecting plants that attract pollinators.*

**Protecting Native Plants and Animals: Taking on Invaders**

The Nature Conservancy

[www.nature.org](http://www.nature.org)

*A resource for learning more about invasive species and how to control their spread.*

**Vibrant Communities: Trees are the Key Online Toolkit**

Sustainable Urban Forests Coalition

<http://vibrantcities.org/>

*An online resource center and communication toolkit with a variety of materials that can be used and/or adapted to provide education on the benefits of city trees.*

\*Information on water testing can be found through a local Cooperative Extension Office. A list of offices by state is provided in Appendix 2 of this manual.

# Lesson 8

## Selecting Materials for Sustainability



M. TAYLOR

### Overview

**T**he principles of “reduce, reuse, and recycle” can help in selecting the materials needed to create sustainable home gardens and surrounding landscapes. Using recycled or reused materials and reducing the quantity, transport, and packing of these products can conserve energy and decrease pollution throughout a material’s life cycle. In this lesson, homeowners learn to use the concepts of reduce, reuse, and recycle to creatively minimize waste and create sustainable gardens.

Every material or product in a garden has environmental, economic, and human health impacts. The manufacturing of materials is a consumptive and an often wasteful process. Each phase, including the raw material extraction, processing, manufacturing, packaging, distribution, installation, and disposal, requires energy and can produce harmful air, water, and soil pollutants and wastes. Sustainable gardens minimize these negative impacts by creating a circular material life cycle that is built upon the use of recycled or reused materials.

***Sustainable landscapes minimize waste by encouraging the use of reclaimed and recycled materials.***



### **Unsustainable vs. Sustainable Gardens: How They Compare** **MATERIALS**

#### **Unsustainable Gardens**

*The life cycle of materials is a linear process that begins with extraction and ends with disposal. Materials move through the cycle once and then become waste products.*

*Materials are not local and therefore do not support community businesses or the regional economy.*

*Little information is known about the human health and environmental costs of materials.*

#### **Sustainable Gardens**

*The life cycle of materials is a circular process, in which materials and products are reused or recycled to avoid the extraction of virgin feedstock and minimize energy and resource consumption.*

*Materials represent the regional identity of the area and support the local economy.*

*When selecting materials, consideration is given to not only the cost but also the human health and environmental impacts.*

**Reduce**

Homeowners can minimize waste, energy consumption, and pollution associated with the manufacturing process by limiting the use of new materials and other products. Of the reduce, reuse, and recycle hierarchy, reducing the amount of materials or products imported into a project provides the greatest benefits.

Some strategies are especially helpful:

- › Design garden features using standard material sizes to avoid waste and additional cuts and labor
- › Select manufacturers or suppliers that reuse or eliminate packaging materials
- › Use durable materials that will last the life of the project and can be reused in the future
- › Design garden elements to be exposed. Avoid covering garden elements with additional materials for aesthetic purposes, such as covering a concrete wall with brick or stone facade

**Lesson 8**

## Discussion

- *How does reduce relate to the concepts of reuse and recycle?*
- *What are some creative ways to reduce garden waste?*

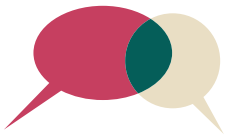
## Finalize Basemap and Site Assessment

### Assignment

*If student's basemaps and site assessment are not yet complete, they should take time to finish them this week. In the following class students will work with classmates to explore potential design options for their home gardens. The basemap template and site assessment findings are essential to determining the best strategies for their gardens. At the end of the next class, students should be prepared to discuss potential implementation of concepts explored throughout the series.*

For the final class, students will need to bring the following items:

- › Two copies of their finalized basemap
- › All site assessment materials
- › Ruler
- › Colored pencils
- › Trace paper



*Class Wrap-up: Closing Questions or Comments*

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# 5



## Class Preparation Checklist

- Prepare computer, projector, screen, and other necessary items required to lead the Class Five PowerPoint presentation.
- Research reclaimed materials that can be obtained locally and provide students with a list of vendors in the area, page 123
- Research local recycling centers and compile a list of the materials they accept, page 124
- Provide examples of local or indigenous materials, page 125



# Class 5

## Lesson 9: Successful Materials Practices

## Lesson 10: Student Presentations

**Learning objectives** *After completing this class students will be able to:*

### Lesson 9

- List strategies for reducing, reusing, and recycling materials in the garden
- Make informed decisions when selecting garden materials
- Identify local salvage and recycling centers

### Lesson 10

- Describe existing features of their home garden that either contribute to or take away from its overall sustainability
- Demonstrate how sustainable practices can be implemented into their home gardens

# Lesson 9

## Successful Materials Practices



### Overview

In this second materials lesson, homeowners continue to learn how to use the concepts of reduce, reuse, and recycle to prevent negative environmental impacts and creatively minimize waste in their garden. The lesson discusses the factors for selecting sustainable garden materials along with information on locating these materials.

## Reuse

Reuse is the repurposing of materials in a way that requires little or no processing. Reuse is one of the most effective strategies for offsetting the initial environmental and human health impacts of material or products because a majority of the material's life cycle can be bypassed. For example, reusing reclaimed brick, rather than allowing the brick to go to the dump, bypasses the raw material extraction, manufacturing, and disposal portions of the brick's life cycle. If the brick is reclaimed from the site, the pollutants released during transportation and distribution can also be eliminated.

In addition to providing numerous environmental benefits, using **reclaimed** materials in the garden can also provide design details unique to the site and help reduce costs. Strategies for reusing materials include the following:

- › **CONSIDER THE MANY OPTIONS** Reclaimed materials can be used in whole form or deconstructed and dismantled to create a completely new object.
- › **BE CREATIVE** Homeowners should be open to new and creative ways in which materials may be incorporated into the garden. When reusing materials it is often helpful to let the material inspire design.
- › **LOCATE MATERIALS EARLY IN THE DESIGN PROCESS** Determining what materials are available for reuse early in the design process will allow time for creativity and design exploration.
- › **SELECT MATERIALS THAT CAN BE REUSED** When designing new site features, homeowners can encourage the reuse of materials in future projects by selecting durable and non-toxic materials that come in modular and/or standard sizes.
- › **DESIGN FOR DECONSTRUCTION** Design site features to allow them to be disassembled with reasonable effort and without extensive damage to the material. For example, use screws instead of nails and avoid the use of glues or other liquid adhesives.

### Locating Reclaimed Materials

When shopping for reclaimed materials, homeowners have a variety of options. Common suppliers include recycling centers, salvage stores, Habitat for Humanity, and websites like freecycle.com or Craigslist. To prepare for this section, the instructor will need to research local resources for reclaimed materials and provide students with a list of vendors in the area.

## Recycle

Materials that are collected, reprocessed, and used again to make a new product are known as **recycled materials**. Recycled materials lessen the need for virgin feedstock and avoid sending useful materials to the landfill; however, significant energy and resources are often required during the recycling process. Recycled materials should be considered

after options to reuse and reduce materials have been fully explored. Homeowners can support the use of recycled materials in two ways. First, they may purchase materials with recycled content. Typically, the higher the recycled content, the better. Second, they may purchase materials that can be easily recycled in their local area.

### **Post-consumer vs. Pre-consumer Content**

Recycled materials can contain either post-consumer or pre-consumer content. Post-consumer items are usually preferred because they are made from materials that were once consumer items and have now been diverted from the landfill. Pre-consumer content is made from defective or waste products (e.g., cracked boards, metal shavings, or wood chips) produced during the manufacturing process. These materials can often be broken down and remade into similar or different products.

### **Recycling Materials Locally**

Unfortunately, not all materials can be recycled in all areas. Knowing the materials accepted by local recycling centers can save time and help homeowners make more informed decisions. Prior to teaching this section, the instructor will need to research local recycling centers and compile a list of the materials they accept.

### **Purchase local materials**

Using materials produced in the region has multiple advantages. It reduces the fossil fuels required for shipping and their associated pollutants, including greenhouse gas emissions. It supports local businesses and the larger regional economy. One of the additional benefits of landscaping with local materials is that they can showcase the region's unique sense of place.

What constitutes "local" varies to some extent, depending on the type of material. The heavier the material, the more energy it consumes and the more pollutants emitted during transport, and therefore the closer the source should be.

There a number of guidelines provided by SITES that homeowners should follow when purchasing local materials:

- ▶ Crushed concrete and other aggregates used as a foundation for paths and driveways should be extracted, recovered, or manufactured within 50 miles of the site
- ▶ Compost and other soil amendments should come from within 50 miles of the site
- ▶ Plants should be grown at a facility within 250 miles of the site
- ▶ All other materials should be extracted, harvested, recovered, and manufactured within 500 miles of the site

### Examples of Local Materials

When preparing for this section, instructors will need to research examples of materials that meet the guidelines above. Local landscape architecture firms, who have pursued LEED certification from the US Green Building Council or who are following the SITES criteria, have likely undertaken this type research and can serve as a valuable resource. Other potential sources of information include local nurseries or garden centers.

*Decomposed granite, a byproduct of the granite mining process, is a local material commonly used in Central Texas for pathways or as decorative mulch.*



## Use minimally processed materials

The ecological and human health impacts of materials typically increase with each additional manufacturing phase. Therefore, materials that have reduced manufacturing and processing requirements often pose fewer environmental and human health risks.

Examples of minimally processed materials:

- › Uncut stone
- › Compressed earth blocks
- › Bamboo

## Use certified wood

Experts are hesitant to compile definitive lists of sustainable wood species because variability in harvesting techniques can lead to a tree being endangered in one area and responsibly harvested in another. In the case of domestic trees like Douglas fir, it is not the species itself but rather the **old-growth forests** from which specimens can be cut that are becoming rare.

Traditionally, forests both here and abroad have been managed for maximum timber yield and profit. In order to be truly a renewable resource, wood must be managed on a **sustainable yield** basis—that is, it should not be cut down faster than it can be regrown or replaced in nature. The term sustainable yield has entered the lexicon of forestry schools only in the past few decades, and it is just beginning to filter down into the ranks of foresters in the field. Most forest lands are still managed primarily for just one species and one size of tree in what are called **even-age stands**, drastically limiting plant and wildlife diversity. Ecologically managed forests incorporate a number of environmental protections, such as protecting riparian zones from logging to prevent erosion and damage to aquatic habitats and preserving zones of critical habitat for rare and endangered species. Wood plantations are managed so they reduce pressures on natural forests and promote their **restoration** and **conservation**.

The best way to guarantee that the lumber and other wood products you purchase have been harvested sustainably is to choose products certified by the **Forest Stewardship Council** (FSC) or other independent nonprofit organizations that have determined that the materials meet a set of rigorous standards. Information on the FSC standards, the certification process, and how to find suppliers is available on the website of the US chapter of the FSC [www.fscus.org](http://www.fscus.org).



RUSSELL LEE

*Know how your mulch or wood products were harvested.*

### **More Wood Tips**

To maximize the benefits to the environment as well as the local economy, keep the following tips in mind when shopping for wood:

- › Reusing materials already on the property or those salvaged from a nearby location is more environmentally friendly than purchasing products made of virgin resources.
- › To eliminate off-gassing or **leaching** of toxins into the air, soil, and water, do not use wood treated with chemicals. Instead, use local rot-resistant species.
- › Keep in mind that wood may require maintenance over its lifetime. When paints or other finishes are necessary, choose the least toxic products available.

### **Avoid the use of PVC**

**Polyvinyl chloride (PVC)** releases dioxin, a known carcinogen, during its manufacturing and disposal phases. PVC is commonly used in products such as plastic fencing, irrigation pipe, decking, and garden hoses. It cannot be recycled and has a relatively short life span. Homeowners should consider alternatives to PVC such as high-density polyethylene (HDPE) piping or wooden decking or fencing.

## Choose no or low VOC products

The term **volatile organic compounds (VOCs)** refers to a large number of mostly petrochemical-derived substances that readily volatilize, or become a gas, at room temperature. VOCs can be bad for the environment and harmful to human health. Among the hundreds of VOCs found in consumer products are formaldehyde; benzenes; toluene; styrene; xylenes; and chlorinated solvents such as trichloroethylene, carbon tetrachloride, and methylene chloride. Garden products that contain VOCs include primers, paints, stains, sealers, other finishes, paint strippers, adhesives, caulks, and pesticides.

VOCs have been linked to a variety of negative health effects including dizziness, irritation of the eyes and respiratory tract, damage to the nervous system, and cancer. When used outdoors, they contribute to the formation of ground-level ozone, which is the primary component of **smog**.

### Products That Have No or Low VOC Content

While VOCs were once necessary for good performance in many products, most companies now produce effective and cost-competitive alternatives. For example, less toxic paints, stains, and varnishes use water as a carrier instead of petroleum-based solvents to reduce emissions.

Check product labels and literature for information on VOC content. Usually listed in grams per liter (g/l), it can range from 5 to 200. Using a product with the lowest VOC content will yield the lowest overall environmental and health risk. Paints that meet the Green Seal standard are certified lower than 50 g/l for flat finish or 100 g/l for non-flat finish.

