LANDSCAPE FOR LIFE™

Based on the principles of the Sustainable Sites Initiative™

Student's Manual

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Student's Manual

NATIONAL FUND
United States Botanic Garden

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

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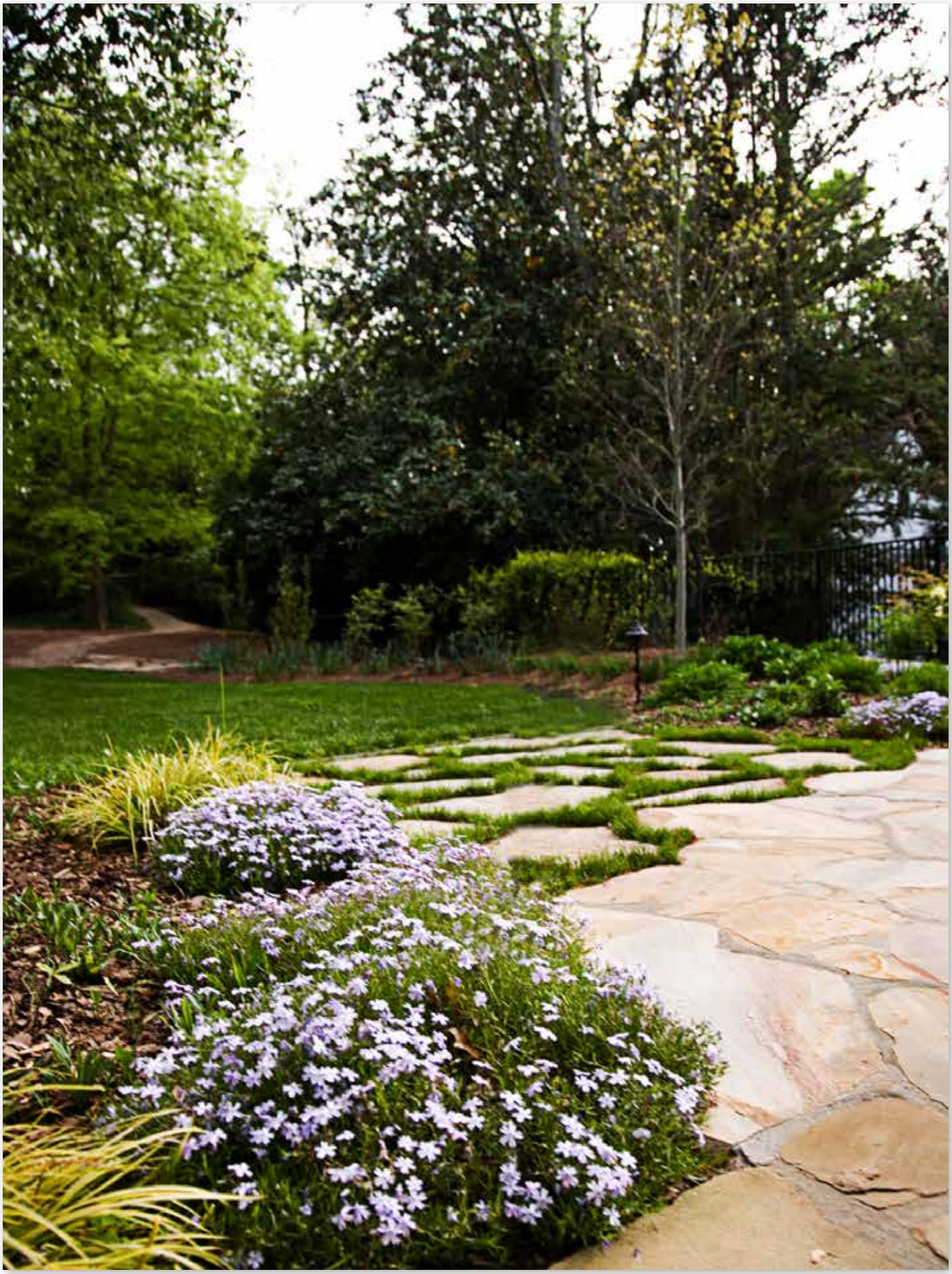
Based on the principles of the Sustainable Sites Initiative™

United States Botanic Garden

Lady Bird Johnson Wildflower center
THE UNIVERSITY OF TEXAS AT AUSTIN



ED CASTRO LANDSCAPES

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

The purpose of this manual is to teach homeowners and beginning gardeners about creating and maintaining sustainable gardens that can help alleviate some of the pressure being placed on the earth's vital natural resources. The manual is organized into a series of five sections that explore the role of soils, water, vegetation, and materials in sustainable garden design.

A resource section, divided by topic, has been added after each of the major sections to help the student access more information. Additional tools, including a downloadable version of the manual and a series of adaptable power point presentations, can be found on the Landscape for Life website, www.landscapeforlife.org.

ARTY SCHRONCE

Table of Contents

Lesson 1
Sustainability in Home Gardens

Learning objectives

After completing this lesson you will be able to:

- ☐ 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

DARREN BAKER, BIGSTOCK

Overview

Unsustainable 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:

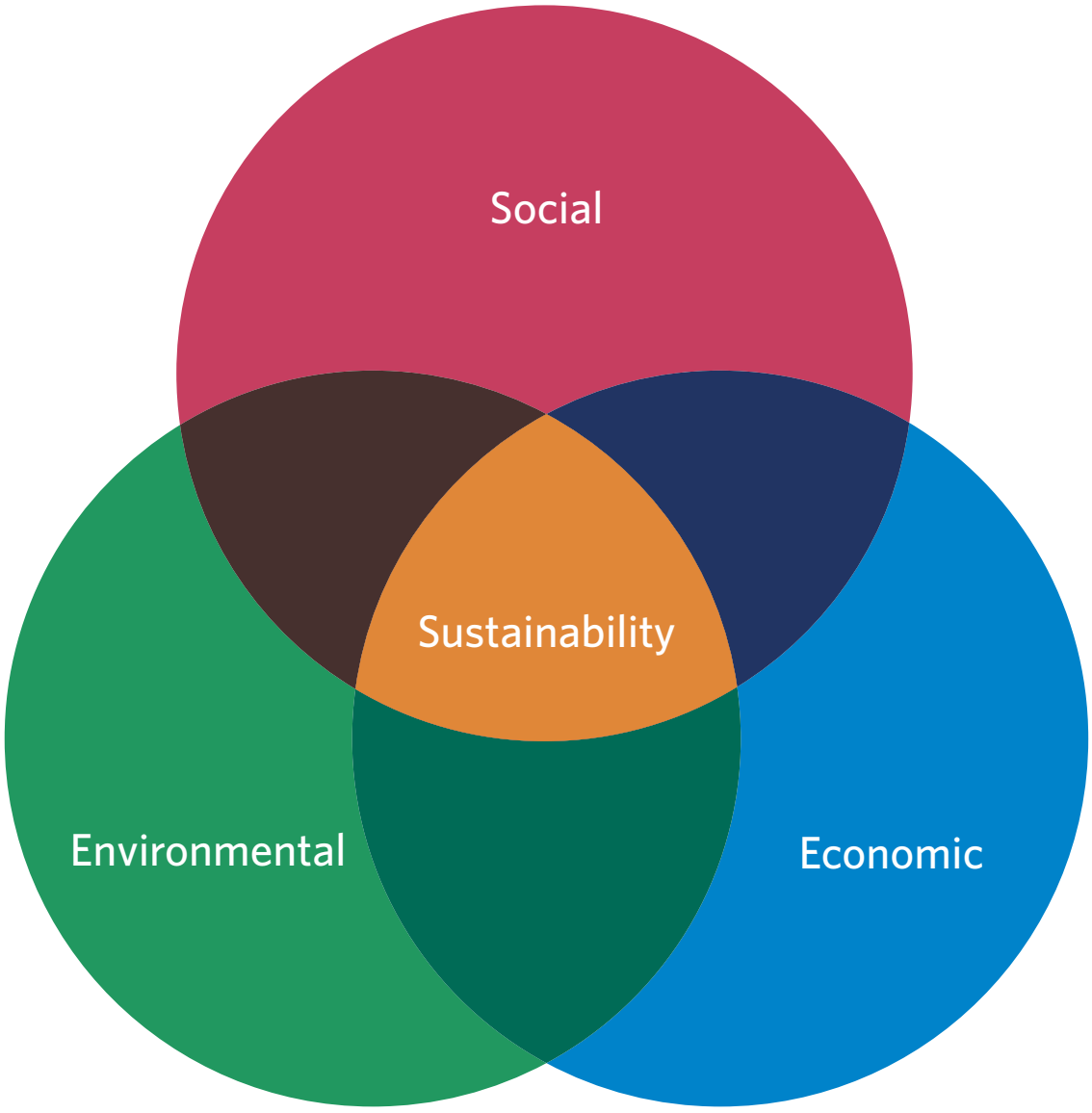
ENVIRONMENTAL Humans and other organisms depend upon the natural environment and the goods and services it provides, including clean air and water; **habitat**; **erosion control**; and food, timber, and other materials. Sustainable gardens protect and restore the land's ability to provide these benefits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

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.

DVORTYGIRL/WIKIMEDIA COMMONS

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

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, shaded dark 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 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.

Unsustainable vs. Sustainable Gardens: How They Compare

OVERVIEW

Unsustainable Gardens	Sustainable Gardens
Requires regular application of potable water to sustain plants.	*Minimizes the use of potable water to support plants by using the following water sources:* ▪ *Local precipitation* ▪ *Harvested rainwater and/or air conditioner condensate* ▪ *Runoff directed from impervious surfaces to gardens*
Plant trimmings are disposed of in the landfill.	*Plant trimmings are composted and used as mulch.*
Fertilizers are needed to support healthy plant growth.	*The natural soil food web, properly chosen plant species, and organic matter from on-site vegetation promote healthy plant growth.*
The reuse of site structures or materials at the end of the project life is not considered.	*Garden structures and features can be adapted and reused in place or easily deconstructed and reclaimed or recycled.*
More time, resources, and maintenance are needed because the layout and design does not incorporate local soils, vegetation, materials, and culture.	*Design solutions fit the place and are representative of the local soils, vegetation, materials, and/or culture.*

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

This websites 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 though 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

Learning objectives

After completing this lesson you will be able to:

- ☐ 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

VITALIY PAKHNYUSHCHYY, BIGSTOCK

Overview

Soil 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

Unsustainable vs. Sustainable Gardens: How They Compare

SOILS

Unsustainable Gardens	Sustainable Gardens
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.	*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.*
Soils are exposed to sunlight, rain, and wind.	*Soils are protected by vegetation or mulch.*
Soils require frequent amending to support healthy vegetation.	*Vegetation is selected based on what can thrive in the existing soil type.*
Organic matter, such as leaves or grass clippings, is removed from the soil and disposed of offsite.	*Organic matter from these gardens are used to support the soil food web and healthy vegetation.*

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 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/. 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.