## Lesson 9

### Discussion

- *What is the difference between reused and recycled materials?*
- *Can you provide any creative examples of how you have incorporated reused or recycled materials into your garden design?*
- *What are some local or regional materials that can be incorporated into the garden?*
- *Do you have any ideas on where to obtain these materials or how these materials can be creatively incorporated into a garden design?*



*Recommend a short break while instructor prepares for Lesson 10: Student Presentations*



## Resources: Materials

### Publications

#### **A Bay-Friendly Landscaping Guide to Recycled Content and Salvaged Materials**

Stopwaste.org

<http://www.stopwaste.org/docs/salvaged.pdf>

*This well-illustrated guide provides resources, examples, and tips on using salvaged and recycled landscape materials.*

#### **Materials for Sustainable Sites: A Complete Guide to the Evaluation, Selection, and Use of Sustainable Construction Materials**

Meg Caulkins

John Wiley & Sons (2008)

*This complete guide features strategies to minimize environmental and human health impacts of conventional site construction materials as well as green materials. It introduces tools, techniques, ideologies, and resources for evaluating, sourcing, and specifying sustainable site materials.*

### Useful Websites

#### **American Forest Stewardship Council (FSC)**

<https://us.fsc.org/>

*This website provides information on obtaining forest-based construction materials that have been sustainably managed and meet FSC certification standards.*

#### **Bay Friendly Landscaping Materials Database**

Stopwaste.org

<http://www.stopwaste.org/home/index.asp?page=382>

*This website provides a materials database that lists products, suppliers, and service providers that meet the Green Building and Bay-Friendly Landscaping Guidelines and have been developed in collaboration with green industry professionals.*

#### **Programme for the Endorsement of Forest Certification (PEFC)**

<http://www.pefc.org/>

*This website provides information on obtaining forest-based construction materials that have been sustainably managed and meet PEFC certification standards.*

#### **Recycling Landscapes and Hardscapes Calculator**

Sustainable Cities Institute

[http://www.sustainablecitiesinstitute.org/view/page.basic/calculator/feature.calculator/Calculator\\_Landscape\\_Waste\\_Costs](http://www.sustainablecitiesinstitute.org/view/page.basic/calculator/feature.calculator/Calculator_Landscape_Waste_Costs)

*This website provides a cost calculator that estimates the cost savings associated with recycling and reusing hardscape and green waste.*

**Wastes: Comprehensive Procurement Guidelines**

US EPA

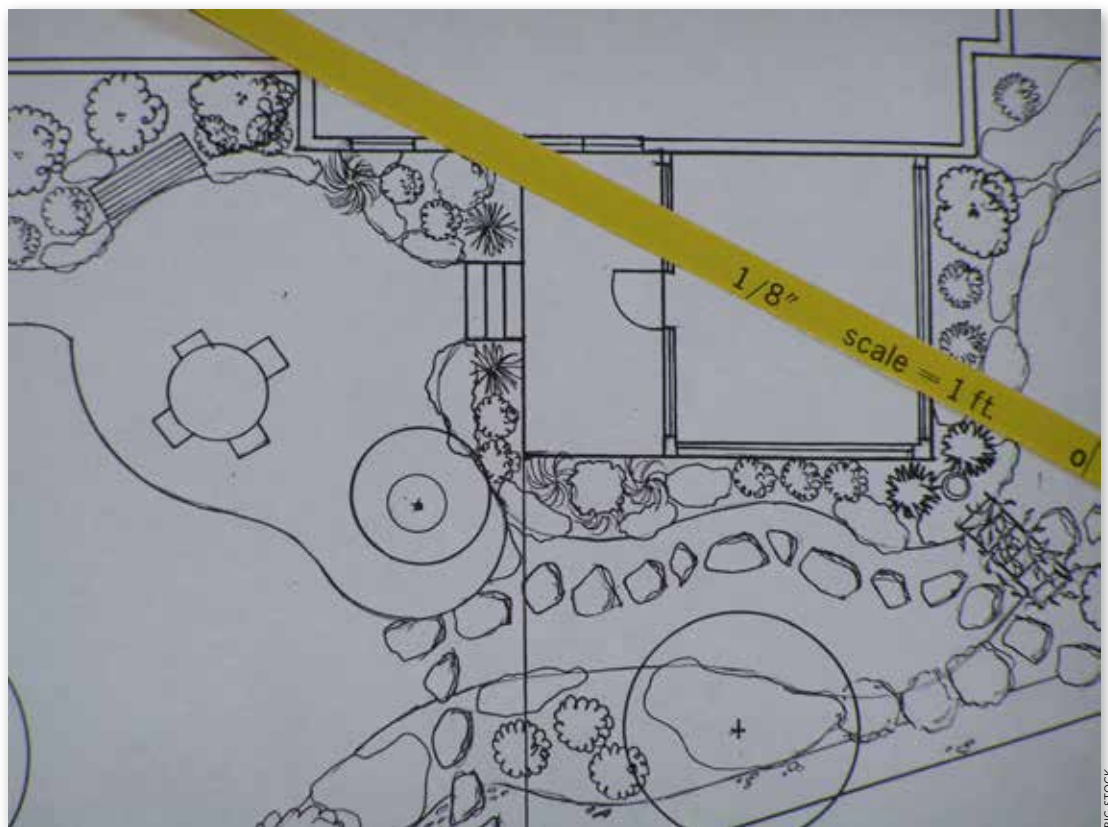
<http://www.epa.gov/epawaste/consERVE/tools/cpg/>

*The Comprehensive Procurement Guideline (CPG) Program provides standards for recycled content materials as well as a list of suppliers who produce products made from recovered material content.*

\*Information on plant disease diagnostics can be found through a local Cooperative Extension Office. A list of offices by state is provided in Appendix 2 of this manual.

# Lesson 10

## Student Presentations



BIG STOCK

### Overview

**N**ow that the class is complete, it is time for students to put what they have learned into practice. The purpose of this last lesson is to provide design inspiration, facilitate discussion, and resolve any unanswered questions. Using their basemaps and site assessment information, students will explore potential design strategies for their homes and discuss their findings with classmates.

## Design inspiration

When looking for creative solutions it is often helpful to see what others have accomplished. In this section, instructors will share example projects that have implemented various sustainable practices. Project examples from across the US have been compiled in the accompanying Landscape for Life PowerPoint presentation. Instructors may choose to use these materials or include others from their personal photo libraries.

### Exploring sustainable design strategies

#### Activity

*In this exercise, students will begin to explore potential sustainable design strategies for their home gardens. Using their basemaps and site assessment information, ask students to determine the following:*

- ▶ Does your garden contain any invasive species or other plants not appropriate for the site conditions that need to be replaced with native or adapted vegetation? If so, what vegetation would make a good replacement?
- ▶ What strategies will you use to minimize the use of potable water in the garden?
- ▶ What strategies will you use to reduce or prevent stormwater runoff from your site? Bioswale, rain garden, rainwater harvesting, or other?
- ▶ How will garden trimmings or other plant waste be managed? Compost, worm bin or other? Where will these items be located in the garden?
- ▶ Where in the garden does vegetation need to be located to help cool your home and reduce energy consumption in the summer months? What plants would work best?
- ▶ Where in the garden does a windbreak need to be located to block prevailing winter winds?

Students should explore each of these questions briefly and quickly draw their ideas on trace paper overlying their basemap. During this time, the instructor can assist students by answering questions but should avoid creating design solutions. After 30 to 45 minutes, group students into pairs to discuss their design ideas and explore options. Continue this exercise until the last 15 minutes of class.

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## Wrap-Up and Course Evaluations

### Course Evaluation

- *What portions of the educational series were most helpful to you?*
- *In what topic area would you like to receive more information?*
- *What garden project will you take on first?*

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# Glossary

**Acidity (Soil):** Soils with a pH below 7.0 that become increasingly acidic as this value decreases.

**Acid Rain:** Rainfall that is made unusually acidic (pH less than 5 to 6) by atmospheric pollution. Acid rain can be detrimental to many environmental components, including soils and water, fish and wildlife, and humans.

**Active Rainwater Harvesting:** A method of collecting rainwater (using a barrel, cistern, or tank) for later reuse in the garden.

**Adapted (Plant):** A plant that is not native, but thrives in the ecological and climatic conditions of the area without being invasive.

**Aggregates:** Groups of soil particles that are bound together by cohesive force and ultimately contribute to soil structure.

**Air Conditioner (A/C) Condensate:** The water byproduct produced by an air conditioning system that can be collected and used to help irrigated plants.

**Algal Bloom:** The rapid accumulation of algal growth often due to excessive nutrient input (e.g., potassium-based fertilizer) into an aquatic system. Negative effects to water quality caused by algae may include the release of toxins and the depletion of oxygen through cellular respiration.

**Alkalinity (Soil):** Soils with a pH above 7.0, that become increasing alkali as this value increases.

**Amendment:** A material incorporated into the soil to improve physical properties (water retention, permeability, drainage, etc.) and ultimately aid in the growth and vitality of plants.

**Annual (Plant):** A plant that completes its normal growth cycle (i.e., germination, flowering, dieback) in one year or less. Compare with **Perennial**.

**Aquifer:** An underground layer of permeable rock or unconsolidated soil from which water can be obtained.

**Bedrock:** hard, consolidated rock lying beneath looser surface materials, such as soil and gravel.

**Berm:** A level space, shelf, or raised barrier separating two areas in a garden. Berms can serve multiple purposes in garden design, including enhancing aesthetics, directing the flow of excess rainwater, and separating different areas of the garden.

**Biodiversity:** The diversity (number and variety of species) of plant and animal life within a given area.

**Biofiltration:** Any pollution control technique (e.g., raingarden and bioswale) that uses living material (plants, bacteria, etc.) to capture and break down pollutants.

**Bioswale:** A garden feature composed of a shallow depression or channel used to redirect, absorb, and filter stormwater runoff.

**Broadcast:** The act of scattering large quantities of seed by hand.

**Capillary Action:** The ability of water to be pulled up and moved through very narrow spaces (within soils, plants, etc.) by forces of adhesion, cohesion, and surface tension.

**Cellulose:** The principle component of plant cell walls that provides structural support.

**Certified Wood:** Wood that meets responsibly managed forest standards. Two of the largest international forest certification programs are the Forest Stewardship Council (FSC) and the Programme for the Endorsement for Forest Certification (PEFC).

**Chlorotic:** The abnormal yellowing of plant tissue due to a decrease in chlorophyll production, which is often caused by a disease or nutrient deficiency.

**Cistern:** A large tank that is used to collect, store, and manage rainwater resources. It is larger in size than a rain barrel.

**Clay:** The smallest soil separate with particles <0.002 mm in diameter.

**Climate:** The average weather conditions for a location, taken over a long period of time.

**Coevolution:** The interdependent evolution of closely associated species that have an obvious ecological relationship (e.g., predator/prey relationships).

**Compaction (Soil):** The process by which stress applied to soil causes an increase in bulk density (weight per unit volume) and a decrease in soil porosity.

**Complete Fertilizer:** A fertilizer that contains the three major plants nutrients including, Nitrogen (N), Phosphorous (P), and Potassium (K).

**Compost:** Decomposed organic matter that is incorporated into the ground to help fertilize and amend soil.

**Conifer:** A tree or shrub that is characterized by having mainly evergreen leaves (i.e., needlelike or scalelike) and cones that hold seeds.

**Conservation:** The wise management of natural resources (e.g., wildlife, plants, soils, and water), that attempts to restore, enhance, protect, and sustain ecological services for current and future generations. Compare with **Preservation**.

**Contact Herbicide:** A substance that kills only the parts of the unwanted vegetation it comes in contact with. Compare to **Systemic herbicide**.

**Cover Crop:** A crop that is grown to protect soil from erosion. Like green manures, cover crops can also be grown to improve soil quality.

**Damping-off:** The destruction of seeds or young seedlings caused by a fungal pathogen, usually occurring under excessively damp soil conditions.

**Deciduous:** A tree or shrub that sheds its leaves during the winter. Compare with **Evergreen**.



**Decomposer:** An organism, usually a bacterium or fungi, that carries out decomposition by breaking down dead or decaying organic matter.

**Decomposition:** The process by which decomposers break down complex organic materials, such as dead plants or animals, into simpler substances that can be used by other organisms.

**Drip irrigation System:** An automatic watering system, which uses a hose with a series of small holes to deliver a frequent, slow application of water directly to the root zone of a plant or crop.

**Drought Tolerant:** The degree in which a plant is adapted to arid or drought conditions.

**Ecoregion:** An area characterized by distinct ecological factors including climate, landform, vegetation, soil, and hydrology.

**Ecosystem Services:** The benefits, including the resources and processes (e.g., food, medicine, pollination, nutrient cycling), that humans derive from natural systems.

**Ephemeral (Plant):** A plant characterized by a short life cycle (approximately 6-8 weeks).

**Erosion:** The process by which land surface materials are gradually worn away by the action of water, glaciers, winds, waves, etc.

**Evaporation:** The process by which water is lost from a surface (soil, plant, etc.), converted into a gas, and returned to the atmosphere.

**Evapotranspiration:** A collective term for the process in which water is return to the atmosphere by evaporation from soil and other surfaces and the transpiration from plants

**Even-age Stand:** A stand that contains trees in which there is no more than one to two age classes (less than 20 years) between the oldest and youngest trees.

**Evergreen:** A plant that retains green leaves throughout the year. Compare with **Deciduous**.

**Fauna:** Animal life, often used in the context of a particular region or period of time.

**Fertilizer:** A natural or synthetic material added to soil to increase fertility and plant yield. See **Natural Fertilizer** and **Synthetic Fertilizer**.

**Fossil Fuels:** A natural fuel (e.g., coal, oil, petroleum) that is formed in the earth over millions of years from the remains of living organisms.

**Fragment (Habitat):** See **Fragmentation (Habitat)**.

**Fragmentation (Habitat):** The disturbance or spatial separation of large, continuous blocks of habitat into smaller, often less productive (reduced biodiversity, interruption of sustainable yield of natural resources, etc.) units.

**Generalist (Species):** A species that has a broad niche or is able to thrive in a wide range of environmental conditions and make use of a variety of different resources (e.g., an animal with a varied diet).

**Grading (Soil):** The leveling of soil to support construction activities. Heavy equipment used during the grading process often leads to compaction and poor soil structure.

**Graywater:** Non-industrial waste water produced from activities such as laundry, dishwashing, and bathing that can be collected and reused to irrigate non-food plants.

**Greenhouse Gas:** Gases in the atmosphere (e.g., water vapor, carbon dioxide, methane, ozone) that cause warming by absorbing and emitting infrared radiation.

**Green Manure:** A crop (e.g., soybeans, clover, rye, vetch) that is grown and then plowed under to improve soil fertility.

**Greenroof:** A roof system designed to support the installation and growth of plants. Greenroofs can be used to reduce building and surrounding temperatures, filter pollution, and lessen stormwater runoff.

**Greenwaste:** Biodegradable waste, including yard trimmings, leaves, plants, wood waste, food waste, and other organic materials.

**Habitat:** Area or natural environment where an organism or population normally lives, which comprises all physical factors such as light, moisture, and temperature and biological factors such as food and predators.

**Hardiness:** The ability of a plant to tolerate particular growing conditions. Often used in reference to temperature (i.e., cold) tolerance.

**Hardiness zone:** A geographically defined zone, established by climatic conditions or minimum temperatures, in which a plant is capable of growing.

**Heavy Metals:** Metals (e.g., copper, lead, and zinc) that are often a byproduct of industrial process, many of which cause environmental pollution and have tendency to bioaccumulate in living organisms and lead to serious health problems.

**Herbicide:** A pesticide used to kill unwanted plants. See **Systemic herbicide** and **Contact herbicide**.

**Humidity:** Amount of water vapor present in the air.

**Humus:** A dark, rich, and stable (i.e., will not breakdown further and can remain as is for centuries) organic material formed by the decomposition of organic matter.

**Impervious Surface:** An impenetrable surface (asphalt, concrete, brick, stone, urban soils, etc.) that prevents infiltration and promotes water runoff.

**Infiltration:** The process by which water on the ground surface is able to enter the soil.

**Invasive (Species):** A non-native species whose introduction does or is likely to lead to economic or environmental harm or harm to human health.

**Irrigation:** The application of water to land to supply plants and crops with the necessary water for growth.

**Leaching:** The loss of water soluble plant nutrients from soil, caused by the downward flow of water through the soil.

**Loam:** A rich, fertile soil with relatively even concentrations of sand, silt, and clay (40-40-20 percent, respectively).

**Macronutrients:** The essential nutrients that plants require in the largest quantities, including Nitrogen (N), Phosphorous (P), Potassium (K), Calcium (Ca), Magnesium (Mg), and Sulfur (S).

**Macropores:** Large soil pores (>0.08 mm) between aggregates, which aid in the infiltration and drainage of soil water. Compare to **Micropores**.

**Microclimate:** The climate of a smaller, self-contained environment (e.g., a valley, shady spot in a garden, etc.) that is different from the larger, surrounding environment.

**Micronutrients:** Nutrients that are needed by plants in small amounts, including Chlorine (Cl), Boron (B), Iron (Fe), Magnesium (Mn), Zinc (Zn), Copper (Cu), and Molybdenum (Mo). Unlike macronutrients, these nutrients are usually readily available in the soil and do not require supplementation.

**Microorganism:** A microscopic organism, such as a bacterium, protozoan, certain fungi, and algae.

**Micropores:** Small soil pores (<0.08 mm) within aggregates in which water may be stored for use by plants. Compare to **Macropores**.

**Mulch:** A protective covering (usually organic matter such as sawdust, compost, or paper) spread of the ground to improve soil quality, reduce evaporation, maintain temperature, prevent erosion, control weeds, etc.

**Native:** A species that occurs naturally in a particular region, state, ecosystem, or habitat without direct or indirect human introduction.

**Natural Fertilizer:** A material that occurs regularly in nature, such as bone meal, bat guano, poultry humus, fish emulsion, fish meal, or cotton seed meal, that can be added to soil to improve fertility and plant yield. Compare to **Synthetic Fertilizer**.

**Natural Resources:** Naturally occurring materials and substances, such as mineral deposits, forests, and water that are valuable in their unmodified form.

**Niche:** The role (e.g., unique sum of abiotic and biotic interactions) and space an organism occupies in a given ecosystem.

**Nitrogen Fixation:** A natural (bacterial means) or artificial process (chemical means) which converts unusable atmospheric nitrogen into a form that can be used by plants.

**Old-growth Forest:** A forest that that has attained great age (usually greater than 200 years) without significant disturbance.

**Organic Matter:** Carbon-based material composed of once living organisms such as plants and animals and their waste products.

**Passive Rainwater Harvesting:** A method of utilizing rainwater, often accomplished through the use of a raingarden or bioswale that makes immediate use of the water resource. Compare with active rainwater harvesting.

**Pathogen (Plant):** A organism (typically a bacterium, virus, or fungus) that causes disease in plants.

**Ped:** An aggregate of sand, silt, or clay of a characteristic shape and size.

**Perennial:** A plant that lives two or more years. Compare to **Annual**.

**Pesticide:** A substance, usually synthetic although sometimes biological, used to prevent, destroy, or repel any unwanted pest (insects, plants, fungi, microorganisms, etc.).

**pH:** See **Soil pH**.

**Photosynthesis:** The process by which plants and other autotrophic organisms use energy produced from the sun to convert carbon dioxide and water into fuel (carbohydrates) for the plant.

**Phytotoxic:** Toxic to plants.

**Platy:** A soil structure consisting of peds that are flat and horizontally arranged.

**Polycyclic Aromatic Hydrocarbons (PANs):** Potent atmospheric pollutants that enter the atmosphere through the combustion process (e.g., automobile exhaust, fossil fuel power plants, forest fires).

**Polyvinyl Chloride (PVC):** An environmentally harmful synthetic plastic used in many landscaping materials and fixtures including fencing, rain gutters, and garden furniture.

**Pore Space:** The space in rock, soil, or unconsolidated sediment that is not occupied by mineral matter and allows for the passage and movement of both water and air.

**Potable Water:** Water that is considered safe enough for human consumption or drinking water.

**Prescribed Burning:** Prescribed burn or controlled burn is the planned and skillful application of fire to accomplish specific land management objectives (e.g., reduce fuel load, decrease the likelihood of serious hotter fires, etc.).

**Preservation:** To maintain land, an ecosystem, or a component of an ecosystem in its original state, protecting it from the influence of outside forces. Compare with **Conservation**.

**Primary Consumers:** Organism that obtain their energy from feeding on producers (plants, algae, or other autotrophs) or associated organic matter.

**Radial Trenching:** A practice which using air excavation tools to create narrow trenches in spoke pattern around a tree and then backfills with porous material to remediate soils compaction.

**Rain Barrel:** A container that is often connected to a downspout or rooftop, that is used to collect, store, and manage rainwater resources. Smaller in size (50 gallons) than a cistern.

**Rain Garden:** A vegetative depression that captures and filters runoff from impervious surfaces such as roofs, driveways, and walkways.

**Rain Gauge:** An instrument used for catching and measuring rainfall.

**Reclaimed Materials:** Waste materials or byproducts that have been recovered and reused, without being reprocessed. Compare with **Recycled Materials**.

**Recycled Materials:** Waste materials or byproducts that have been reprocessed to form a new product. Compare with **Reclaimed Materials**.

**Restoration:** The return of an ecosystem or some component of an ecosystem to a close approximation of its condition prior to disturbance.

**Reuse** is the repurposing of materials in a way that requires little or no processing.

**Riparian:** Of or relating to wetlands adjacent to a stream or other body of water.

**Runoff:** Water from rainfall, snowmelt, or otherwise discharged that flows across the ground surface instead of infiltrating the ground.

**Saline Soil:** A soil containing high concentrations of soluble salts, often with levels high enough to adversely affect plant production.

**Sand:** The largest soil separate with particles ranging from 2.0-0.05 mm in diameter.

**Secondary Consumer:** An animal that obtains its energy from feeding on primary consumers (plant eating organisms).

**Semi-evergreen:** A plant that is green only part of the year or only retains part of its foliage during the winter.

**Shallow Soil:** A soil that is characterized by its shallow depth (10-20"), often tending to be water and nutrient deficient.

**Silt:** A medium sized soil separate with particles ranging from 0.05-0.002 mm in diameter.

**Soil:** The unconsolidated mineral or organic material on the earth's surface that supports a wide range of biotic life.

**Soil Amendment:** A material, natural or synthetic, applied to the soil to increase fertility, improve structure, or balance pH.

**Soil Food Web:** The complex living system in the soil comprised of plants, organic matter, microorganisms, and their interactions.

**Soil pH:** A measure of acidity or alkalinity of a solution represented by a logarithmic scale that ranges from 0-14. Values of 7 represent a natural solution, increasing with increasing alkalinity and decreasing with increasing acidity.

**Soil Moisture Probe:** soil moisture sensor or tensiometer, is a device used to measure soil moisture and help determine irrigation needs. It works by measuring the tension that plant roots must exert to extract available water from the soil.

**Soil Structure:** The arrangement of individual soil particles (sand, silt, clay, and organic matter) into larger secondary particles called aggregates of various shapes, sizes, and degrees of adhesion to one another.

**Soil Texture:** The relative proportions of sand, silt, and clay comprising a soil.

**Smog:** A type of air pollution created by the reaction of sunlight with hydrocarbons, nitrogen compounds, and other gases produced largely by automobile exhaust.

**Stormwater:** Excess rainwater that is not absorbed by the ground and instead flows over land surfaces to the nearest body of water.

**Sustainability:** The practice of creating and maintaining conditions which promote coexistence of human and nature in a way that supports the social, economic, and other requirements of current and future generations.

**Sustainable Sites Initiative (SITES):** Voluntary national guidelines and performance benchmarks for sustainable land design, construction, and maintenance practices.

**Sustainable Yield (Forestry):** The largest amount of forest harvest activity that can occur without degrading the productivity of the stock.

**Stewardship:** A commitment to environmental responsibility that aids in the management and protection the earth's natural resources.

**Synthetic Fertilizer:** Manufactured soil nutrients, often nitrogen (N), phosphorus (P), or potassium (K), that are applied independently or combined to improve soil fertility and plant yield. Compare to **natural Fertilizer**.

**Systemic Herbicide:** A substance that kills a whole plant by being absorbed and translocated through the vascular tissue. Compare to **Contact Herbicide**.

**Terrace:** A piece of sloped plane that has been cut into a series of successively receding flat surfaces or platforms, which resemble steps. The practice of terracing can be used to help slow and disperse water throughout the garden.

**Till:** A technique used to turn over and break up soil, for purposes including incorporating amendments, correcting compaction issues, or killing weeds.

**Topsoil:** The top most layer of soil, ranging from about 2-10 inches in depth that is often characterized by its high concentration of organic matter and biological activity.

**Urban Heat Island:** An urban area that is significantly warmer than surrounding suburban or rural areas. This phenomenon is large due to the increase of anthropogenic activity and built surfaces in urban areas.

**Urbanization:** A phenomenon that describes the conversion of land use to an urban pattern of organization and the increase in population concentration in these areas.

**Vegetative Buffer:** An area of existing, dense vegetation, often directly adjacent to a body of water that is intended to slow runoff, trap sediment, and provide some infiltration into underlying soil.

**Vertical Mulching:** A practice which involves drilling holes within the root zone of a tree and backfilling with porous material to remediate soil compaction.

**Volatile Organic Compounds (VOCs):** Toxins commonly found in paints, sealer, and finishes, that are released during product use and have been found to be hazardous to the environment and human health.

**Waterlogged:** The saturation of soil with water, which can damage soil structure and create anoxic conditions lethal to plant roots.

**Watershed:** A geographic area where all the water that is under it or drains off of it goes into a single stream or drainage system.

**Water Table:** The upper surface of a below ground area filled with groundwater, separating the zone of aeration from the zone of saturation.

**Wildlife Corridor:** An area of land used to link habitats and help facilitate the migration and dispersal of species.

**Windbreak:** A windbreak or shelterbelt, is a row of trees and shrubs typically planted to provide protection from wind or lessen soil erosion.

# Appendix 1:

## List of Additional Resources by Subject

### SUSTAINABLE GARDENS

#### *Publications*

#### **Bay-Friendly Landscape Guidelines: Sustainable Practices for the Landscape Professional**

<http://www.stopwaste.org/>

*Guidelines written for the professional landscape industry to provide an integrated approach to environmentally friendly landscaping.*

#### **Sustainable Gardens**

Rob Cross and Roger Spencer  
Csiro Publishing (2009)

*Developed for amateur and professional horticulturist, this book illustrates how to make informed decisions when designing, constructing, and maintaining parks and landscapes for reduced environmental impacts.*

#### **Sustainable Sites Design: Integrated Design Strategies for Residential and Small Scale Sites**

Heather Venhaus  
John Wiley & Sons Inc. (2012)

*A sustainable landscape design guide that explores strategies for alleviating some of the most common and pressing environmental and human health issues. A detailed overview of each strategy is provided and includes design considerations, illustrations, and images to help readers determine the best options for their site. Case studies from public and private projects are provided throughout the book.*

#### **The Conscientious Gardener**

Sarah Reichard  
University of California Press (2011)

*This book explores the many benefits of sustainable gardening and provides straightforward, practical advice on topics such as pest control, water conservation, living with native animals, mulching, and controlling invasive species.*

#### **The New American Landscape: Leading Voices on the Future of Sustainable Gardening**

Tomas Christopher (ed.)  
Timber Press (2011)

*This book brings together the best thinkers on the topic of gardening sustainably, and asks them to describe the future of the sustainable landscape.*

#### **The Sustainable Sites Handbook: A Complete Guide to the Principles, Strategies, and Best Practices for Sustainable Landscapes**

Meg Calkins (ed.)  
John Wiley & Sons Inc. (2011)

*A technical guide, authored by many involved in the development of SITES, that contains information on principles, strategies, technologies, tools, and best practices sustainable site design for any type of landscape.*



### **The Sustainable Sites Initiative: The Case for Sustainable Landscapes**

<http://www.sustainablesites.org/report/>

*A companion volume to the Sustainable Sites Initiative: Guidelines and Performance Benchmarks, 2009. This publication provides arguments—economic, environmental, and social—for the adoption of sustainable land practices.*

### **Useful Websites**

#### **Designing Our Future: Sustainable Landscapes**

American Society of Landscape Architects  
<http://www.asla.org/sustainablelandscapes/>

*This website provides educational resources and innovative design ideas on sustainable landscaping through a series of case studies from across the United States.*

#### **Fresh Landscape Design: Inspiring Places and People**

<http://www.freshlandscape.com.au/>

*A case study featuring an impressive sustainably designed landscape in Australia.*