Using soil maps to explore characteristics of soil in the region

Activity

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.

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.

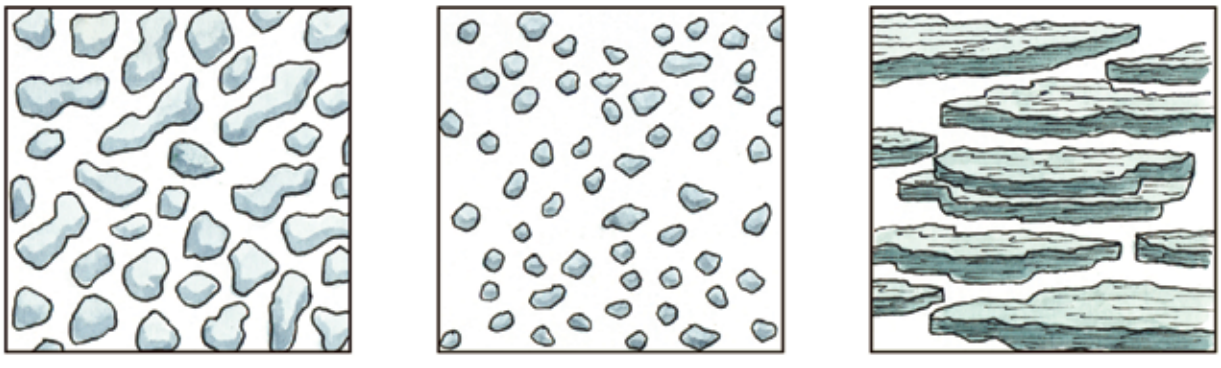
Determining soil type

Gardeners must determine the **texture**, **structure**, and **pH** of a given soil to properly identify it.

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 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.

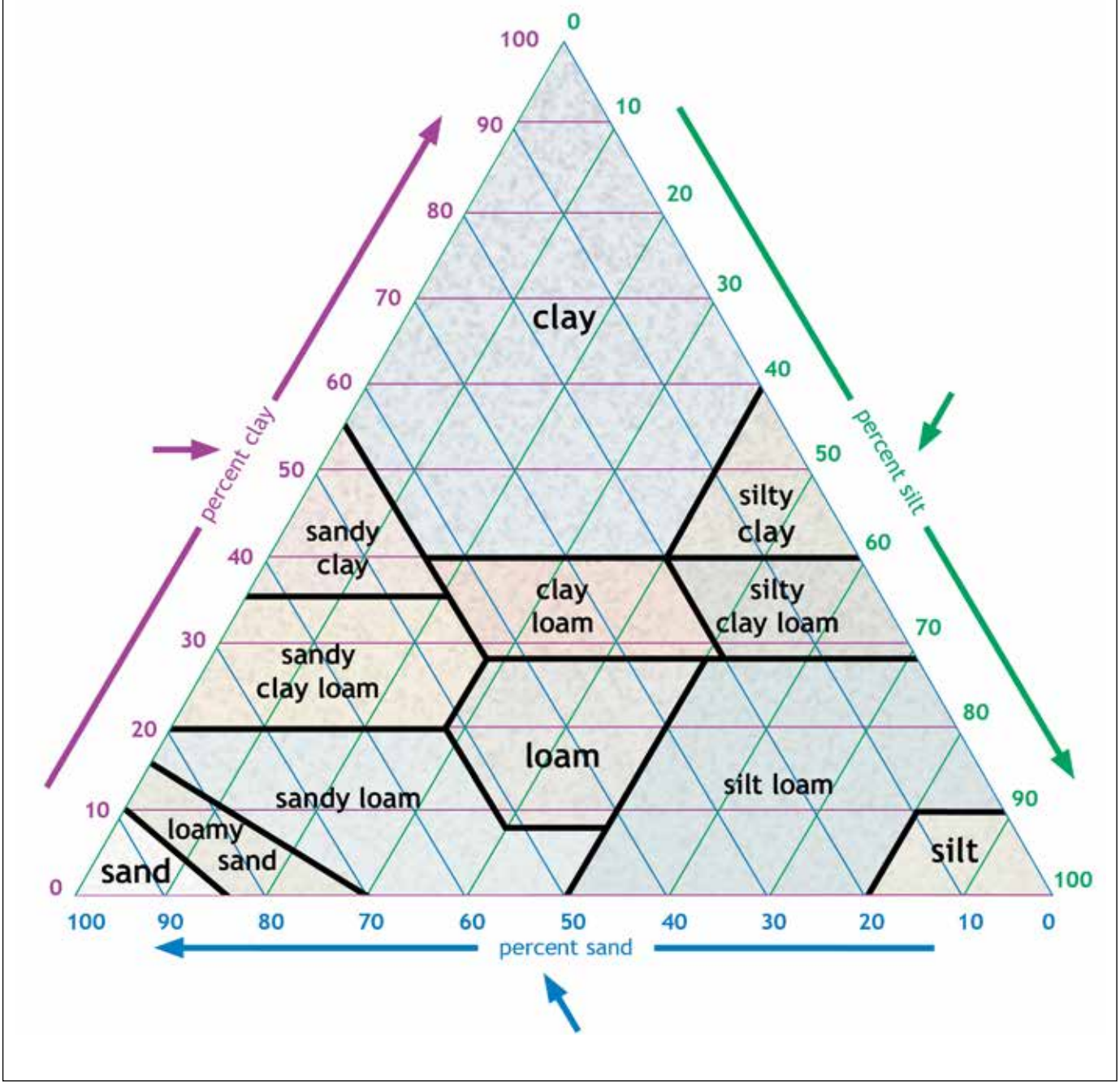
The Structure of Healthy, Sandy, and Compacted Soils



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

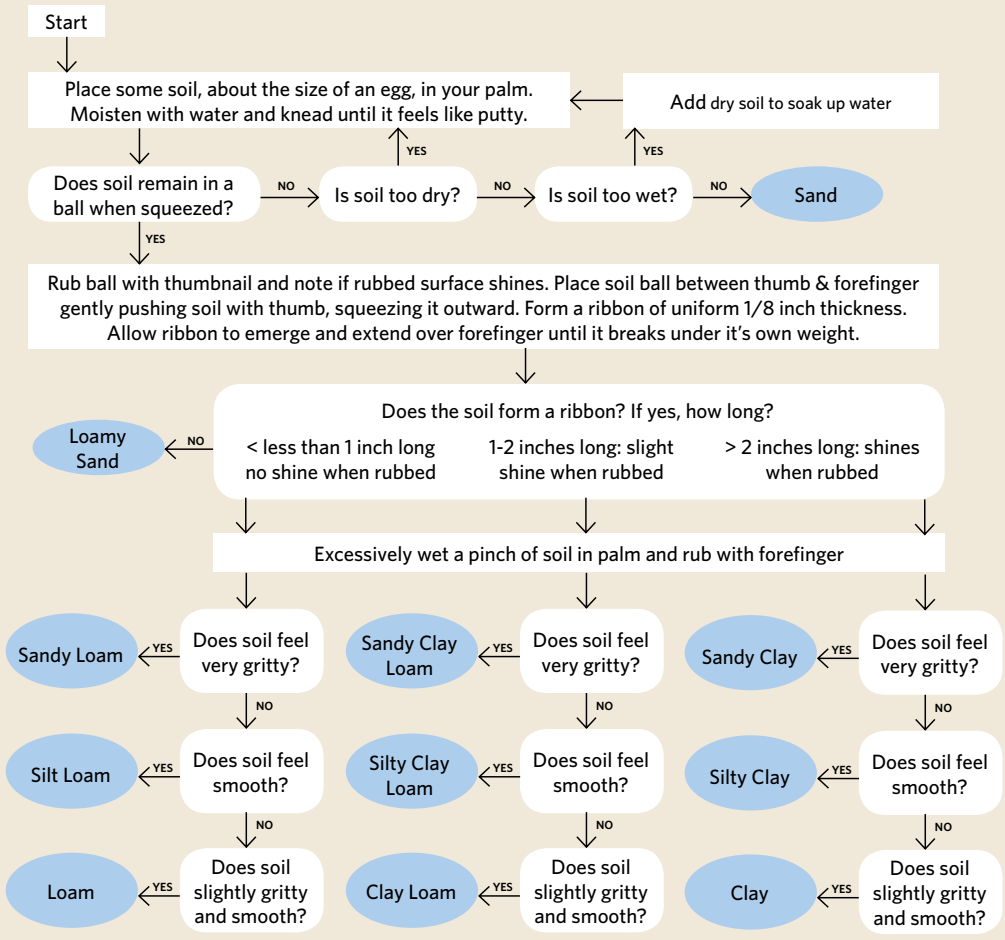


Scientists divide soil into 12 textural classes. The soil texture triangle can help determine which class of soil you have.

- *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 you soil's textural class.*

The soil texture flow chart is a basic tool that can help determine soil texture.

Soil Texture Flow Chart



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 20 or 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 (See Page 21 or Appendix 3). 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 below.

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

Supplies:

- ☐ **Water**
- ☐ **2 cups of soil**
- ☐ **Wet paper towels or wash rag**
- ☐ **Quart-sized jar with lid**
- ☐ **1 teaspoon of liquid dish soap**

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.

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 on page 20 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.

II. Additional Tests

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 on page 21 provides a series of questions that may guide you through the soil tests described above.

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 "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.

LYNN BETTS

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

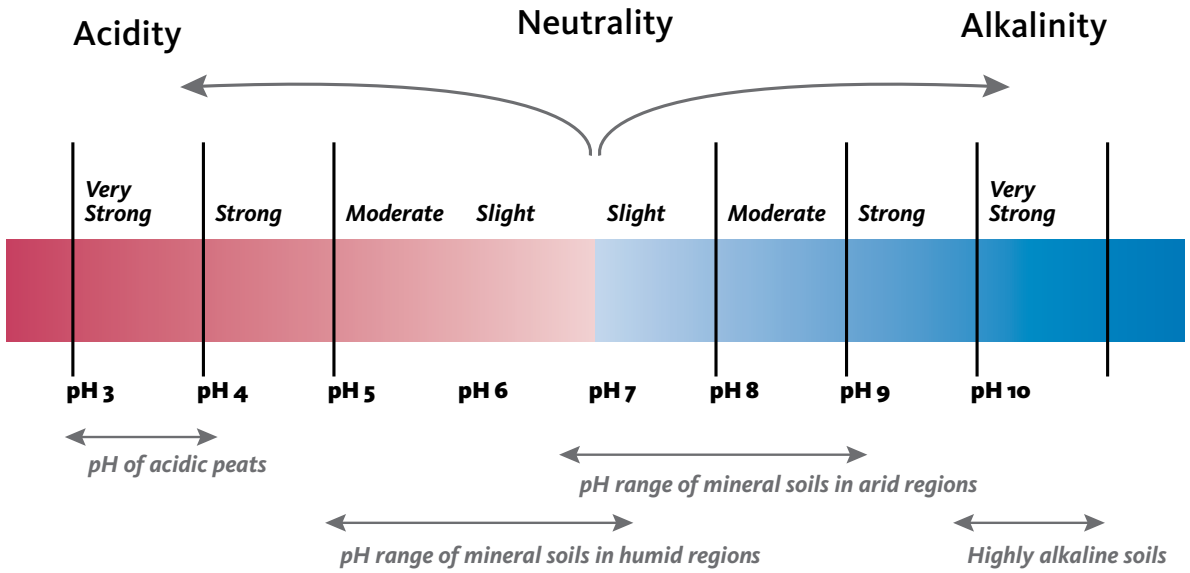
Soil pH

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 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.

Soil pH



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.

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.

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.

Site Assessment — Basemap & Soils

Assignment

Site Assessment — Basemap & Soils

A site assessment evaluates the current conditions of the garden to determine the resources, constrains, 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 29)

Design a template for the site assessment and garden design by creating a base map 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

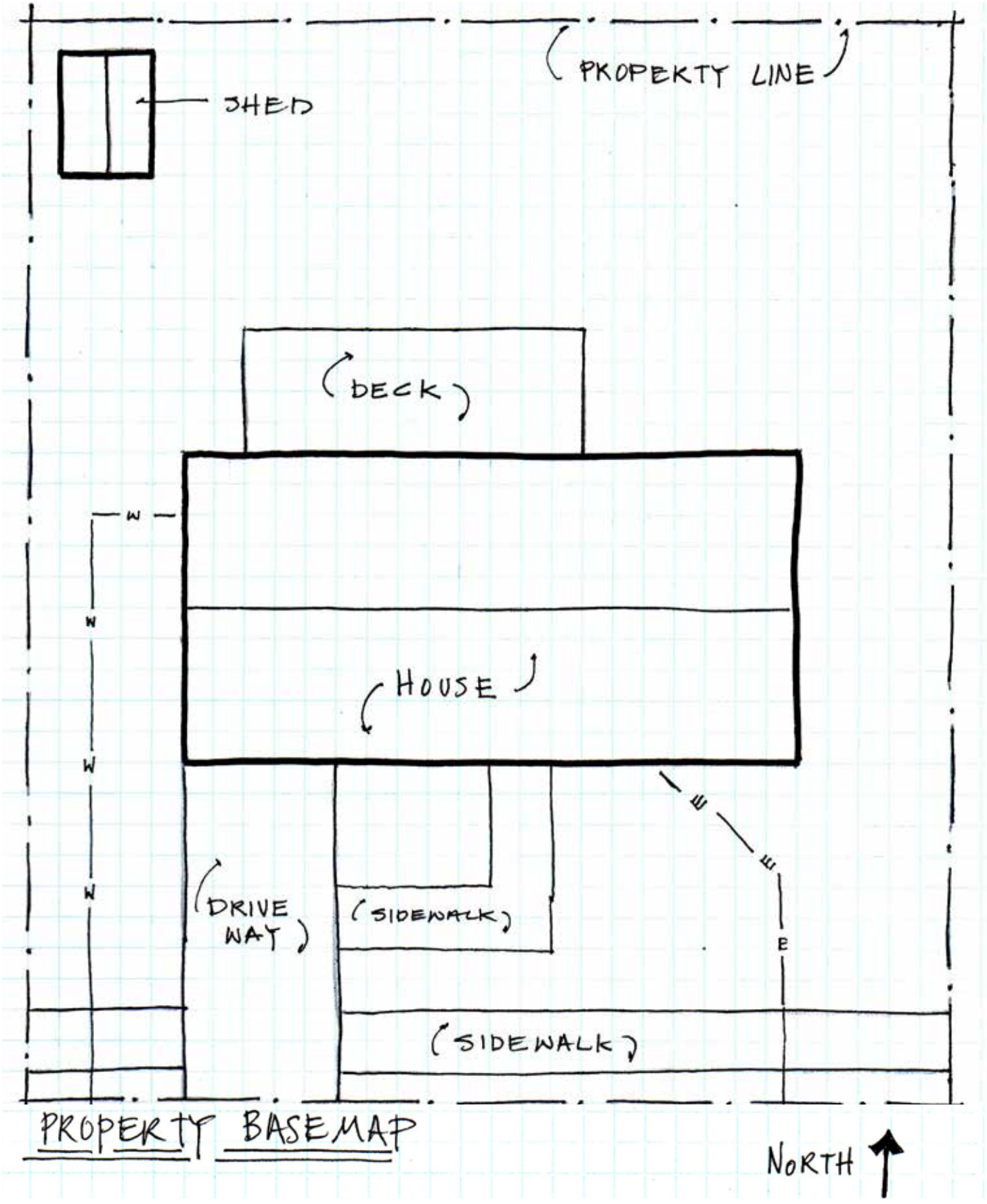
Part 2: Soil assessment (See example on Page 30)

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.

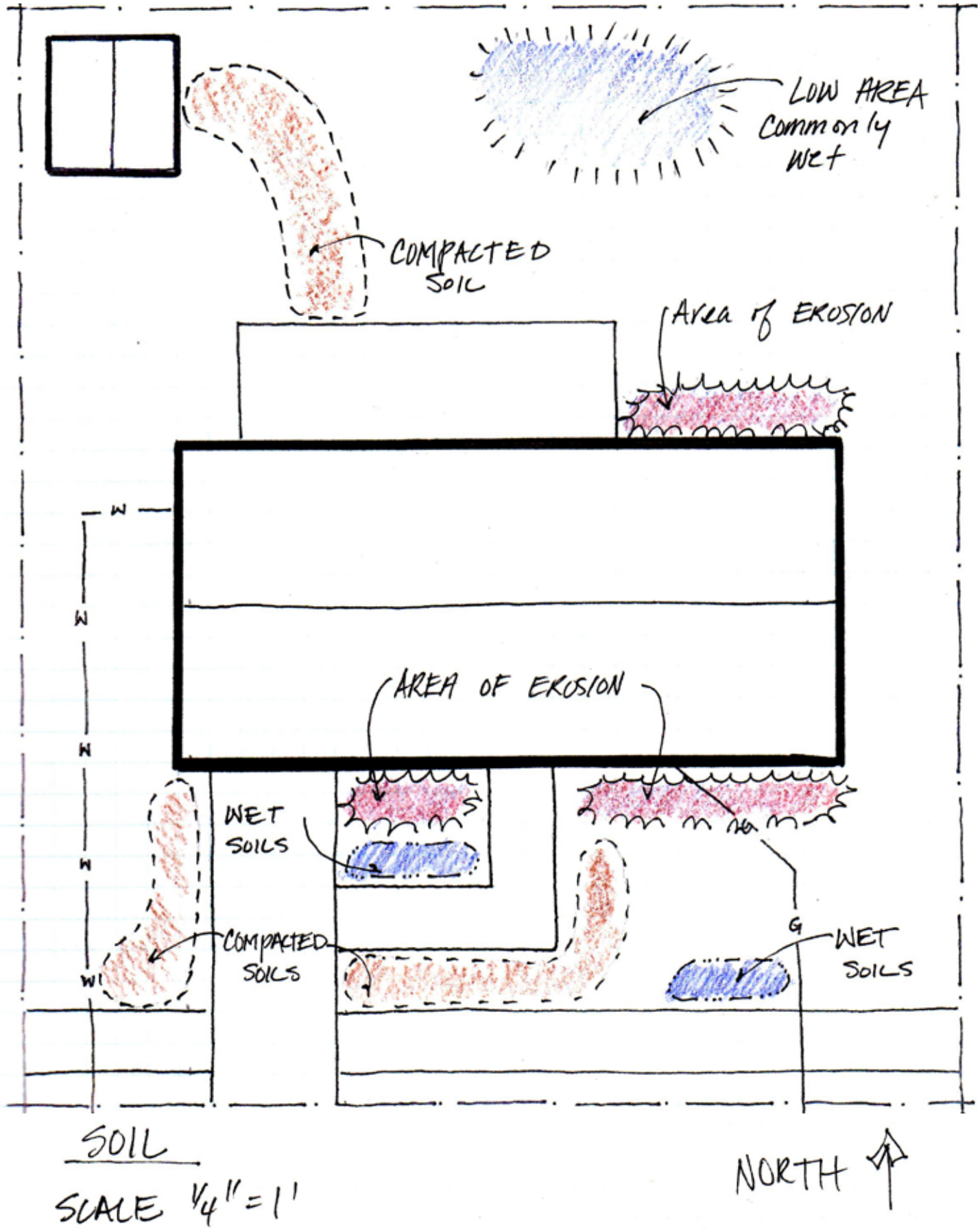
Using tracing paper over the basemap, outline the following characteristics:

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

Example: Basemap



Example: Soil Assessment



Lesson 3
Successful Soil Practices

Learning objectives

After completing this lesson you will be able to:

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

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:

SHAW NATURE PRESERVE

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

- 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.

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:

SALLY AND ANDY WASOWSKI

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

- 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.

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:

SALLY AND ANDY WASOWSKI

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

- 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 planting beds.
- Divert rainwater from the waterlogged area using practices such as rainwater harvesting or bioswales.

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:

SALLY AND ANDY WASOWSKI

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

- 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.

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:

SALLY AND ANDY WASOWSKI

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

- 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.