#### **Organic Land Care**

Rutgers New Jersey Agricultural Experiment Station

<http://njaes.rutgers.edu/organiclandcare/>

*This website provides information and resources in organic land care. In addition, information is offered on Rutgers' Land Care Certification Program, which provides landscape professionals with the tools needed to apply organic land care practices.*

#### **Sustainable Gardening Articles**

Brooklyn Botanic Garden

[http://www.bbg.org/gardening/category/sustainable\\_gardening](http://www.bbg.org/gardening/category/sustainable_gardening)

*This website provides articles on sustainable gardening topics such as sustainable garden*

*design, gardening for wildlife, native flora, and urban gardening.*

### **Sustainable Sites Initiative**

<http://www.sustainablesites.org/>

*This website provides guidelines for obtaining SITES certification and a series of example SITES-certified pilot projects. The publication "Sustainable Sites Initiative: The Case for Sustainable Landscapes" listed above, along with the complete 2009 volume "Sustainable Sites Initiative: Guidelines and Performance Benchmarks" can be download on this website.*

## **SOIL**

### **Publications**

#### **Interpreting Soil Test Results: What do all the Numbers Mean?**

Pam Hazelton and Brian Murphy  
CSIRO Publishing (2007)

*A guide that explains important soil properties and how to interpret the results of soil laboratory tests.*

#### **Let it Rot!: The Gardener's Guide to Composting**

Stu Campbell  
Story Publishing, LLC (1998)

*A guide to the basic principles of starting and maintaining a composting system.*

#### **Selecting and Using a Soil Testing Laboratory**

University of Maryland Cooperative Extension (revised 2005)

<http://hgic.umd.edu/documents/SelectingSoilTestLabandSoilTestChart.pdf>

*General information on selecting and using soil testing labs.*

### **Soil Design Protocols for Landscape Architects and Contractors**

Timothy Craul and Phillip Craul  
John Wiley & Sons, Inc. (2006)

*Provides step-by-step technical skill sets for implementing productive planting soils.*

### **Teaming with Microbes: The Organic Gardener's Guide to the Soil Food Web, Revised Edition**

Jeff Lowenfels and Wayne Lewis  
Timber Press, Inc. (2010)

*A publication about using organic gardening techniques to strengthen the soil food web and create healthy soils.*

### **Useful Websites**

#### **A Free Directory of Composting Facilities throughout North America**

Biocycle  
<http://www.findacomposter.com/index.php>

*A searchable webpage that provides lists of local facilities that accept organic waste for composting and/or sell compost.*

#### **Composting for Facilities**

US EPA  
<http://www.epa.gov/compost/>

*This website provides composting and compost application information for compost facilities, businesses, industry, and local governments.*

#### **Cornell Soil Health**

Cornell University College of Agriculture and Life Science  
<http://soilhealth.cals.cornell.edu>

*Information about testing and improving soil health.*

### **Soil Texture Calculator**

USDA NRCS  
<http://soils.usda.gov/technical/aids/investigations/texture/>

*A web-based calculator that can help determine soil texture.*

### **Web Soil Survey**

USDA NRCS  
<http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm>

*The National Cooperative Web Soil Survey produced by the USDA Natural Resources Conservation Service (NRCS) provides soil maps and data for most of the United States. In addition, a web soil survey app formatted for mobile devices, allows for real-time access to soil survey data. This app can be downloaded for free at <https://play.google.com/store/apps/details?id=casoilresource.apps.soilweb&hl=en>.*

## **WATER**

### **Publications**

#### **Create an Oasis with Greywater**

Art Ludwig  
Oasis Design (2009)

*A step-by-step guide to greywater harvesting and reuse in residential settings.*

#### **Rain Gardens: A How to Manual for Homeowners**

Roger Bannerman and Ellen Considine  
Wisconsin Department of Natural Resources and University of Wisconsin-Extension (2003)  
<http://learningstore.uwex.edu/assets/pdfs/GWQ037.pdf>

*This manual contains comprehensive, step-by-step instructions on all aspects of creating a rain garden. It includes a number of rain garden planting designs and plant lists for*

varying sun and soil conditions that are especially appropriate for the Midwest.

**Rain Gardens: Managing Water Sustainably in the Garden and Designed Landscape**

Nigel Dunnett and Andy Clayden  
Timber Press (2007)

*Drawing on examples from around the world, this book explores the ways in which landscapes can harvest and reuse stormwater to make beautiful gardens.*

**The Texas Manual on Rainwater Harvesting**

Texas Water Development Board (2005)  
[http://www.twdb.state.tx.us/publications/reports/rainwaterharvestingmanual\\_3rdedition.pdf](http://www.twdb.state.tx.us/publications/reports/rainwaterharvestingmanual_3rdedition.pdf)

*Detailed manual providing information on how to harvest, treat, and reuse rainwater.*

**Useful Websites**

**Depave**

<http://depave.org/>

*This organization promotes the removal of unnecessary pavement from urban areas to create community green spaces and mitigate stormwater runoff.*

**Lake Shoreland Protection Resources**

US EPA  
<http://water.epa.gov/type/lakes/shoreland.cfm>

*This website provides information and resources about lakeshore protection and restoration.*

**Low Impact Development (LID)**

US EPA  
<http://water.epa.gov/polwaste/green/#info>

*This website provides factsheets, reports, design and guidance manuals, informational resources, and videos and other multimedia on low impact development. Low impact*

*development is an approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible. Free downloadable videos on this topic are available at <http://water.epa.gov/polwaste/green/video.cfm>*

**Water Environment Research Foundation (WERF)**

<http://www.werf.org/>  
*Clearinghouse for stormwater best management practices.*

**Water Sense**

US EPA  
<http://www.epa.gov/watersense/>

*This website includes water efficiency tips, water usage calculators, and resources for rebates.*

**Watershed Academy Webcast Seminars**

US EPA  
[http://water.epa.gov/learn/training/wacademy/webcasts\\_index.cfm](http://water.epa.gov/learn/training/wacademy/webcasts_index.cfm)

*Provides monthly webcast seminars on implementing best watershed practices. Archives of previous webcasts are available on this website.*

**Water Use in the United States**

USGS  
<http://water.usgs.gov/watuse/>

*Provides water use data for county, state, and national level.*

**Water Use it Wisely**

<http://wateruseitwisely.com/links-and-resources/#regional>

*Provides a comprehensive list of water conservation related websites, along with an interactive database of water-use authorities by state.*

**Where Does your Water Come From?**

All Hands on Earth

<http://www.nature.org/all-hands-on-earth/where-does-your-water-come-from-3.xml>

*An interactive map of water sources throughout the United States.*

**PLANTS****Publications****Bringing Nature Home: How You Can Sustain Wildlife with Native Plants**

Douglas Tallamy

Timber Press, Inc. (2007)

*A book about using native plants to create habitat for local wildlife.*

**Edible Estates: Attack on the Front Lawn, Expanded 2nd Edition**

Fritz Haeg

Metropolis Books (2010)

*A well-illustrated book that showcases edible gardens across the US.*

**Energy-Wise Landscape Design: A New Approach for your Home and Garden**

Sue Reed

New Society Publishers (2010)

*This book demonstrates how homeowners can use plants and other standard landscape materials to reduce energy use.*

**Native Alternatives to Invasive Plants**

C. Colston Burrell

Brooklyn Botanic Garden (2011)

*This handbook provides recommendations for a variety of beautiful, regionally native, trees, shrubs, vines, herbaceous plants, and grasses that can replace commonly planted invasive species.*

**Trees in the Urban Landscape: Site Assessment, Design, and Installation**

Peter Trowbridge and Nina Bassuk

John Wiley and Sons, Inc. (2003)

*A well-illustrated guide to successful planting in urban landscapes, from design conceptualization to daily maintenance.*

**Useful Websites****ACTrees**

Alliance for Community Trees

<http://actrees.org/what-we-do/>

*This organization provides resources geared at creating healthy urban and community forests.*

**Casey Trees**

<http://caseytrees.org/>

*This organization provides information on how to install, select, and care for trees in urban areas.*

**Celebrating Wildflowers: Gardening for Pollinators**

US Forest Service

<http://www.fs.fed.us/wildflowers/pollinators/gardening.shtml>

*This website provides basic tips and a list of additional resources about using wildflowers to attract pollinators.*

**Growing Green Lawns**

Community IPM Network

[www.growinggreenlawns.org/](http://www.growinggreenlawns.org/)

*A resource that provides integrated best management practices for residential landscapes, lawns, gardens, and home pests.*

**Invasive and Exotic Species of North America**

Center for Invasive Species and Ecosystem Health

[www.invasive.org/](http://www.invasive.org/)

*A comprehensive resource for invasive species identification and control.*

### **Least Wanted: Alien Plant Invaders of Natural Areas**

Plant Conservation Alliance's Alien Plant Work Group (PCA)

<http://www.nps.gov/plants/alien/factmain.htm>

*Illustrated, easy-to-read fact sheets on invasive alien plants with native ranges, plant descriptions, ecological threats, US distributions and habitats, background of introductions, plant reproduction and dispersal, management approaches, alternative native plants, and other useful information.*

### **National Tree Benefit Calculator**

Casey Trees and Davey Tree Expert Co.

<http://www.treebenefits.com/calculator/>

*Calculates the environmental and economic value trees provide on an annual basis.*

### **Native Plant Information Network (NPIN)**

Lady Bird Johnson Wildflower Center, the University of Texas at Austin

<http://www.wildflower.org/plants/>

*The largest native plant database in North America.*

### **North American Native Plant Society**

<http://www.nanps.org/>

*This organization provides information and resources on the cultivation and conservation of native plants.*

### **PLANTS Database**

Natural Resource Conservation Service (NRCS)

<http://plants.usda.gov/java/>

*This database provides standardized information about vascular plants, mosses, liverworts, hornworts, and lichens of the US and its territories. It includes names, plant symbols, checklists, distributional data, species abstracts, characteristics, images, crop information, automated tools, and references.*

### **Pollinator Friendly Plant Guides**

Pollinator Partnership

<http://www.pollinator.org/>

*This website provides ecoregional native planting guides focused on selecting plants that attract pollinators.*

### **Protecting Native Plants and Animals: Taking on Invaders**

The Nature Conservancy

[www.nature.org](http://www.nature.org)

*A resource for learning more about invasive species and how to control their spread.*

### **Vibrant communities: Trees are the Key Online Toolkit**

Sustainable Urban Forests Coalition

<http://vibrantcities.org/>

*An online resource center and communication toolkit with a variety of materials that can be used and/or adapted to provide education on the benefits of city trees.*

## **MATERIALS**

### **Publications**

#### **A Bay-Friendly Landscaping Guide to Recycled Content and Salvaged Materials**

Stopwaste.org

<http://www.stopwaste.org/docs/salvaged.pdf>

*This well-illustrated guide provides resources, examples, and tips on using salvaged and recycled landscape materials.*

#### **Materials for Sustainable Sites: A Complete Guide to the Evaluation, Selection, and Use of Sustainable Construction Materials**

Meg Caulkins

John Wiley & Sons (2008)

*This complete guide features strategies to minimize environmental and human health*

*impacts of conventional site construction materials as well as green materials. It introduces tools, techniques, ideologies, and resources for evaluating, sourcing, and specifying sustainable site materials.*

### **Useful Websites**

#### **American Forest Stewardship Council (FSC)**

<https://us.fsc.org/>

*This website provides information on obtaining forest-based construction materials that have been sustainably managed and meet FSC certification standards.*

#### **Bay Friendly Landscaping Materials Database**

Stopwaste.org

<http://www.stopwaste.org/home/index.asp?page=382>

*This website provides a materials database that lists products, suppliers, and service providers that meet the Green Building and Bay-Friendly Landscaping Guidelines and have been developed in collaboration with green industry professionals.*

#### **Programme for the Endorsement of Forest Certification (PEFC)**

<http://www.pefc.org/>

*This website provides information on obtaining forest-based construction materials that have been sustainably managed and meet PEFC certification standards.*

#### **Recycling Landscapes and Hardscapes Calculator**

Sustainable Cities Institute

[http://www.sustainablecitiesinstitute.org/view/page.basic/calculator/feature.calculator/Calculator\\_Landscape\\_Waste\\_Costs](http://www.sustainablecitiesinstitute.org/view/page.basic/calculator/feature.calculator/Calculator_Landscape_Waste_Costs)

*This website provides a cost calculator that estimates the cost savings associated with recycling and reusing hardscape and green waste.*

#### **Wastes: Comprehensive Procurement Guidelines**

US EPA

<http://www.epa.gov/epawaste/conserve/tools/cpg/>

*The Comprehensive Procurement Guideline (CPG) Program provides standards for recycled content materials as well as a list of suppliers who produce products made from recovered material content.*

## Appendix 2: List of Public Agencies that Offer Diagnostic Services

This appendix provides a list of public agencies (often associated with the State Department of Agriculture or with the United States Department of Agriculture (USDA) research facilities) that offer diagnostic services. In addition to this list, there are many private entities that can provide similar services. Many homeowner samples may not need to be sent to a lab for testing, but may be analyzed by a Master Gardener or County Extension agent. Check your Cooperative Extension office before pursuing testing, as their services are often free of charge. A complete listing of extension offices by state is available at <http://www.csrees.usda.gov/Extension/>.