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:

H. ZELL

***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.

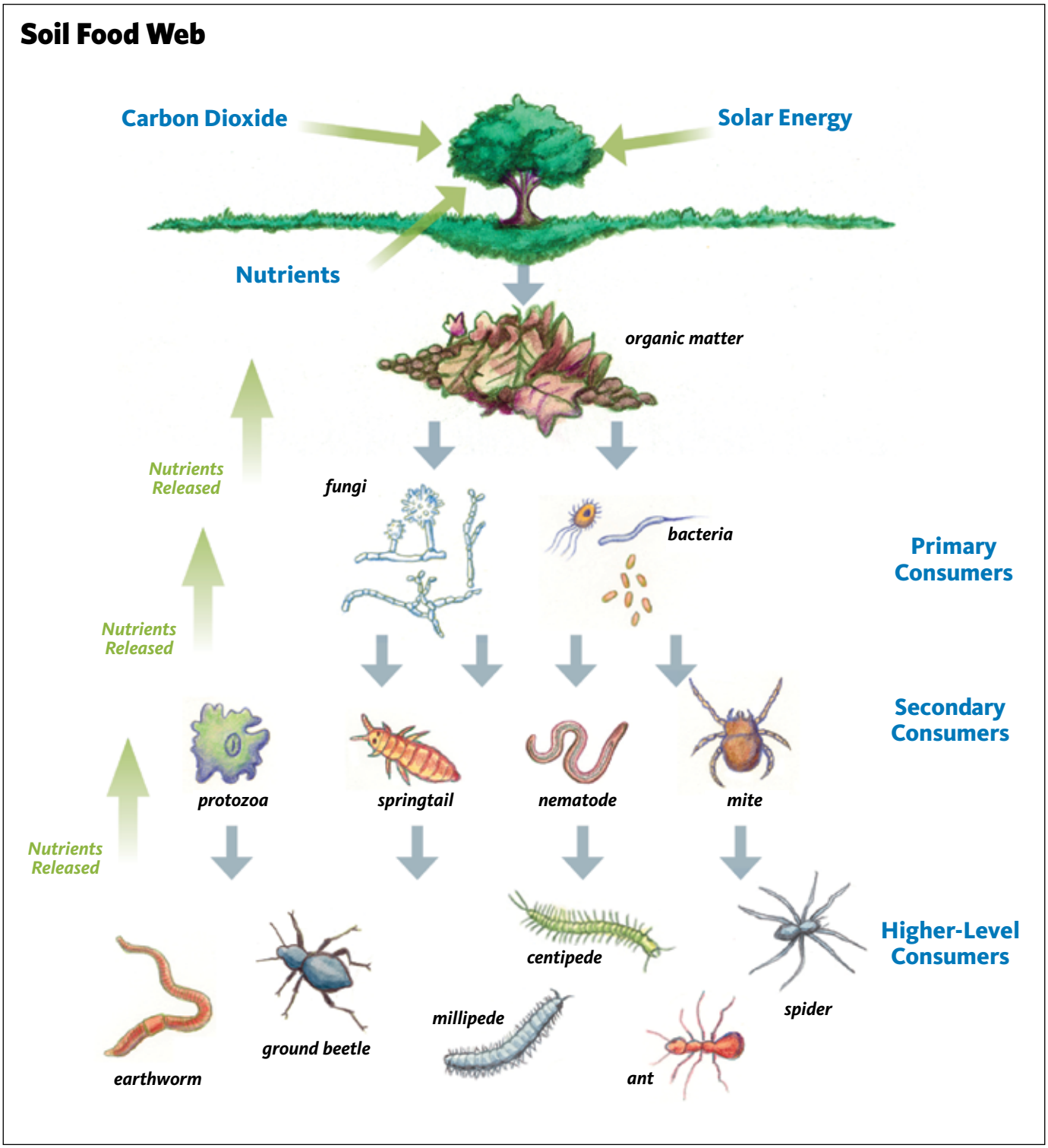
Most often calcium and magnesium deficiency appears as an imbalance between the two micronutrients. This is especially common when dolomitic lime is used repetitively to increases magnesium relative to calcium. Calcium levels are ideally twice that of magnesium or 2:1. While there may be adequate calcium 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 ($CaSO_4$) 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

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.

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** 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.

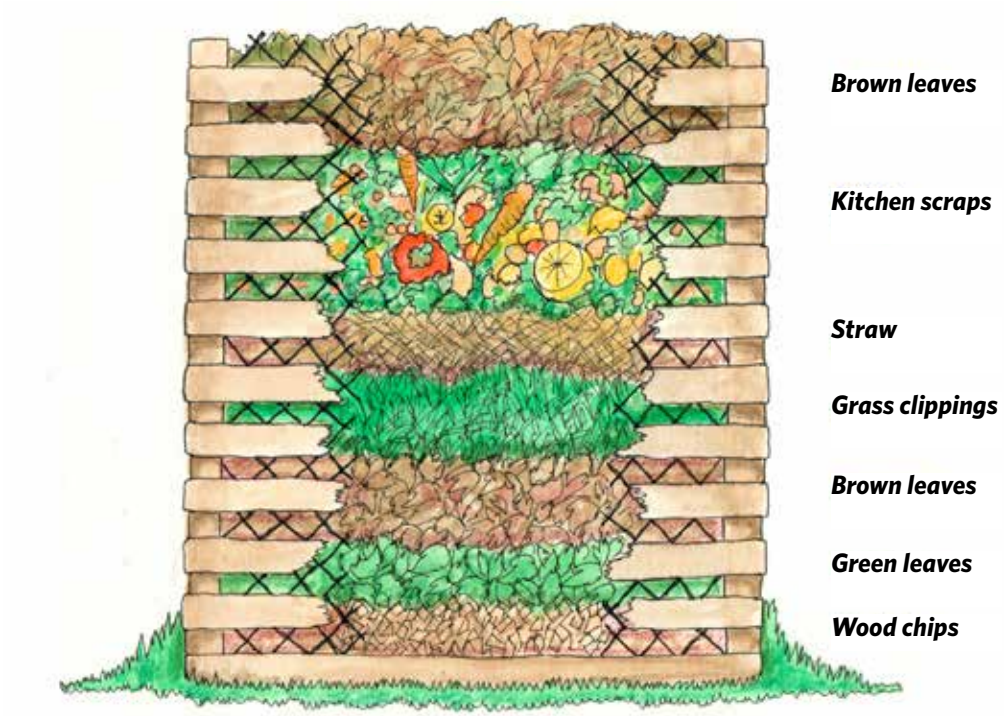
How to Build a Compost Pile—

- **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.

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.

- **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 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.

SHENAGENZIUK

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

How to build a compost pile or vermicompost bin

Activity

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

Vermicompost

- ☐ Worm bin
- ☐ Bedding material such as shredded newspaper or cardboard, leaves, or straw
- ☐ Two cups of garden soil
- ☐ Water
- ☐ Food scraps
- ☐ Red worms

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 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

RAINBOXRED, WIKIMEDIA COMMONS

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

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 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. Aviod 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.

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 though 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

Learning objectives

After completing this lesson you will be able to:

- ☐ 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

ED CASTRO LANDSCAPES

Overview

Clean 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.

BIG STOCK

Stormwater overflow from sewers can cause pollution of nearby waterways.

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 vs. Sustainable Gardens: How They Compare

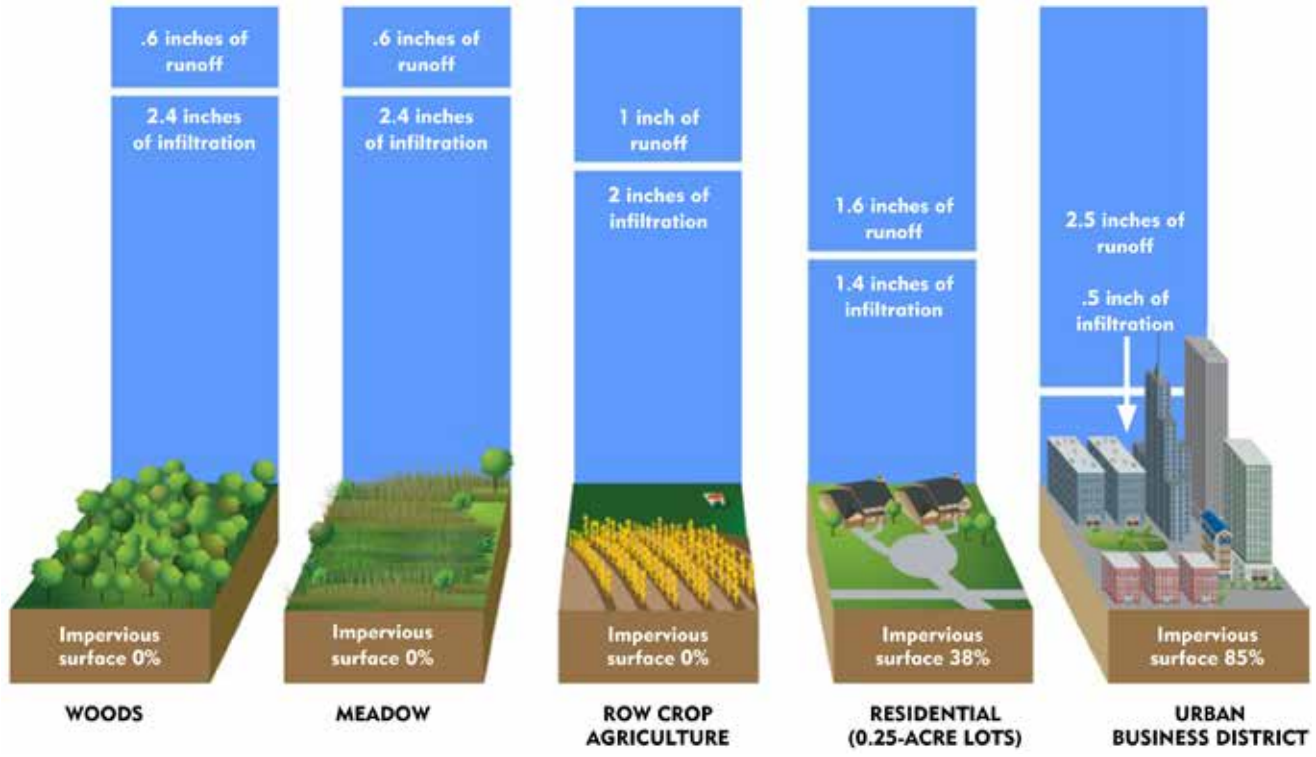
WATER

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

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

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.

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 cooper and zinc roofs or gutters, galvanized materials, and treated lumber
- Coal tar sealants used on paved roads

Site Assessment — Water

Assignment

Site Assessment — Water (See example on page 55)

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.