### ALABAMA

*Auburn University Soil Testing Laboratory*  
ALFA Agricultural Services and Research  
Building  
961 South Donahue Drive  
Auburn University, AL 36849  
Phone: 334-844-3958  
Email: [soillab@auburn.edu](mailto:soillab@auburn.edu)  
<http://www.aces.edu/anr/soillab/>

#### Services:

- ✓ Soil testing
- ✓ Plant tissue analysis (nutrient status of plant)
- ✓ Water testing

*Auburn University Plant Diagnostic Laboratory*  
ALFA Agricultural Services and Research  
Building  
961 South Donahue Drive  
Auburn University, AL 36849  
Phone: 334-844-4336  
Contact: Dr. Charles Ray  
Email: [raychah@auburn.edu](mailto:raychah@auburn.edu)  
<http://www.aces.edu/dept/plantdiagnosticlab/>

#### Services:

- ✓ Plant problem and disease diagnostic testing
- ✓ Insect identification
- ✓ Nematode soil analysis

*Plant Diagnostic Lab at Birmingham*  
C. Beaty Hanna Horticulture and  
Environmental Center  
2612 Lane Park Road  
Birmingham, AL 35223  
Phone: 205-879-6964 ext. 19  
Contact: James Jacobi  
Email: [jacobjc@auburn.edu](mailto:jacobjc@auburn.edu)  
<http://www.aces.edu/counties/Jefferson/plantlab/>

#### Services:

- ✓ Plant problem and disease diagnostic testing
- ✓ Insect Identification
- ✓ Nematode soil analysis

### ALASKA

*University of Alaska Soil Testing Laboratory*  
Agricultural Experiment Station  
1509 S. Georgeson Drive  
Palmer, AK 99645  
907-746-9482  
Email: [pnlaw@uaa.alaska.edu](mailto:pnlaw@uaa.alaska.edu)  
Services:  
✓ Soil testing

*Plant Pathology and Biotechnology Laboratory*  
Department of High Latitude Agriculture  
School of Natural Resources and  
Agriculture Sciences  
University of Alaska Fairbanks

Fairbanks, AK 99775-7200  
 Contact: Jenifer Huang McBeath  
 Phone: 907-474-7431  
 Email: jhmcbeath@alaska.edu

**Services:**

Contact Jenifer Huang McBeath (above) for details.

**ARIZONA**

\*\* No soil testing service offered by a public agency.

*Extension Plant Pathologist*  
 University of Arizona Yuma  
 Agriculture Center  
 6425 W. 8<sup>th</sup> Street Yuma, AZ 85364  
 Contact: Mike Matheron  
 Phone: 928-782-5863  
 Email: matheron@ag.arizona.edu

**Services:**

✓ Plant problem and disease diagnostic testing

*Extension Plant Pathologist*  
 Department of Plant Sciences  
 University of Arizona  
 Forbes Building 303  
 1140 East South Campus Drive  
 Tucson, AZ 85721  
 Contact: Mary Olsen  
 Phone: 520-626-2681  
 Email: molsen@ag.arizona.edu  
<http://ag.arizona.edu/PLP/plpext/>

**Services:**

✓ Plant problem and disease diagnostic testing

**ARKANSAS**

*Soil Testing and Research Laboratory*  
 University of Arkansas  
 P.O. Drawer 767  
 Marianna, AR 72360  
 Phone: 870-295-2851  
 Contact: Dr. Morteza Mozaffari  
 Email: mmozaff@uark.edu or soiltest@uark.edu  
<http://www.uark.edu/depts/soiltest>

**Services:**

✓ Soil testing

*Plant Health Clinic*  
 University of Arkansas  
 2601 N. Young Avenue  
 Fayetteville, AR 72704  
 Phone: 479-575-2727 or 479-575-3189  
 Contact: Sherrie Smith  
 Email: ssmith@uaex.edu  
[http://bumperscollege.uark.edu/health\\_clinic/](http://bumperscollege.uark.edu/health_clinic/)

**Services:**

Contact Sherrie Smith (above) for additional details.

**CALIFORNIA**

\*\* No soil testing service offered by a public agency.

\*\* For plant diagnostics contact your local County Farm Advisor or Extension Specialist at your nearest university.

A list of private laboratories that provide plant disease diagnostics and soil tests can be found at the following website:

[http://ceventura.ucanr.edu/Com\\_Ag/Subtropical/Avocado\\_Handbook/Resources/Plant\\_Disease\\_Diagnostics\\_and\\_Soil\\_Testing\\_Labs\\_in\\_California-1999/](http://ceventura.ucanr.edu/Com_Ag/Subtropical/Avocado_Handbook/Resources/Plant_Disease_Diagnostics_and_Soil_Testing_Labs_in_California-1999/).

Because this list has not been updated recently, please contact the laboratory prior to submitting samples.

**COLORADO**

*Soil, Water, and Plant Testing Laboratory*  
 Room A-319 NESB  
 Colorado State University  
 Fort Collins, CO 80523-1120  
 Phone: 970-491-5061  
 Contact: Dr. James Self  
 Email: james.self@colostate.edu  
<http://www.soiltestinglab.colostate.edu>

**Services:**

✓ Plant tissue analysis (nutrient status of plant)  
 ✓ Soil testing  
 ✓ Water analysis



*Plant Diagnostic Clinic*  
 Jefferson County Extension  
 15200 W. 6<sup>th</sup> Avenue, Unit C  
 Golden, CO 80401  
 Phone: 303-271-6620  
<http://www.extension.colostate.edu/jefferson/>

**Services:**

- ✓ Plant problem and disease diagnostic testing
- ✓ Plant identification
- ✓ Insect Identification

*Plant Diagnostic Clinic*  
 E 215 Plant Sciences Building  
 Department of Bioagriculture Sciences and Pest Management  
 Colorado State University  
 Fort Collins, CO 80523-1177  
 Phone: 970-491-6950  
 Contact: Tamla Blunt  
 Email: [plantlab@lamar.colostate.edu](mailto:plantlab@lamar.colostate.edu)  
<http://plantclinic.agsci.colostate.edu/>

**Services:**

- ✓ Plant problem and disease diagnostic testing
- ✓ Plant identification
- ✓ Insect Identification

**CONNECTICUT**

*Soil Nutrient Analysis Lab*  
 University of Connecticut  
 6 Sherman Place, U-5102  
 Storrs, CT 06269-5102  
 Phone: 860-486-4274  
 Contact: Dawn Pettinelli  
 Email: [dawn.pettinelli@uconn.edu](mailto:dawn.pettinelli@uconn.edu)  
<http://www.soiltest.uconn.edu/>

**Services:**

- ✓ Plant tissue analysis (nutrient status of plant)
- ✓ Soil testing

*Home and Garden Education Center*  
 University of Connecticut  
 Ratcliffe Hicks Rm 4  
 1380 Storrs Road, U-4115  
 Storrs, CT 06269-4115  
 Phone: 860-486-6271

Email: [ladybug@uconn.edu](mailto:ladybug@uconn.edu)  
<http://www.ladybug.uconn.edu/>

**Services:**

- ✓ Plant Problems and Disease diagnostic testing
- ✓ Weed identification
- ✓ Insect identification

**DELAWARE**

*UD Soil Testing Laboratory*  
 152 Townsend Hall  
 531 S. College Avenue  
 University of Delaware  
 Newark, DE 19716-2170  
 Phone: 302-831-1392  
 Soiltest@udel.edu  
<http://ag.udel.edu/DSTP>

**Services:**

- ✓ Soil testing

*UD Plant Diagnostic Clinic*  
 Dept. of Plant and Soil Sciences  
 151 Townsend Hall  
 University of Delaware  
 531 S College Avenue  
 Newark, DE 19716-2170  
 Phone: 302-831-1390  
 Contact: Nancy Fisher Gregory  
 Email: [ngregory@udel.edu](mailto:ngregory@udel.edu)  
<http://extension.udel.edu/ag/plant-diseases/ud-plant-diagnostic-clinic/>

**Services:**

- ✓ Plant problem and disease diagnostic testing
- ✓ Nematode soil analysis

**FLORIDA**

*Soil Testing Laboratory*  
 University of Florida I.F.A.S.  
 Wallace Bldg. No. 631  
 P.O. Box 110740  
 Gainesville, FL 32611-0740  
 Phone: 352-392-1950 ext. 221  
 Email: [soilslab@ifas.ufl.edu](mailto:soilslab@ifas.ufl.edu)  
<http://soilslab.ifas.ufl.edu>

**Services:**

- ✓ Plant tissue analysis (nutrient status of plant)

- ✓ Soil testing
- ✓ Water testing

*UF Plant Diagnostic Center University of Florida*

Building 1291, 2570 Hull Road  
Gainesville, FL 32611  
Phone: 352-392-1795  
Email: [pdc@ifas.ufl.edu](mailto:pdc@ifas.ufl.edu)  
<http://plantpath.ifas.ufl.edu/>

**Services:**

- ✓ Plant problem and disease diagnostic testing

*Three Regional State Labs*

Florida Extension Plant Diagnostic Clinic  
University of Florida,  
IFAS North Florida Research and Education  
Center

155 Research Road Quincy, FL 32351  
Phone: 850-875-7140

Contact: Hank Dankers or Mathews Paret  
Email: [wadan@ufl.edu](mailto:wadan@ufl.edu) or [paret@ufl.edu](mailto:paret@ufl.edu)

[http://nfrec.ifas.ufl.edu/programs/plant\\_diagnostic\\_clinic.shtml](http://nfrec.ifas.ufl.edu/programs/plant_diagnostic_clinic.shtml)

**Services:**

- ✓ Plant problem and disease diagnostic testing

*Florida Extension Plant Diagnostic Clinic*

18710 SW 288 Street  
Homestead, FL 33030-2309  
Phone: (305) 248-3311  
Email: [imaguire@ufl.edu](mailto:imaguire@ufl.edu)  
<http://www.plantclinic.org/>

**Services:**

- ✓ Plant problem and disease diagnostic testing
- ✓ Insect Identification

*Florida Extension Plant Diagnostic Clinic*

Gulf Coast Research and Education Center  
14625 CR 672  
Wimauma, FL 33598  
Phone: 813-634-0000  
Contact: James Mertely  
Email: [jcmert@ufl.edu](mailto:jcmert@ufl.edu)  
<http://strawberry.ifas.ufl.edu/DiagnosticLab/diagnosticpage.htm>

**Services:**

- ✓ Plant problem and disease diagnostic testing

*Insect ID lab*

University of Florida  
Building 70  
PO BOX 110620  
Gainesville, FL 32611-0620  
Phone: 352-392- 1901  
Contact: Lyle Buss  
Email: [ufinsectid@ifas.ufl.edu](mailto:ufinsectid@ifas.ufl.edu)  
<http://fpdn.ifas.ufl.edu/ufmain-insect-lab.shtml>

**Services:**

- ✓ Insect Identification

\*\* A list of addition diagnostic laboratories is available at <http://ddis.ifas.ufl.edu/jsp/html/labs.jsp>.

**GEORGIA**

*Soil, Plant and Water Laboratory*

University of Georgia  
2400 College Station Road  
Athens, GA 30602-9105  
Phone: 706-542-5350  
Contact: David Kissel or Leticia Sonon  
Email: [dkissel@uga.edu](mailto:dkissel@uga.edu) or [Isonon@uga.edu](mailto:Isonon@uga.edu)  
<http://aesl.ces.uga.edu/>

**Services:**

- ✓ Plant tissue analysis (nutrient status of plant)
- ✓ Soil testing
- ✓ Water testing

*Plant Disease Clinic*

Department of Plant Pathology  
2106 Miller Plant  
Sciences Building  
University of Georgia  
Athens, GA 30602  
Phone: 706-542-8987 or 9157  
Contact: Ansuya Jogi  
Email: [ansuya@uga.edu](mailto:ansuya@uga.edu)  
<http://plantpath.caes.uga.edu/extension/clinic.html>

**Services:**

- ✓ Plant problem and disease diagnostic testing (plant material and soil)

*Plant Disease Clinic*  
Tifton Department of  
Plant Pathology  
University of Georgia  
Room 116 4604  
Research Way  
Tifton, GA 31793  
Phone: 229-386-7495  
Contact: Jason Brock  
Email: jbrock@uga.edu  
<http://plantpath.caes.uga.edu/extension/clinic.html>

**Services:**

✓ Plant problem and disease diagnostic testing (plant material and soil)

**HAWAII**

*Agricultural Diagnostic Service Center*  
1910 East-West Road  
Sherman Lab 134  
Honolulu, HI 96822  
Phone: 808-956-6706  
Email: adsc@ctahr.hawaii.edu  
<http://www2.ctahr.hawaii.edu/adsc>

**Services:**

✓ Plant problem and disease diagnostic testing  
✓ Plant tissue analysis (nutrient status of plant)  
✓ Nematode soil analysis (plant and soil)  
✓ Soil testing  
✓ Insect analysis  
✓ Water testing

**IDAHO**

\*\* No soil testing is offered by a public agency.

*Plant Pathology Laboratory*  
University of Idaho  
29603 U of I Lane Parma, ID 83660-6699  
Phone: 208-722-6701 Ext. 218  
Contact: Krishna Mohan  
Email: kmohan@uidaho.edu  
Nematology Contact: Saad Hafez  
Email: shafez@uidaho.edu  
Phone: 208-722-6701 Ext. 237

**Services:**

Contact Krishna Mohan or Saad Hafez (above) for additional details

**ILLINOIS**

\*\*No soil testing service is offered by a public agency. Contact the Plant Clinic for a partial listing of private soil testing labs.

*Plant Clinic*  
University of Illinois  
S-417 Turner Hall  
1102 S. Goodwin Avenue  
Urbana, IL 61801  
Phone: 217-333-0519  
Contact: Suzanne Bissonnette  
Phone: 217-333-2478  
Email: sbissonn@illinois.edu  
Contact: Stephanie Porter  
Phone: 217-244-3254  
Email: satterle@illinois.edu  
<http://web.extension.illinois.edu/plantclinic/>

**Services:**

✓ Plant problem and disease diagnostic testing  
✓ Plant identification  
✓ Nematode soil analysis  
✓ Insect identification

**INDIANA**

\*\*No soil testing service is offered by a public agency. A list of private soil testing labs is available at <http://www.ppd.l.purdue.edu/PPDL/services.html>.

*Plant and Pest Diagnostic Laboratory*  
Purdue University  
LSPS 101  
915 W. State Street  
West Lafayette, IN 47907-2054  
Phone: 765-494-7071  
Contact: Tom Creswell  
Email: creswell@purdue.edu or ppdl-info@purdue.edu  
<http://www.ppd.l.purdue.edu/>

**Services:**

✓ Plant problem and disease diagnostic testing  
✓ Plant and weed identification

**IOWA**

*ISU Soil and Plant Analysis Laboratory*  
G501 Agronomy  
Iowa State University

Ames, IA 50011  
 Phone: 515-294-3076  
 Email: soiltest@iastate.edu  
<http://www.agron.iastate.edu/soiltesting>

**Services:**

- ✓ Plant tissue analysis (nutrient status of plant)
- ✓ Soil testing

*Plant and Insect Diagnostic Clinic*  
 Department of Plant Pathology  
 327 Bessey Hall  
 Iowa State University  
 Ames, IA 50011  
 Phone: 515-294-0581  
 Email: sickplant@iastate.edu  
<http://clinic.ipm.iastate.edu>

**Services:**

- ✓ Plant problem and disease diagnostic testing
- ✓ Plant and mushroom identification
- ✓ Insect identification

**KANSAS**

*Soil Testing Laboratory*  
 Kansas State University  
 Throckmorton Hall, Room 2308  
 Manhattan, KS 66506  
 Phone: 785-532-7897  
 Email: soiltesting@ksu.edu  
<http://www.agronomy.ksu.edu/soiltesting>

**Services:**

- ✓ Plant tissue analysis (nutrient status of plant)
- ✓ Soil testing
- ✓ Water testing

*Plant Disease Diagnostic Lab*  
 Extension Plant Pathology  
 4032 Throckmorton Hall  
 Kansas State University  
 Manhattan, KS 66506-5504  
 Phone: 785-532-5810  
 Contact: Judith O'Mara  
 Email: jomara@ksu.edu  
<http://www.plantpath.ksu.edu/DesktopDefault.aspx?tabid=49>

**Services:**

- ✓ Plant problem and disease diagnostic testing

**KENTUCKY**

*Soil Testing Laboratory*  
 103 Regulatory Services Bldg.  
 University of Kentucky  
 Lexington, KY 40546  
 Phone: 859-257-2785  
 Contact: Frank Sikora  
 Email: fsikora@uky.edu  
<http://soils.rs.uky.edu/index.php>

**Services:**

- ✓ Plant tissue analysis (nutrient status of plant)
- ✓ Soil testing
- ✓ Water testing

*Regulatory Services Soil Testing Laboratory*  
 (Serving Western Kentucky)  
 P.O. Box 469  
 1205 Hopkinsville Street  
 Princeton, KY 42445  
 Phone: 270-365-7541 Ext. 217  
 Contact: Paula Hill  
 Email: paula.hill@uky.edu  
<http://soils.rs.uky.edu/>

**Services:**

- ✓ Plant tissue analysis (nutrient status of plant)
- ✓ Soil testing
- ✓ Water testing

*Plant Disease Diagnostic Laboratory* (Serving Central and Eastern Kentucky)  
 Agricultural Science Building-North  
 University of Kentucky  
 Lexington, KY 40546-0091  
 Phone: 859-257-8949  
 Contact: Julie Beale  
 Email: jbeale@uky.edu  
[http://www.ca.uky.edu/agcollege/plantpathology/extension/pdd\\_lab.html](http://www.ca.uky.edu/agcollege/plantpathology/extension/pdd_lab.html)

**Services:**

- ✓ Plant problem and disease diagnostic testing

*Plant Disease Diagnostic Laboratory* (Serving Western Kentucky)  
 Department of Plant Pathology  
 UK Research and Education Center  
 P.O. Box 469  
 1205 Hopkinsville Street  
 Princeton, KY 42445

Phone: 270-365-7541 Ext. 228  
 Contact: Brenda Kennedy  
 Email: [brenda.kennedy@uky.edu](mailto:brenda.kennedy@uky.edu)  
[http://www.ca.uky.edu/agcollege/plantpathology/extension/pdd\\_lab.html](http://www.ca.uky.edu/agcollege/plantpathology/extension/pdd_lab.html)

**Services:**

- ✓ Plant problem and disease diagnostic testing

**LOUISIANA**

*Soil Testing and Plant Analysis Lab*  
 School of Plant, Environmental, and Soil Sciences  
 Louisiana State University  
 104 Sturgis Hall  
 Baton Rouge, LA 70803  
 Phone: 225-578-1219  
 Email: [stpal@agcenter.lsu.edu](mailto:stpal@agcenter.lsu.edu)  
<http://www.stpal.lsu.edu/>

**Services:**

- ✓ Plant tissue analysis (nutrient status of plant)
- ✓ Soil testing
- ✓ Water testing

*Plant Diagnostic Center*  
 Department of Plant Pathology and Crop Physiology  
 LSU Agricultural Center  
 302 Life Science Building  
 Baton Rouge, LA 70803  
 Phone: 225-578-4562  
 Contact: Raghuwinder Singh "Nick"  
 Email: [rsingh@agcenter.lsu.edu](mailto:rsingh@agcenter.lsu.edu)  
<http://www.lsuagcenter.com/plantdiagnostics>

**Services:**

- ✓ Plant problem and disease diagnostic testing (biotic and abiotic causes)
- ✓ Weed identification
- ✓ Nematode analysis

**MAINE**

*Maine Soil Testing Service*  
 5722 Deering Hall  
 University of Maine  
 Orono, ME 04469-5722  
 Phone: 207-581-2945  
 Contact: Bruce Hoskins  
 Email: [hoskins@maine.edu](mailto:hoskins@maine.edu)

<http://anlab.umesci.maine.edu>

**Services:**

- ✓ Plant tissue analysis (nutrient status of plant)
- ✓ Soil testing
- ✓ Water testing

*Pest Management Office*  
 Cooperative Extension University of Maine  
 491 College Avenue  
 Orono, ME 04473-1295  
 Phone: 207-581-3880  
 Contact: Bruce Watt  
 Email: [bruce.watt@maine.edu](mailto:bruce.watt@maine.edu)  
<http://umaine.edu/ipm/ipddl/>

**Services:**

- ✓ Plant problem and disease diagnostic testing
- ✓ Insect identification

**MARYLAND**

\*\*The University of Maryland soil lab is no longer active. No soil testing service is offered by a public agency. A chart of regional soil testing laboratories can be found at [http://www.hgic.umd.edu/media/documents/hg110a\\_007.pdf](http://www.hgic.umd.edu/media/documents/hg110a_007.pdf).

*Plant Diagnostic Laboratory*  
 Department of Entomology  
 University of Maryland  
 4112 Plant Sciences Bldg  
 College Park, MD 20742-4454  
 Phone: 301-405-1611  
 Contact: Karen Rane  
 Email: [rane@umd.edu](mailto:rane@umd.edu)  
<http://www.plantclinic.umd.edu/>

**Services:**

- ✓ Plant problem and disease diagnostic testing
- \*\*Priority is placed on specimens from Cooperative Extension educators, commercial growers, and industry professionals. Homeowners should work with the Home and Garden Information Center to solve garden problems (below).

*Home and Garden Information Center*  
 Maryland Cooperative Extension  
 University of Maryland

12005 Homewood Road  
 Ellicott City, MD 21042-1542  
 Phone: 410-531-5556  
 Contact: David Clement  
 E-mail: [clement@umd.edu](mailto:clement@umd.edu)  
<http://extension.umd.edu/hgic>

**Services:**

Contact David Clement (above) for additional details

**MASSACHUSETTS**

*Soil and Plant Tissue Testing Laboratory*  
 University of Massachusetts  
 682 North Pleasant Street  
 Amherst, MA 01003  
 Phone: 413-545-2311  
 Email: [soiltest@umass.edu](mailto:soiltest@umass.edu)  
<http://soiltest.umass.edu>

**Services:**

- ✓ Plant tissue analysis (nutrient status of plant)
- ✓ Soil testing

*Extension Plant Diagnostic Lab*  
 University of Massachusetts  
 101 University Drive, Suite A-7  
 Amherst, MA 01002  
 Contact: M. Bess Dicklow  
 Phone: 413-545-3209  
 Email: [mbdicklo@umext.umass.edu](mailto:mbdicklo@umext.umass.edu)  
<http://ag.umass.edu/services/plant-problem-diagnostics>

**Services:**

- ✓ Plant problem and disease diagnostic testing (turf, tree, shrub, fruit tree, vegetable and floriculture diagnostics)
- ✓ Weed and invasive plant identification

**MICHIGAN**

*MSU Soil and Plant Nutrient Laboratory*  
 A81 Plant and Soil Sciences  
 East Lansing, MI 48824  
 Phone: 517-355-0218  
 Contact: Jon Dahl  
 Email: [dahl@msu.edu](mailto:dahl@msu.edu)  
<http://www.psm.msu.edu/SPNL/index.htm>

**Services:**

- ✓ Plant tissue analysis (nutrient status of plant)

- ✓ Soil testing
- Contact Jon Dahl (above) for additional details

*Diagnostic Services*

578 Wilson Rd., Rm. 107  
 East Lansing, MI 48824-6469  
 Phone: 517-355-4536  
 Contact: Jan Byrne (plant questions)  
 Email: [byrnejm@msu.edu](mailto:byrnejm@msu.edu)  
 Contact: Howard Russell (insect questions)  
 Email: [bugman@msu.edu](mailto:bugman@msu.edu)  
 Fred Warner (nematode questions)  
 Email: [fwnemalb@msu.edu](mailto:fwnemalb@msu.edu)  
<http://www.pestid.msu.edu/>

**Services:**

- ✓ Plant problem and disease diagnostic testing
- ✓ Plant and weed identification
- ✓ Insect identification (other arthropods including mites, ticks, spiders)
- ✓ Nematode analysis (soil and plant material)

**MINNESOTA**

*Soil Testing Laboratory*  
 University of Minnesota  
 Room 135 Crops Research Bldg.  
 1902 Dudley Avenue  
 St. Paul, MN 55108-6089  
 Phone: 612-625-3101  
 Email: [soiltest@umn.edu](mailto:soiltest@umn.edu)  
<http://soiltest.cfans.umn.edu/>

**Services:**

- ✓ Soil testing

*Plant Disease Clinic*

Department of Plant Pathology  
 495 Borlaug Hall  
 1991 Upper Buford Circle  
 University of Minnesota  
 St. Paul, MN 55108  
 Phone: 612-625-1275  
 Contact: Dimitre Mollov  
 Email: [dmollov@umn.edu](mailto:dmollov@umn.edu)  
<http://pdc.umn.edu/>

**Services:**

- ✓ Plant problem and disease diagnostic testing
- ✓ Nematode analysis

**MISSISSIPPI**

*Mississippi State Extension Service*  
Soil Testing Laboratory  
Room 1, Bost Extension Center  
Box 9610  
Mississippi State, MS 39762-9610  
Telephone: 662-325-3313  
Contact: Keith Crouse  
Email: keithc@ext.msstate.edu  
<http://msucares.com/crops/soils/testing.html>

**Services:**

- ✓ Soil testing

*Plant Pathology and Nematology Clinic*  
190 Bost North, Room 9  
Box 9612  
Mississippi State, MS 39762-9612  
Phone: 662-325-2146  
Contact: Clarissa Balbalian  
Email: cbalbali@ext.msstate.edu  
<http://msucares.com/lab>

**Services:**

- ✓ Plant problem and disease diagnostic testing
- ✓ Nematode analysis

**MISSOURI**

*Soil Testing and Plant Diagnostic Service Labs*  
23 Mumford Hall  
University of Missouri  
Columbia, MO 65211  
Contact: Manjula Nathan (soil questions)  
Phone: 573-882-0623  
Email: nathanm@missouri.edu  
Contact: Dr. Lee Miller (plant/turf questions)  
Phone: 573-882-5623  
Email: TurfPath@missouri.edu  
Contact: Robert Heinz (nematode questions)  
Phone: 573-884-9118  
Email: Heinzr@missouri.edu  
<http://soilplantlab.missouri.edu/>

**Services:**

- ✓ Plant problem and disease diagnostic testing (\*\*turf only at this time!)
- ✓ Plant tissue analysis (nutrient status of plant)
- ✓ Weed identification

- ✓ Soil testing
- ✓ Nematode analysis
- ✓ Insect identification
- ✓ Water testing

**MONTANA**

\*\*No soil testing service is offered by a public agency.  
*Schutter Diagnostic Lab*  
119 Plant Bioscience Building  
Department of Plant Sciences and Plant Pathology  
Montana State University  
Bozeman, MT 59717-3150  
Email: diagnostics@montana.edu  
<http://diagnostics.montana.edu>

**Services:**

- ✓ Plant problem and disease diagnostic testing
- ✓ Plant and mushroom identification (including aquatic plants)
- ✓ Insect identification

**NEBRASKA**

\*\*No soil testing service is offered by a public agency.

*Plant and Pest Diagnostic Clinic*  
Department of Plant Pathology  
448 Plant Sciences  
University of Nebraska  
Lincoln, NE 68583-0722  
Phone: 402-472-2559  
Contact: Kevin Korus  
Email: kkorus2@unl.edu  
<http://pdc.unl.edu/diagnosticclinics/plantandpest>

**Services:**

- ✓ Plant problem and disease diagnostic testing (biotic and abiotic)
- ✓ Plant and weed identification
- ✓ Insect identification

**NEVADA**

\*\*No soil testing service is offered by a public agency. A list of regional soil testing laboratories can be found at <http://www.unce.unr.edu/publications/files/ag/2009/fs0938.pdf> (University of Nevada Cooperative Extension Fact Sheet 09-38).

\*\*No disease diagnostic is offered by a public agency.