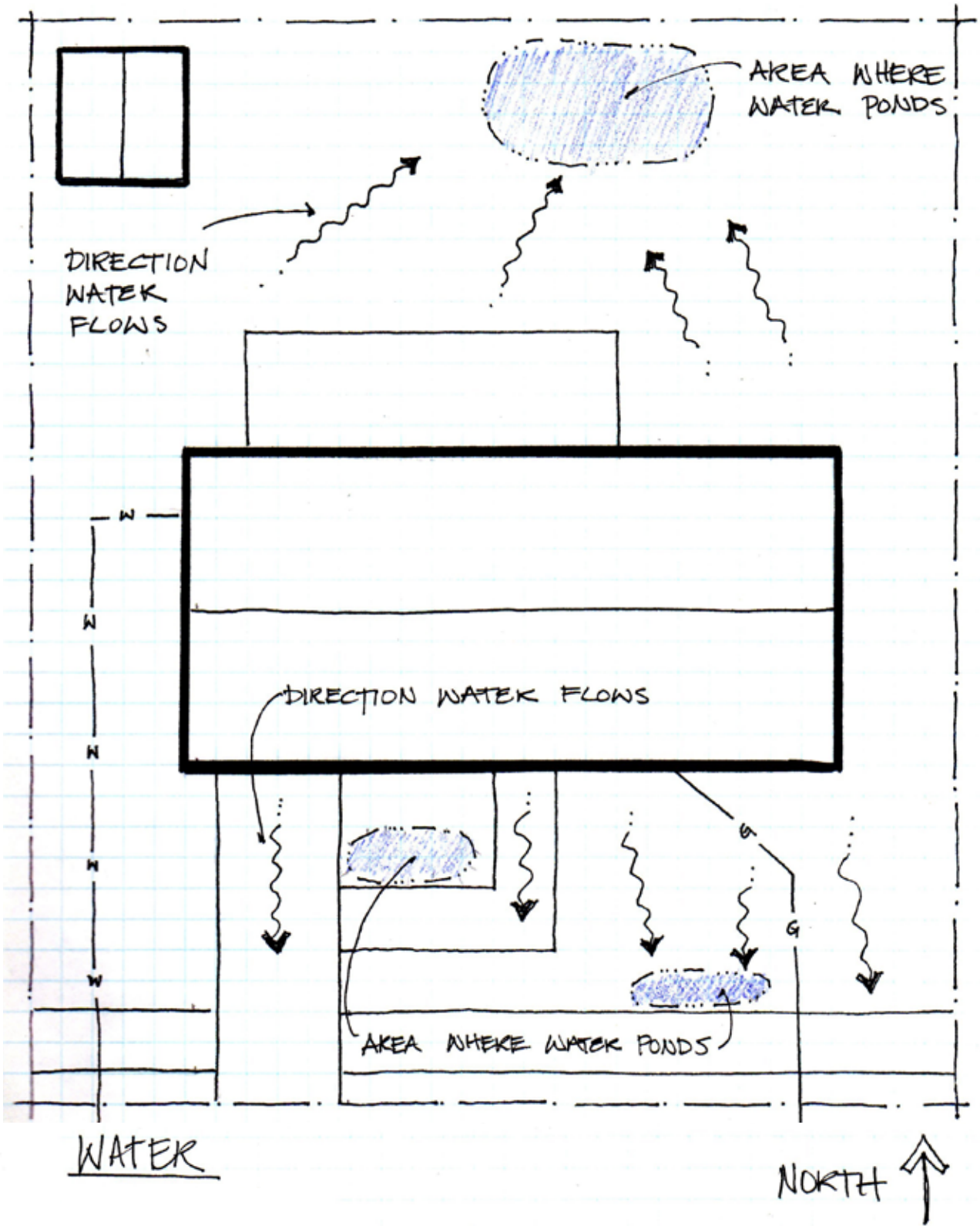
Using trace paper over the basemap, outline the following:

- 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^2 shingle roof, 200 ft^2 concrete driveway, 500 ft^2 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



Lesson 5
Successful Water Practices

Learning objectives

After completing this lesson you will be able to:

- ☐ 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

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.

EPA

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


WARD WILSON


EPA

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

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^2 (m^2) × in (cm) of rain × 600 gal (2,271 L) per in (2.54 cm) / 1,000 ft^2 (93 m^2)

Table 1: Example of the potential for rainwater harvesting off of a 2000 ft^2 house in Boston, MA.

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
Total	**42.5**	**108**	**51,000**	**193,055**

*Metric answers are based on unrounded conversions.

should be estimated for each month. Approximately 600 gallons (2,271 L) of water can be collected for each inch (2.54 cm) of rain falling on a 1,000 ft^2 (93 m^2) 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.

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 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.


ARCHITECTSEA


ARCHITECTSEA

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:

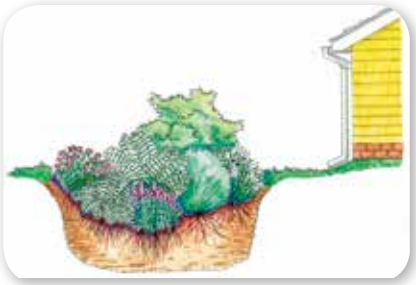
- Locate underground service lines or utilities prior to digging
- Keep the rain garden at least 10 feet from the house to prevent moisture problems
- Place the garden at least 25 feet from septic systems
- Avoid placing the garden directly under trees to prevent conflicts with roots
- Avoid placing 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

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^2 (m^2) × 30 percent

EPA

Vegetated bioswale

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 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

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

EPA

events, large areas of impervious surfaces allow runoff to gather volume, speed, and pollutants leading to excessive flooding and the damage of nearby ecosystems.

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 34 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.

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

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

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

Water Use in the Unites 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.

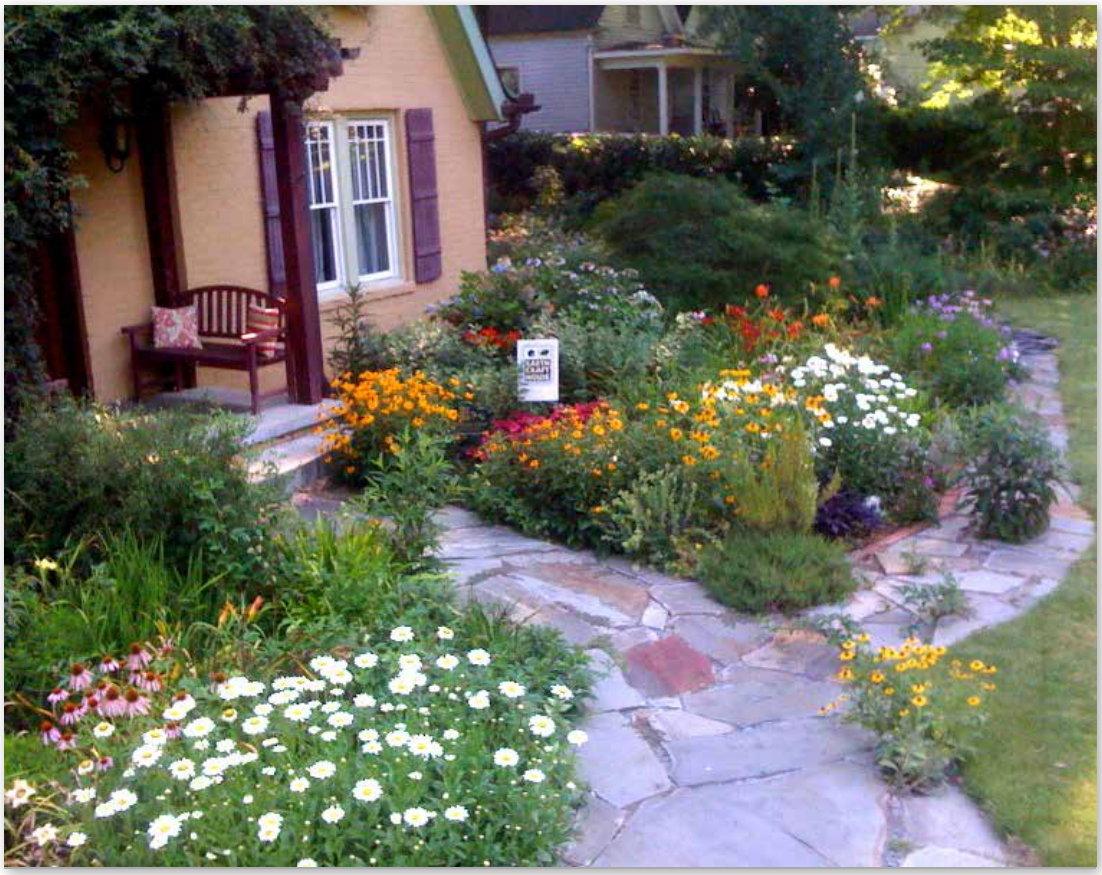
*Information on water testing can be found though a local Cooperative Extension Office. A list of offices by state is provided in Appendix 2 of this manual.

Lesson 6
The Role of Plants in Sustainable Gardens

Learning objectives

After completing this lesson you will be able to:

- ☐ 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



GERI LAUFER

Overview

Vegetation 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 landscapes. 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 CO2 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.
- **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.

Unsustainable vs. Sustainable Gardens: How They Compare

PLANTS

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

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 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) 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

Activity

Familiarize yourself with plants commonly grown in the area. This can be done by visiting a local botanic garden, nursery, or garden club demonstration. If the weather is not conducive or a trip to one of these locations is not possible, you can also conduct research online. The Native Plant Information Network (NPIN), available at http://www.wildflower.org/explore/, is a good resource for identifying common plants by region.

Site Assessment — Plants

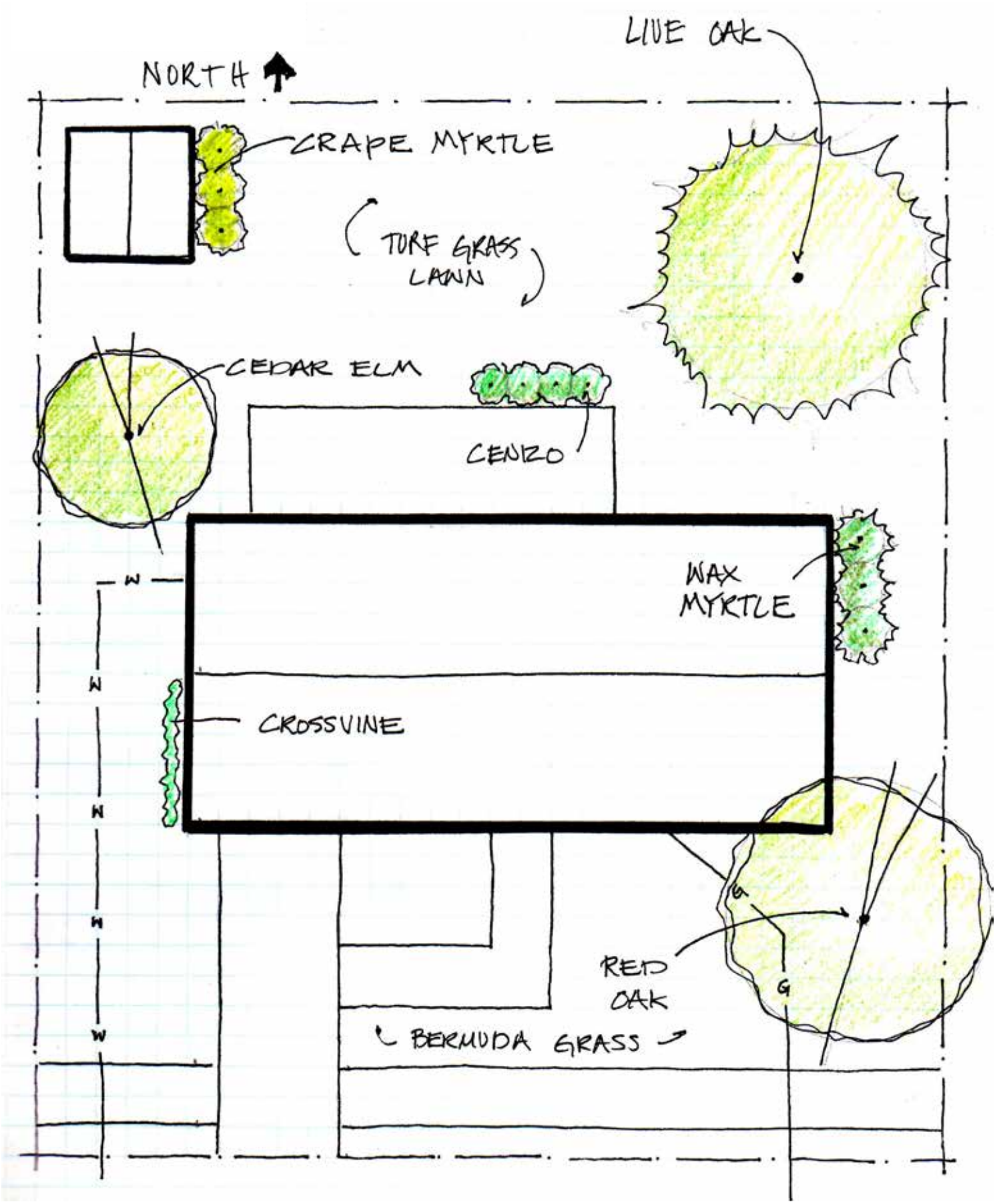
Assignment

Site Assessment — Plants

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.