### NEW HAMPSHIRE

*UNH Cooperative Extension*

Soil Testing

G28 Spaulding Hall

38 Academic Way

University of New Hampshire

Durham, NH 03824

Phone: 603-862-3200

Contact: Suzanne Hebert

Email: soil.testing@unh.edu

<http://extension.unh.edu/Agric/AGPDTs/SoilTest.htm>

#### Services:

- ✓ Soil testing

*Plant Diagnostic Lab*

G37 Spaulding Hall

38 Academic Way

University of New Hampshire

Durham, NH 03824

Phone: 603-862-3841

Contact: Cheryl Smith

Email: cheryl.smith@unh.edu

<http://unhpdl.org>

#### Services:

- ✓ Plant problem and disease diagnostic testing (biotic and abiotic)

### NEW JERSEY

*Soil Testing Laboratory*

NJAES/Rutgers University

ASB-II, Cook Campus

57 US Highway 1

New Brunswick, NJ 08901

Phone: 848-932-9295

soiltest@njaes.rutgers.edu

<http://www.njaes.rutgers.edu/services/>

#### Services:

- ✓ Plant tissue analysis (nutrient status of plant)
- ✓ Soil testing
- ✓ Water testing

*Plant Diagnostic Laboratory*

NJAES/Rutgers University

P.O. Box 550

Milltown, NJ 08850

Phone: 732-932-9140

Email: clinic@aesop.rutgers.edu

<http://www.njaes.rutgers.edu/services/>

#### Services:

- ✓ Plant problem and disease diagnostic testing
- ✓ Plant and weed identification
- ✓ Fungus and mold identification
- ✓ Nematode analysis
- ✓ Insect identification

### NEW MEXICO

\*\*No soil testing is offered by a public agency.

*Plant Diagnostic Clinic*

P.O. Box 30003, MSC. 3AE

Plant Sciences

Cooperative Extension Service

New Mexico State University

Las Cruces, NM 88003

Phone: 575-646-1621

Contact: Natalie Goldberg

Email: ngoldber@nmsu.edu

<http://plantclinic.nmsu.edu>

#### Services:

- ✓ Plant problem and disease diagnostic testing
- ✓ Facilitates weed identification
- ✓ Facilitates insect identification

### NEW YORK

*Cornell Nutrient Analysis Laboratory*

College of Agriculture and Life Sciences

804 Bradfield Hall Cornell

University Ithaca, NY 14853

Phone: 607-255-4540

Email: soiltest@cornell.edu

<http://cna.cals.cornell.edu>

#### Services:

- ✓ Plant tissue analysis (nutrient status of plant)
- ✓ Soil analysis
- ✓ Water testing

*Plant Disease Diagnostic Clinic*

Department of Plant Pathology

Cornell University

334 Plant Science Bldg.

Tower Road



Ithaca, NY 14853-4203  
 Contact: Karen Snover-Clift  
 Phone: 607-255-7860  
 Email: kls13@cornell.edu  
 Sandra Jensen  
 Phone: 607-255-7850  
 Email: slj2@cornell.edu  
<http://plantclinic.cornell.edu>  
 Services:  
 ✓ Plant problem and disease diagnostic testing  
 ✓ Nematode analysis

### **NORTH CAROLINA**

*North Carolina Soil Testing/ Plant/Waste/Solution/  
 Media and Nematode Assay Laboratories*  
 Agronomic Division  
 North Carolina Department of Agriculture  
 and Consumer Services  
 1040 Mail Service Center  
 Raleigh, NC 27699-1040  
 Phone: 919-733-2655  
 Contact: Dr. Colleen Hudak-Wise  
 Email: colleen.hudak@ncagr.gov  
<http://www.ncagr.gov/agronomi/>

#### **Services:**

- ✓ Plant tissue analysis (nutrient status of plant)
- ✓ Nematode analysis
- ✓ Soil testing
- ✓ Water testing

*Plant Disease and Insect Clinic*  
 Campus Box 7211, Room 1227 Gardner Hall  
 North Carolina State University  
 Raleigh, NC 27695-7211  
 Phone: 919-515-3619  
<http://www.ncsu.edu/pdic>

#### **Services:**

- ✓ Plant problem and disease diagnostic testing (biotic and abiotic; including turf)
- ✓ Plant identification
- ✓ Identification of insects and other arthropods
- ✓ Water testing (for waterborne plant pathogens)

\*\* No longer accepts mushrooms samples.

### **NORTH DAKOTA**

*NDSU Soil Testing Laboratory*  
 Dept. 7680  
 PO Box 6050  
 North Dakota State University  
 Fargo, ND 58108-6050  
 Phone: 701-231-8942  
 Email: NDSU.STL@ndsu.edu  
[http://www.ndsu.edu/soils/services/soil\\_testing\\_lab/](http://www.ndsu.edu/soils/services/soil_testing_lab/)

#### **Services:**

- ✓ Plant tissue analysis (nutrient status of plant)
- ✓ Soil testing
- ✓ Water testing (runoff and waste water analysis)

*NDSU Plant Diagnostic Lab*  
 NDSU Dept 7660  
 PO Box 6050  
 Fargo, ND 58108-6050  
 Phone: 701-231-7854  
 Email: ndsu.pdl@ndsu.edu  
<http://www.ag.ndsu.edu/pdl/>

#### **Services:**

- ✓ Plant problem and disease diagnostic testing
- ✓ Plant and weed identification
- ✓ Identification of insects and other arthropods
- ✓ Nematode analysis

### **OHIO**

\*\*No soil testing service is offered by a public agency.

*C. Wayne Ellett Plant and Pest Diagnostic Clinic*  
 8995 East Main Street  
 Plant Industry Building, #23  
 The Ohio State University  
 Reynoldsburg, OH 43068  
 Phone: 614-292-5006  
 Contact: Nancy Taylor  
 ppdc@osu.edu  
<http://ppdc.osu.edu/>

#### **Services:**

- ✓ Plant problem and disease diagnostic testing (infectious and non-infectious)
- ✓ Identification of plants and aquatic weeds

- ✓ Nematode analysis
- ✓ Identification of insects and other arthropods

### OKLAHOMA

*SWFAL Oklahoma State University*  
 045 Agriculture Hall  
 Stillwater, OK 74058  
 Phone: 405-744-6630  
 Email: soiltesting@okstate.edu  
<http://www.soiltesting.okstate.edu>

#### Services:

- ✓ Plant tissue analysis (nutrient status of plant)
- ✓ Soil testing
- ✓ Water testing (quality analysis)

*Plant Disease and Insect Diagnostic Lab*  
 Department of Entomology and Plant Pathology  
 127 Noble Research Center  
 Oklahoma State University  
 Stillwater, OK 74078  
 Phone: 405-744-9961  
 Contact: Richard Grantham or Jennifer Olson  
 Email: entoman@okstate.edu or jen.olson@okstate.edu  
<http://entopl.okstate.edu/pddl/pdidl>

#### Services:

- ✓ Plant problem and disease diagnostic testing (infectious)
- ✓ Nematode analysis (soil and plant material)
- ✓ Insect identification

### OREGON

*Central Analytical Laboratory*  
 Oregon State University  
 3017 Ag-Life Science Building  
 Corvallis, OR 97331-7306  
 Phone: 541-737-2187  
 Email: Central.Analytical.Lab@orst.edu  
<http://cropandsoil.oregonstate.edu/content/central-analytical-laboratory-cal>

#### Services:

- ✓ Plant tissue analysis
- ✓ Soil testing
- ✓ Water testing

*Plant Disease Clinic Extension*  
 Plant Pathology  
 1089 Cordley Hall  
 2701 SW Campus Way  
 Oregon State University  
 Corvallis, OR 97331  
 Phone: 541-737-3472  
 Contact: Melodie Putnam  
 Email: putnamm@science.oregonstate.edu  
<http://plant-clinic.bpp.oregonstate.edu/>

#### Services:

- ✓ Plant problem and disease diagnostic testing (infectious and non-infectious)

\*\*Plant and weed identification services are available through the Oregon State University Herbarium. A sample submission form can be found at <http://plant-clinic.bpp.oregonstate.edu/plant-weed-identification>.

*OSU Extension Plant Pathology Lab*  
 HAREC  
 2121 South 1st Street  
 Hermiston, OR 97838  
 Phone: 541-567-8321  
 Contact: Jordan Eggers  
 Email: Jordan.Eggers@oregonstate.edu  
<http://oregonstate.edu/dept/hermiston/plant-pathology-plant-lab-testing>

#### Services:

- ✓ Plant problem and disease diagnostic testing (infectious)

### PENNSYLVANIA

*Agricultural Analytical Services Laboratory*  
 Pennsylvania State University  
 Tower Road  
 University Park, PA 16802  
 Phone: 814-863-0841  
 Email: aaslab@psu.edu  
<http://www.aasl.psu.edu>

#### Services:

- ✓ Plant tissue analysis
- ✓ Soil testing
- ✓ Water testing

*Plant Disease Clinic*  
 220 Buckhout Laboratory  
 Pennsylvania State University  
 University Park, PA 16802  
 Phone: 814-865-2204  
 Contact: Sara May  
 Email: srm183@psu.edu  
<http://plantpath.psu.edu/facilities/plant-disease-clinic>

**Services:**

- ✓ Plant problem and disease diagnostic testing

**RHODE ISLAND**

\*\* No soil testing service is offered by a public agency. Rhode Island soil samples are sent to the University of Massachusetts Soil Testing Lab. For more information call CE Education Center at 401-874-2900.

*URI Plant Protection Clinic*  
 University of Rhode Island  
 CE Education Center  
 3 East Alumni Avenue  
 Kingston, RI 02881-0804  
 Phone: 401-874-967  
 Contact: Heather Faubert  
 Email: hhf@uri.edu  
<http://www.uri.edu/ce/ceec/plantclinic.html>

**Services:**

- ✓ Plant problem and disease diagnostic testing
- ✓ Plant identification
- ✓ Insect identification

**SOUTH CAROLINA**

*Clemson University Agricultural Service Laboratory*  
 Soil Testing Laboratory  
 171 Old Cherry Road  
 Clemson, SC 29634  
 Phone: 864-656-2068  
 Contact: Kathy Moore  
 Email: kmr@clemson.edu  
<http://www.clemson.edu/agsrvlb>

**Services:**

- ✓ Plant tissue analysis
- ✓ Soil testing
- ✓ Water testing

*Clemson University Plant Problem Clinic*  
 511 Westinghouse Rd.  
 Pendleton, SC 29670  
 Contact: Meg Williamson  
 Email: mwillmsn@clemson.edu  
<http://www.clemson.edu/plantclinic>

**Services:**

- ✓ Plant problem and disease diagnostic testing (including turf)
- ✓ Plant and weed identification
- ✓ Insect identification
- ✓ Nematode analysis

**SOUTH DAKOTA**

\*\*No soil testing service is offered by a public agency. A list of regional soil testing laboratories can be found at <http://www.sdstate.edu/ps/extension/soil-fert/soiltestlabs.cfm>.

*SDSU Plant Diagnostic Clinic*  
 1205 Jackrabbit Drive  
 Box 2108  
 Brookings, SD 57007  
 Phone: 605-688-5545  
 Email: sdsu.pdc@sdstate.edu  
<http://www.sdstate.edu/ps/plant-clinic/index.cfm>

**Services:**

- ✓ Plant problem and disease diagnostic testing
- ✓ Nematode analysis

**TENNESSEE**

*Soil, Plant and Pest Center*  
 University of Tennessee  
 5201 Marchant Drive  
 Nashville, TN 37211-5112  
 Phone: 615-832-5850  
 Email: soilplantpestcenter@tennessee.edu  
<http://soilplantandpest.utk.edu/default.htm>

**Services:**

- ✓ Plant tissue analysis
- ✓ Soil testing
- ✓ Insect identification

\*\*Plant and weed identification services offered only through Distance Diagnosis via County Extension Offices.

**TEXAS**

(Address for USPS)  
*Soil, Water, and Forage Testing Laboratory*  
 Texas AgriLife Extension Service  
 2478 TAMU  
 College Station, TX 77843-2478

(Address for other couriers)  
*Soil, Water, and Forage Testing Laboratory*  
 Texas AgriLife Extension Service  
 2610 F&B Road  
 College Station, TX 77845  
 Phone: 979-845-4816  
 Email: soiltesting@ag.tamu.edu  
<http://soiltesting.tamu.edu>

**Services:**

- ✓ Plant tissue analysis
- ✓ Soil testing
- ✓ Water testing

*Texas Plant Disease Diagnostic Lab*  
 Texas AgriLife Extension Service  
 1500 Research Parkway, Suite A 130  
 College Station, TX 77845  
 Phone: 979-845-8032  
 Email: plantclinic@tamu.edu  
<http://plantclinic.tamu.edu/>

**Services:**

- ✓ Plant problem and disease diagnostic testing
- ✓ Nematode analysis (soil or plant materials)

*Texas Plant Diagnostic Clinic*  
 Texas A&M AgriLife  
 Research and Extension Center  
 6500 Amarillo Blvd West  
 Amarillo, Texas 79106  
 Phone: 806-677-5600  
 skledbetter@ag.tamu.edu  
<http://plantdiagnostics.tamu.edu>

**UTAH**

*Soil Testing Laboratory*  
 USU Analytical Lab  
 9400 Old Main Hill  
 1541 N 800  
 E Utah State University  
 Logan, UT 84322-9400

Phone: 435-797-2217  
 usual@usu.edu  
<http://www.usual.usu.edu>

**Services:**

- ✓ Plant tissue analysis
- ✓ Soil testing
- ✓ Water testing

*Utah Plant Pest Diagnostic Lab*  
 Department of Biology  
 Utah State University  
 Logan, UT 84322-5305  
 Phone: 435-797-2435  
 Contact: Ryan Davis  
 Email: ryan.davis@usu.edu  
<http://utahpests.usu.edu/uppld>

**Services:**

- ✓ Plant problem and disease diagnostic testing (\*\* referral services available if disease cannot be diagnosed in lab)
- ✓ Insect and arthropod identification

**VERMONT**

*Agricultural and Environmental Testing Lab*  
 Dept. Plant and Soil Science  
 University of Vermont  
 262 Jeffords Hall  
 63 Carrigan Drive  
 Burlington, VT 05405-1737  
 Phone: 802-656-3030  
 Email: AgTesting@uvm.edu  
[http://pss.uvm.edu/ag\\_testing](http://pss.uvm.edu/ag_testing)

**Services:**

- ✓ Soil testing

\*\*A list of labs that offer additional diagnostic services (including plant tissue analysis and water testing) is available at [http://pss.uvm.edu/ag\\_testing/?Page=otherlabs.html](http://pss.uvm.edu/ag_testing/?Page=otherlabs.html).

*Plant Diagnostic Clinic*  
 Dept. of Plant and Soil Science  
 University of Vermont  
 201 Jeffords Building  
 63 Carrigan Drive  
 Burlington, VT 05405

Phone: 802-656-0493  
 Contact: Ann Hazelrigg  
 Email: ann.hazelrigg@uvm.edu  
<http://pss.uvm.edu/pd/pdc/>

**Services:**

✓ Plant problem and disease diagnostic testing (\*\* referral services available if disease cannot be diagnosed in lab)

**VIRGINIA**

*Virginia Tech Soil Testing*  
 145 Smyth Hall (0465)  
 Blacksburg, VA 24061  
 Phone: 540-231-6893  
 Contact: Steve Heckendorn  
 Email: soiltesting@vt.edu  
<http://www.soiltest.vt.edu/>

**Services:**

✓ Soil testing

*Plant Disease Clinic*  
 106 Price Hall  
 Dept. Of Plant Pathology, Physiology and Weed Science  
 Virginia Tech  
 Blacksburg, VA 24061-0331  
 Phone: 540-231-6758  
 Email: clinic@vt.edu  
<http://www.ppws.vt.edu/~clinic/>

**Services:**

✓ Plant problem and disease diagnostic testing (infectious and non-infectious)  
 ✓ Plant Identification (non-weedy plants only) ✓ Mushroom identification

*Weed ID Laboratory*  
 435 Old Glade Road  
 Blacksburg, VA 24061-0330  
 Contact: Dr. Shawn Askew  
 Phone: 540-231-5835  
 Email: weedid@vt.edu  
<http://www.ppws.vt.edu/~clinic/weeid.php>

**Services:**

✓ Weed identification

*Nematode Assay Lab*  
 115 Price Hall  
 Dept. Of Plant Pathology, Physiology and Weed Science  
 Virginia Tech  
 Blacksburg, VA 24061  
 Phone: 540-231-4650  
 Contact: Jon Eisenback  
 Email: jon@vt.edu  
<http://www.ppws.vt.edu/~clinic/nematode.html>

**Services:**

✓ Nematode analysis (soil or plant materials)

**WASHINGTON**

\*\*No soil testing is offered by a public agency. Contact your local county extension agent for a listing of local labs.

*Plant Diagnostic Clinic*  
 WSU-Puyallup Research and Extension Center  
 2606 W Pioneer  
 Puyallup, WA 98371-4998  
 Phone: 253- 445-4582  
 Contact: Jenny Glass  
 Email: jennyglass@wsu.edu  
<http://www.puyallup.wsu.edu/plantclinic/index.html>

**Services:**

✓ Plant problem and disease diagnostic testing (including turf)  
 ✓ Plant and weed identification  
 ✓ Insect and arthropod identification

*WSU Plant Pest Diagnostic Clinic*  
 316 Johnson Hall  
 Dept. of Plant Pathology  
 P.O. Box 646430  
 Pullman, Washington 99164-6430  
 Phone: 509-335-3292  
 Contact: Karen Ward  
 Email: karen\_flint.ward@wsu.edu  
<http://plantpath.wsu.edu/diagnostics/index.htm>

**Services:**

- ✓ Plant problem and disease diagnostic testing
- ✓ Plant and weed identification
- ✓ Insect and arthropod identification

**WEST VIRGINIA***Soil Testing Laboratory*

1090 Ag Sciences Building  
P.O. Box 6108  
West Virginia University  
Morgantown, WV 26506-6108  
Phone: 304-293 5375  
Contact: James Gorman  
Email: jgorman@wvu.edu  
[http://plantandsoil.wvu.edu/research/areas/soil\\_testing\\_lab](http://plantandsoil.wvu.edu/research/areas/soil_testing_lab)

**Services:**

- ✓ Soil testing

*Plant Diagnostic Clinic*

West Virginia University  
G102 South Agriculture Sciences Building  
Morgantown, WV 26506-6108  
Phone: 304-293-8838  
Contact: M.M. (Mafuz) Rahman  
Email: mm.rahman@mail.wvu.edu  
<http://www.anr.ext.wvu.edu/>

**Services:**

- ✓ Plant problem and disease diagnostic testing
- ✓ Plant and weed identification
- ✓ Insect identification

**WISCONSIN***Soil and Plant Analysis Laboratory*

University of Wisconsin  
8452 Mineral Point Road  
Verona, WI 53593-8696  
Phone: 608-262-4364  
Contact: John Peters, Director  
Email: jbpeter1@wisc.edu  
<http://uwlab.soils.wisc.edu/>

**Services:**

- ✓ Plant tissue analysis
- ✓ Soil testing
- ✓ Water testing

*Soil and Forage Analysis Lab*

2611 Yellowstone Drive  
Marshfield, WI 54449-5501  
Phone: 715-387-2523  
Contact: John Peters, Director  
Email: jbpeter1@wisc.edu  
<http://uwlab.soils.wisc.edu/>

**Services:**

- ✓ Soil testing

*Plant Disease Diagnostics Clinic*

Department of Plant Pathology  
1630 Linden Drive  
University of Wisconsin-Madison  
Madison, WI 53706-1598  
Phone: 608-262-2863  
Contact: Brian Hudelson  
Email: bdh@plantpath.wisc.edu  
<http://pddc.wisc.edu/>

**Services:**

- ✓ Plant problem and disease diagnostic testing

**WYOMING**

\*\*No soil testing is offered by a public agency. Contact your local county extension agent for a listing of local labs.

*Extension Plant Pathology Laboratory*

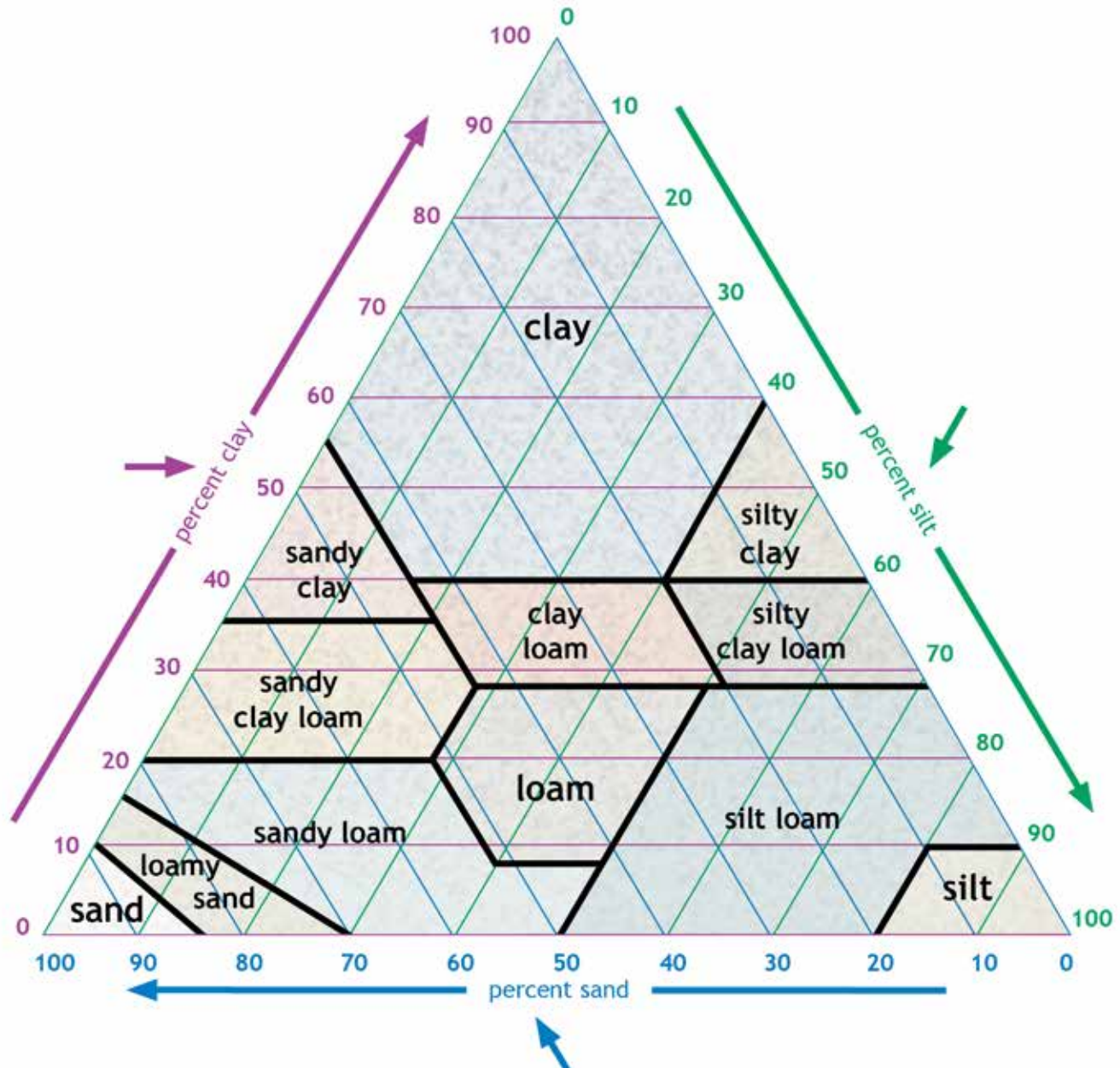
University of Wyoming  
Plant Sciences 3354  
Laramie, WY 82071-3354  
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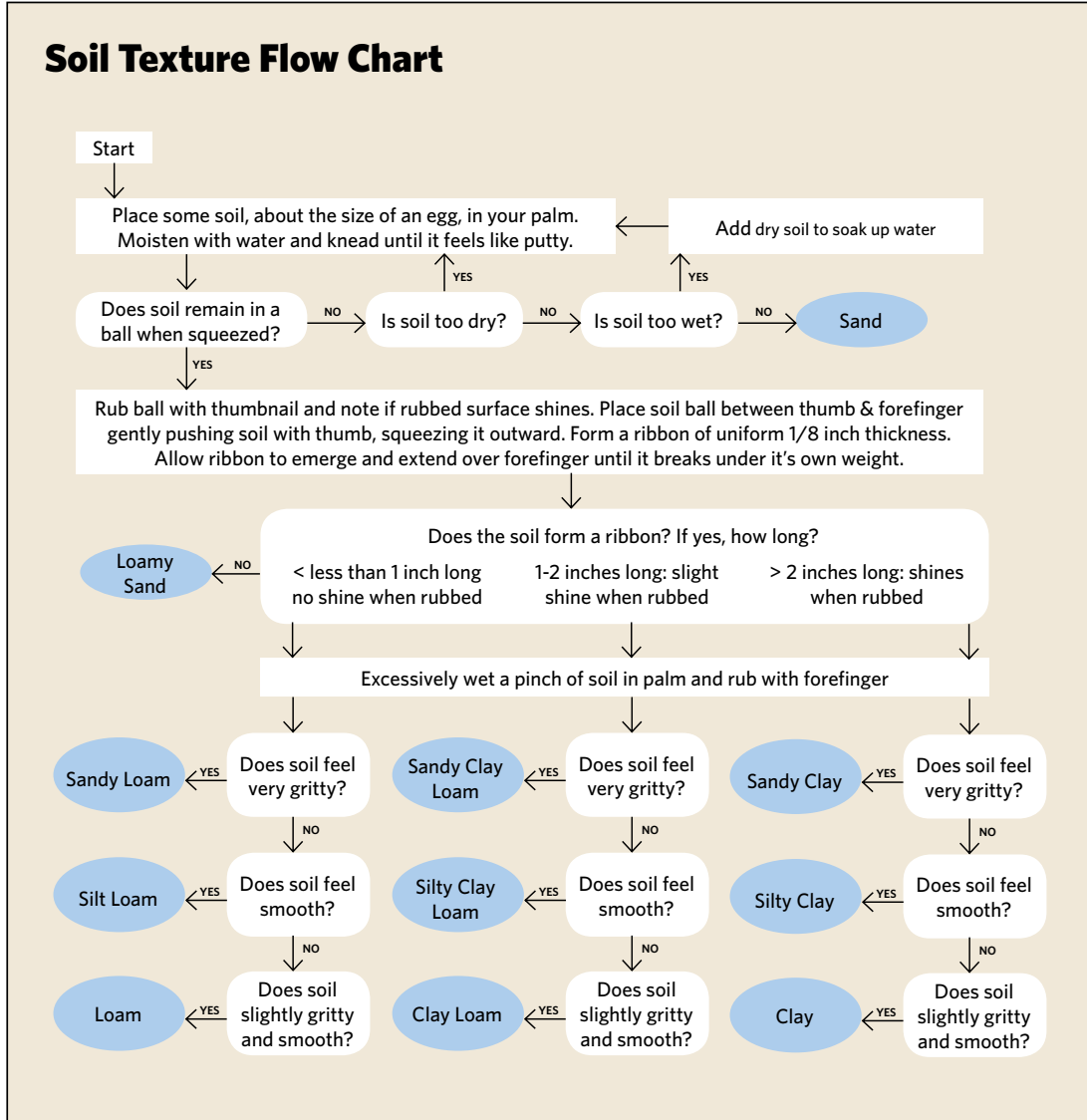
**Services:**

- ✓ Plant problem and disease diagnostic testing

## Appendix 3: Tools for Determining Soil Texture and Structure

**Soil Texture Triangle**







Landscape for Life™ is a project of the United States Botanic Garden and the Lady Bird Johnson Wildflower Center at the University of Texas at Austin. Landscape for Life is based on the principles of SITES™, the Sustainable Sites Initiative™.



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**Landscapes Give Back!** Residential landscapes can have a positive impact on the environmental health and human well-being of an entire region. Sustainable landscapes work with nature to provide clean air and water, fertile soils, and other essential aspects of our daily lives. The Landscape for Life™ educational series instructs homeowners on how to create and maintain healthy and beautiful landscapes that benefit their family and the surrounding community.

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# LANDSCAPE FOR LIFE™

Based on the principles of the Sustainable Sites Initiative™



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BOTANIC GARDEN



Lady Bird Johnson  
**Wildflower center**  
THE UNIVERSITY OF TEXAS AT AUSTIN