Example: Plants Assessment



Lesson 7
Successful Plant Practices

Learning objectives

After completing this lesson you will be able to:

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

USBG

Overview

While 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 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

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.

Identifying native and non-native appropriate plants

Activity

Familiarize yourself with native and appropriate plants of the area. This can be done by visiting local botanic gardens, nurseries, or garden club demonstrations. If the weather is not conducive or a trip to one of these locations is not possible, you can also conduct research online. The Native Plant Information Network (NPIN), available at http://www.wildflower.org/explore/, is a good resource for identifying native plants.

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.

STEVE DEWEY

Salt cedar *(Tamarix spp.)*

Identifying and controlling common invasive species found in your area

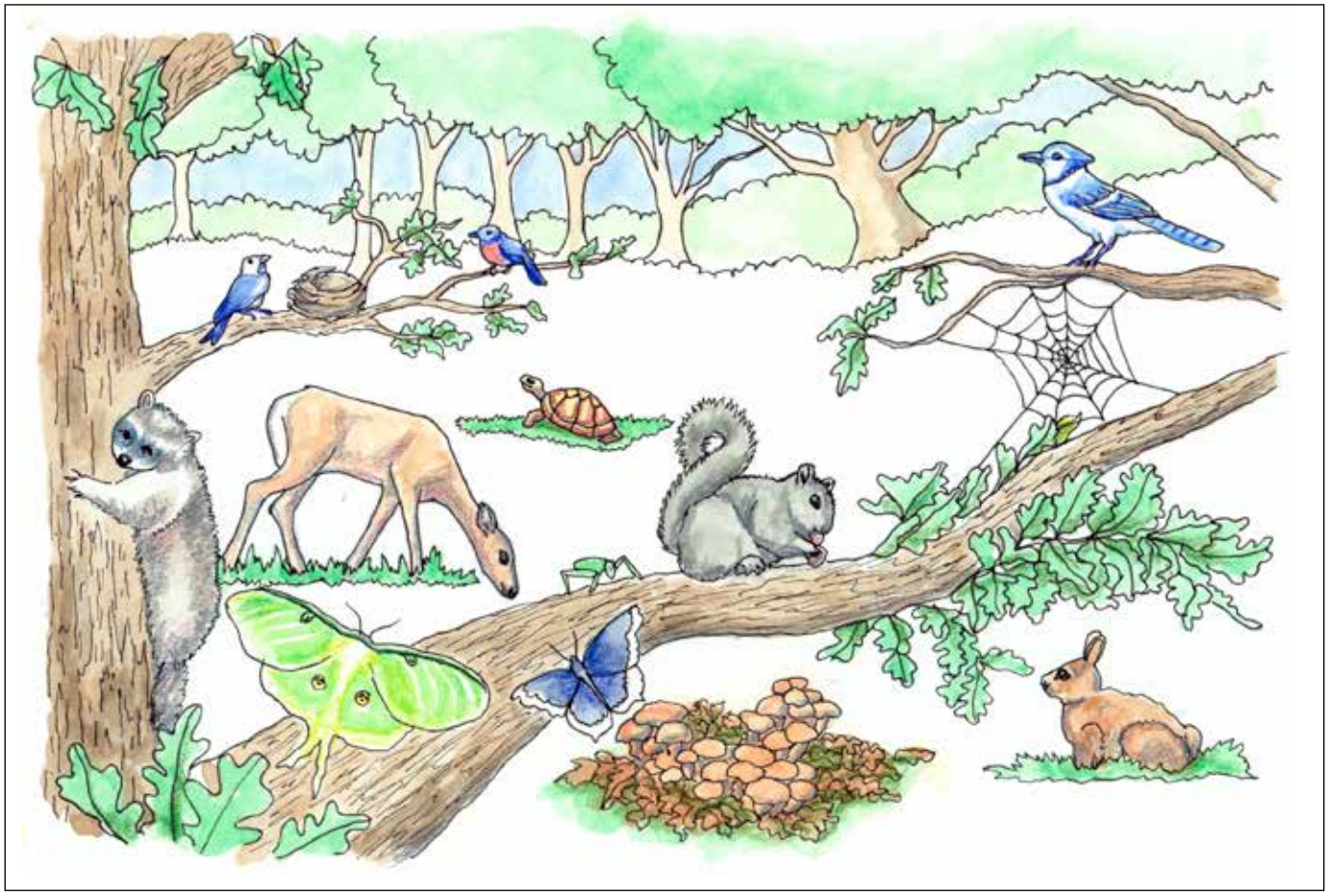
Activity

Familiarize yourself with invasive plants of the area and methods of controlling these invasives. Resources for learning more about the invasive species in your region include www.naeppc.org, 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.

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.



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.

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 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 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 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.

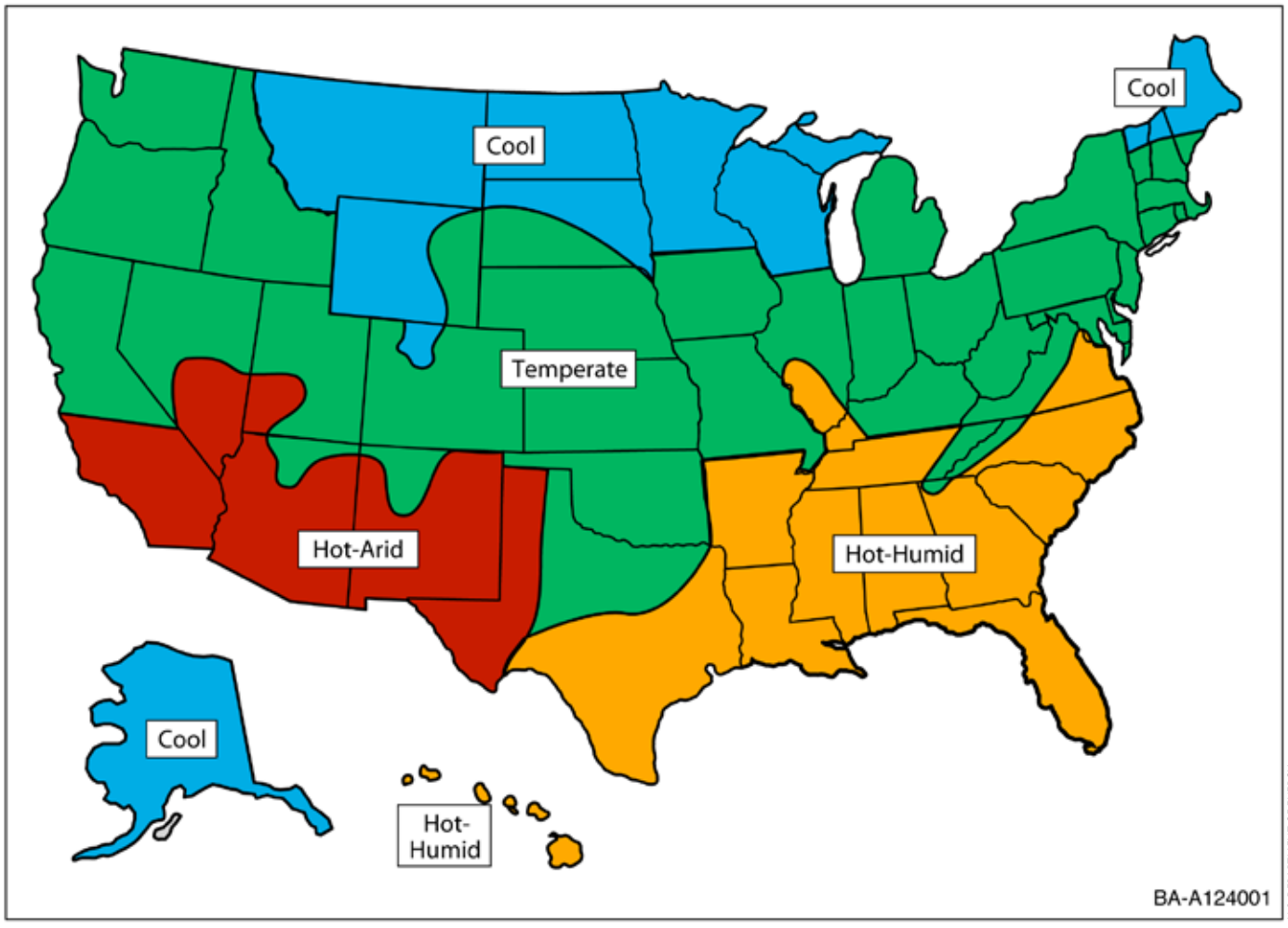
- Shade south and west windows and walls from the direct summer sun if summer overheating is a problem. Deciduous plants can be used to provide shade while still allowing low-angle sunlight of winter to warm your home during the coldest months.

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



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 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

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.

ED CASTRO LANDSCAPE

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

› **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 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.

PROJECT LIVING PROOF

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

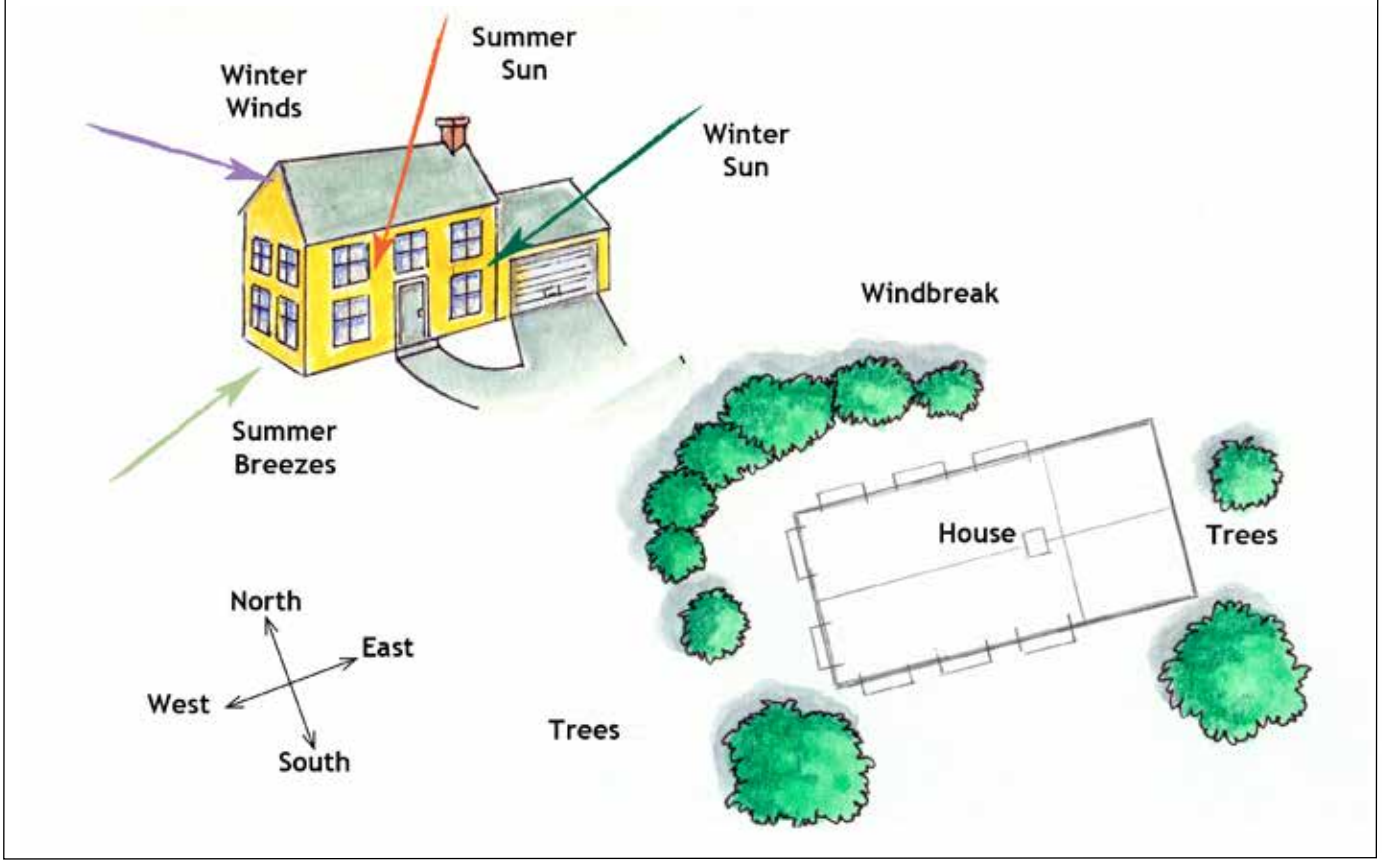
Trees and Shrubs—Large trees and shrubs take longer to fill in but provide the best cooling shade. The air temperature can be as much as 25 degrees F cooler under trees than around nearby asphalt lots. As is true for vines, in cool and temperate climates the placement of trees is more complicated than 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 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.

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.

IOWA STATE UNIVERSITY EXTENSION

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.

Site Assessment — Energy Efficiency

Assignment

Site Assessment — Energy Efficiency

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

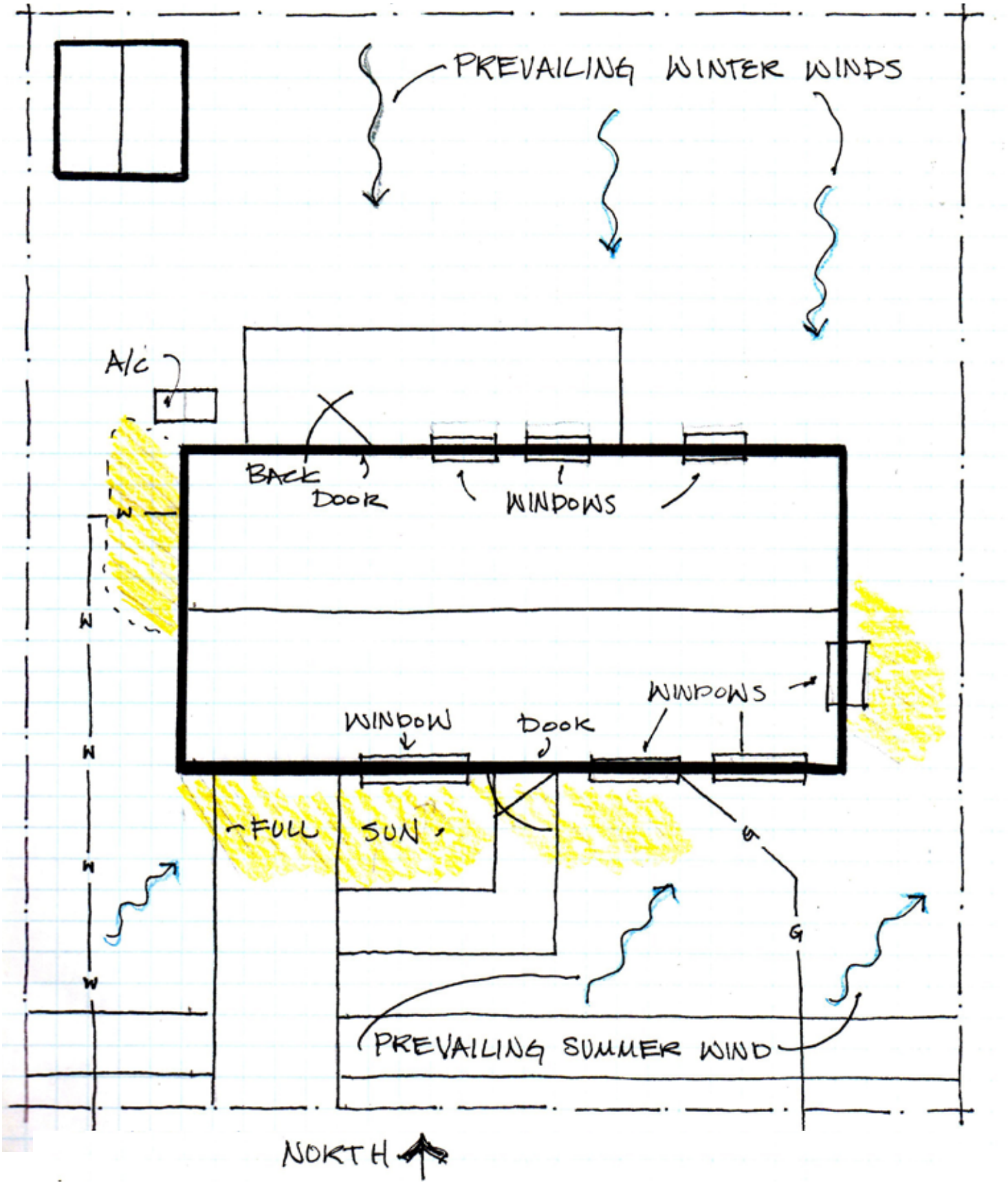
- Direction of prevailing winds in the winter and summer
- Portions of the home that receive sunlight in the morning, afternoon, and evening during the summer and winter

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.

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.

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/

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/

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

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 though 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

Learning objectives

After completing this lesson you will be able to:

☐ List strategies for reducing material use in the garden

M. TAYLOR

Overview

The 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.

EPA

Unsustainable vs. Sustainable Gardens: How They Compare

MATERIALS

Unsustainable Gardens	Sustainable 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.	*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 are not local and therefore do not support community businesses or the regional economy.	*Materials represent the regional identity of the area and support the local economy.*
Little information is known about the human health and environmental costs of materials.	*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 manufactures 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 9
Successful Materials Practices

Learning objectives

After completing this lesson you will be able to:

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

COYOTE GARDEN

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.

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.

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.

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

HEATHER VENHAUS

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 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.

LEWIS GINTER BOTANICAL GARDEN

Use local rot-resistant wood instead of treated wood that may leach toxins into the soil and water.

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.

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/

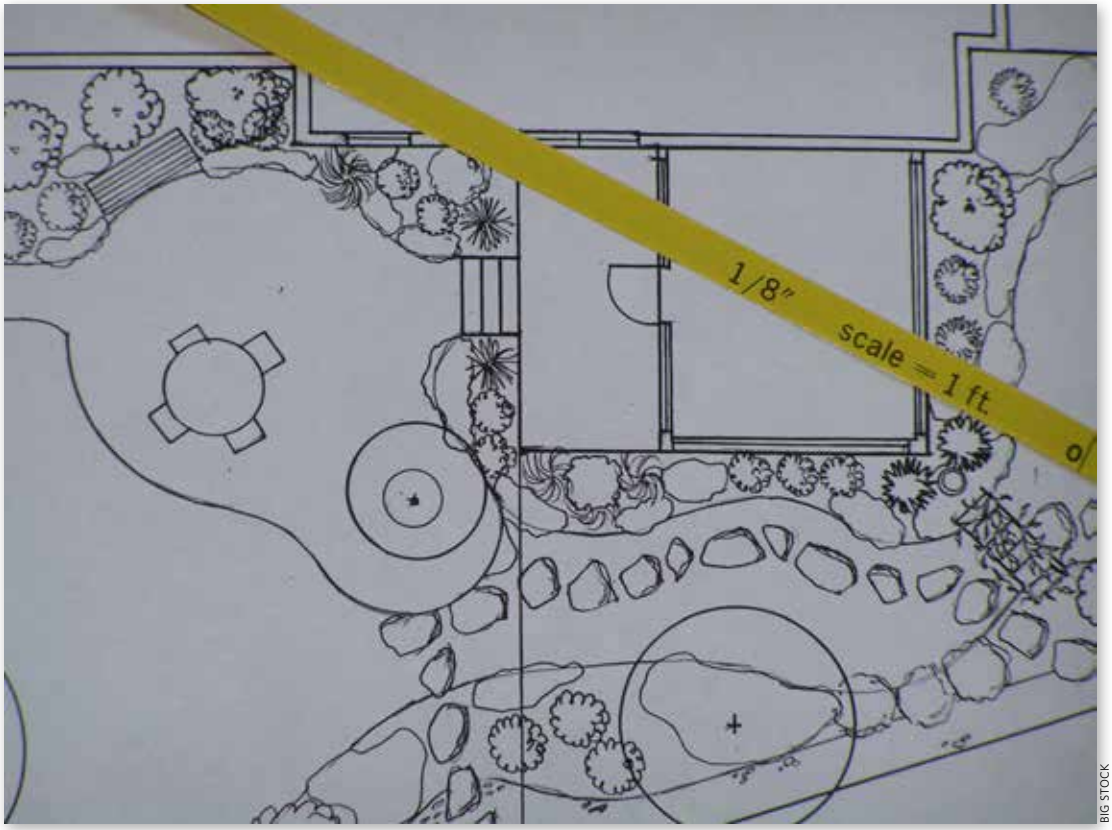
This website provides information on obtaining forest-based construction materials that have been sustainably managed and meet PEFC certification standards.

Recycling Landscapes and Hardscapes Calculator
Sustainable Cities Institute
http://www.sustainablecitiesinstitute.org/view/page.basic/calculator/feature.calculator/Calculator_Landscape_Waste_Costs

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

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

Lesson 10
Exploring Sustainable Garden Strategies



BIG STOCK

Overview

Now that the class is complete, it is time for you to put what you have learned into practice. The purpose of this last lesson is to provide design inspiration and resolve any unanswered questions. Compile your basemaps and site assessment information. Use the questions below to explore potential design strategies for your home garden.

Design inspiration

When looking for creative solutions and design inspiration it is often helpful to see what others have accomplished. Project examples of sustainable gardens from across the US have been compiled in an accompanying Landscape for Life PowerPoint presentation which is available at http://landscapeforlife.org/resources/. Additional project examples that have received SITES certification can be found at http://www.sustainablesites.org/.

Use the questions in the activity below to help guide potential design strategies for your home garden.

Exploring sustainable design strategies

Activity

In this exercise, you will begin to explore potential sustainable design strategies for your home garden. Using your basemaps and site assessment information, 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?

You can explore each of these questions by drawing ideas on trace paper overlying your basemap.

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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 condition system that can 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., needlike 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 inferred 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 sale 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

This websites 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

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

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

Water Use in the Unites 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/

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/

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

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

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 of list of public agencies (often associated 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 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
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
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
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
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. 8th 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/

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_/.
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. 6th 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
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
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
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
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
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
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 or paret@ufl.edu
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
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
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
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 or lsonon@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
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.ppdl.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 Creswel
Email: creswell@purdue.edu or ppdl-info@purdue.edu
http://www.ppdl.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

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
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
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
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
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
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.

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
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
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
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
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
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
Contact: Howard Russell (insect questions)
Email: bugman@msu.edu
Fred Warner (nematode questions)
Email: 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
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
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://cnal.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/

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://entoplp.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: mwllmsn@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/uppdl

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

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.

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/weedid.php

Services:
✓ Weed identification

Nematode Assay Lab
115 Price Hall
Dept. Of Pant 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

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

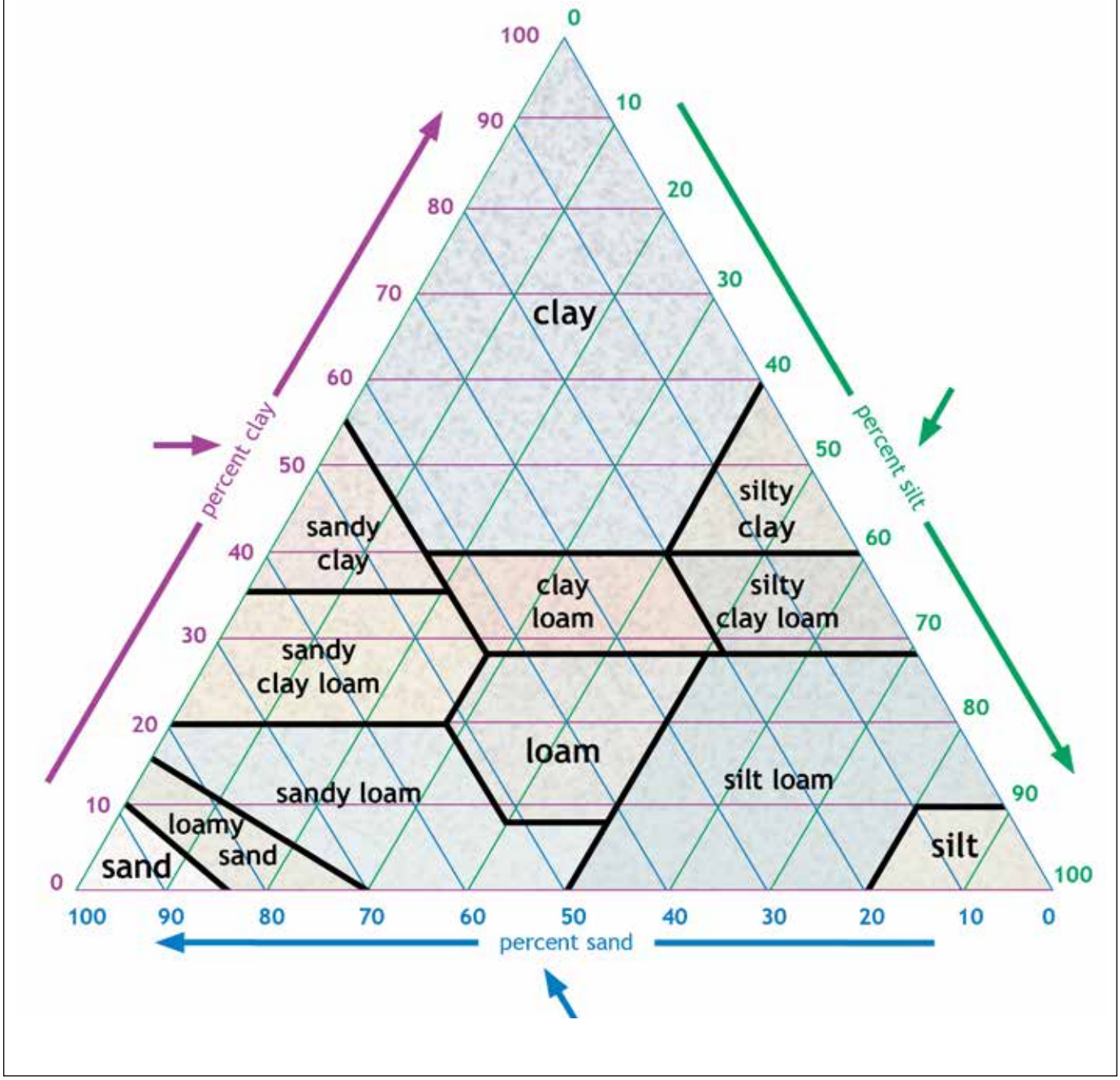
**No soil testing is offered by a public agency. Contact your local county extension agent for a listing of local labs.

Extension Plant Pathology Laboratory
University of Wyoming
Plant Sciences 3354
Laramie, WY 82071-3354
Phone: 307-766-2062
Contact: William Stump
Email: wstump@uwyo.edu

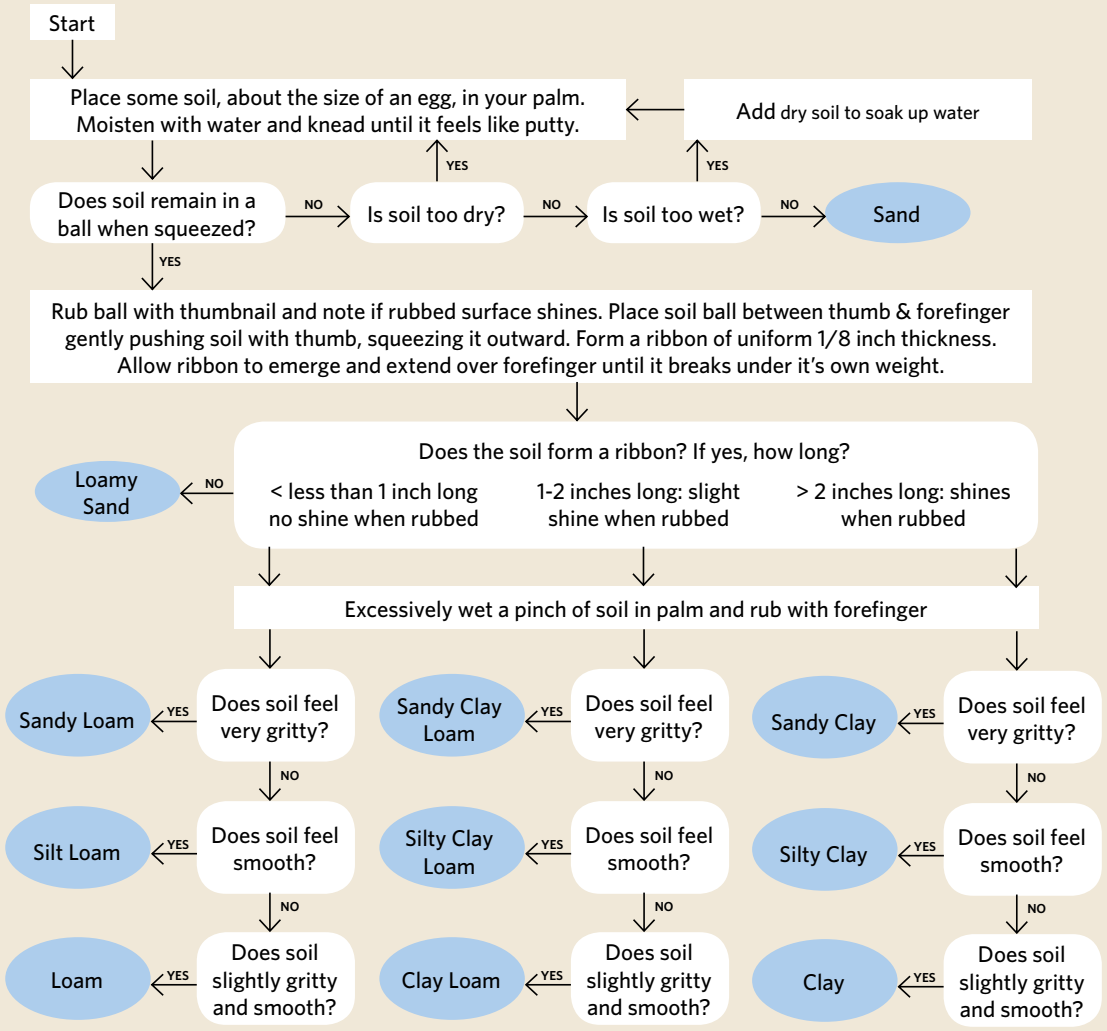
Services:
✓ Plant problem and disease diagnostic testing

Appendix 3: Tools for Determining Soil Texture and Structure

Soil Texture Triangle



Soil Texture Flow Chart



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.

www.landscapeforlife.org

LANDSCAPE FOR LIFE™

Based on the principles of the Sustainable Sites Initiative™

United States Botanic Garden

Lady Bird Johnson Wildflower center
THE UNIVERSITY OF TEXAS AT AUSTIN

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