Cornell Cooperative Extension
Cornell Garden-Based Learning

Gardening in a Warming World

A Climate Smart Gardening Course Book

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Hope never dies in a true gardener's heart. ~ Author unknown

Preface

Gardening is a risky business. Gardeners are always looking up to the sky, checking wind direction and strength, bending over to pull out invasive weeds, agitating over the curled or rusty leaf, and frustrated by the lack of rain, or too much. The conditions for a truly successful, beautiful, and healthy garden, namely good soil, ample water, suitable air temperature, manageable pests -- and a dose of luck -- all need to be in balance with each other.

Across the centuries, gardeners have willingly faced challenges with hope, determination – and joy. Gardeners are keen observers of the nuances required to grow healthy plants of all types and sizes. The slightest variations in growing conditions are cataloged and analyzed. New strategies and solutions to the problems presented by cultivating living things are often contemplative acts of reverence for the earth and the natural environment.

These actions will hold gardeners in good stead as they now face an unprecedented phenomenon that amplifies all those conditions that can make or break our successful gardening efforts – and that is, climate change. The weather extremes and seasonal shifts we have witnessed across the world – and in our own landscapes - are part of the evidence indicating a change in our planet's climate. Deep reflection on our strategies in tending our lawns, trees, shrubs, flowers, and vegetables will be required to manage and adapt to this latest – and biggest - challenge to successful gardening.

Cornell Cooperative Extension (CCE) is committed to educating stakeholders about this intensifying challenge and helping citizens implement the strategies that are needed to adapt to and mitigate climate change. This guide is for gardeners, homeowners, educators, volunteers, teachers, students and anyone interested in exploring how we might examine our gardening practice through the lens of climate change mitigation and adaptation. We hope this resource might strengthen understanding and inspire us to take actions in our gardens and communities that will help address the global crisis of climate change.

The course book is divided into four units that briefly describe the key concepts we believe are fundamental to understanding the challenge of the changing climate and how it relates to gardening skills and techniques. We provide basic facts on climate change and offer methods, materials and activities to launch your learning through actions in cultivating lawns, gardens and landscapes that can lead to ongoing success. Our collective understanding strengthens our capacity. We cannot encourage you enough to engage peers in discussions. Be sure to check out the brief section on how to facilitate dialogue around climate change and sustainability. More in-depth information and guidance for facilitating peer learning can be found in the separate companion publication *Gardening in a Warming World Facilitator's Notebook*.

Acknowledgements

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Table of Contents

UNIT 1: Benefits of Systems Thinking for Sustainable Gardening

What exactly do we see when we look at a forest? We see trees, certainly, as well as other plants, soil, water, birds, animals and often much more. If we placed some trees, soil, a pool of water, and squirrels and chipmunks together, however, we clearly would not have a forest. A forest is the complexity of relationships among these elements and other connected systems such as weather, climate, and human settlements. The systems thinking approach aims to understand the complexity of the world in terms of relationships, connectedness, and context.

Only by **observing relationships** and the impacts of changes on those relationships, can we recognize and analyze the interconnections within the whole versus among its isolated parts. With this observation, we start to develop a comprehensive picture that different parts of a system are so interconnected that if we alter one part of a system it will change other parts. This allows us to ask the important questions that will help us better understand the system. For example, what happens to the soil as plants reach maturity, and eventually die? What happens to the plants and animals as soil health and water quality change?

Figure 1: Northeastern Forest. Photo Credit: CCE Dutchess County.[1]

Figure 2: Habits of a Systems Thinker (next page) provides an alternative and visual format of these characteristics of systems thinking:

- ☐ Sees the whole: interprets the world in terms of interrelated "wholes" or systems, rather than as single events, or snapshots.
- ☐ Looks for connections: assumes that nothing stands in isolation; and tends to look for connections among nature, ourselves, people, problems, and events.
- ☐ Pays attention to boundaries: uses peripheral vision to check the boundaries drawn around problems, knowing that systems are nested and how you define the system is critical to what you consider and don't consider.
- ☐ Changes perspective: changes viewpoints to increase understanding, knowing that what we see depends on where we are in the system.
- ☐ Looks for stocks: knows that hidden accumulations (of knowledge, carbon dioxide, debt, and so on) can create delays and inertia, slowing down causes and effects.
- ☐ Critiques one's own assumptions about how the world works and how that may limit thinking.
- ☐ Anticipates unintended consequences: traces cause and effect asking: "what happens next?"
- ☐ Looks for change over time: sees today's events as a result of past trends and an indication of future ones.
- ☐ Sees "self" as part of the system: looks for influences from within the system, focusing less on blame and more on how the structure (or set of interrelationships) may be influencing behavior.
- ☐ Embraces and holds the tension of paradox and ambiguity, without trying to resolve it quickly.
- ☐ Finds leverage: knows that solutions may be far away from problems and looks for areas of leverage, where a small change can have a large impact on the whole system.
- ☐ Watches for win/lose attitudes: in situations of high interdependence dichotomous views usually make matters worse.

Figure 2: Habits of a Systems Thinker from Second Edition ©2014 Systems Thinking in Schools, watersfoundation.org[2]

A powerful strategy in successful gardens is intentionally observing and recording changes, and noticing the relationships among those changes. As we continually strive for a deeper understanding of the elements and relations within our garden system, we foster **habits of the mind** essential to systems thinking and sustainable gardening success. In the next unit, we consider methods to document foundational knowledge about our garden landscapes.

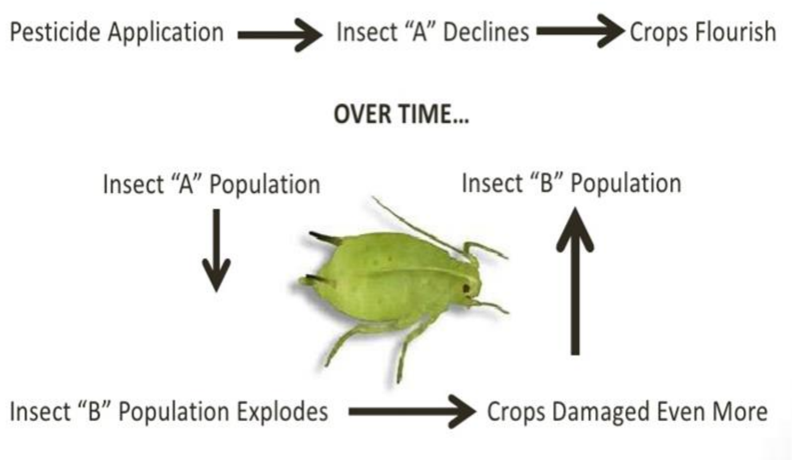


Figure 3: An example of how failing to use systems thinking in pest management can lead to even more damage.[3]

SUMMARY

- The complexity of our changing world demands that we value and develop *Habits of a Systems Thinker* that intentionally recognize and analyze the interconnections within and between systems to resolve problems and to plan for sustainable gardens within our communities.
- You can learn to become a systems thinker by developing habits that include seeing the linkages of events, considering possible unintended consequences of specific actions, and documenting trends.

REFLECTION

- How do you make decisions and/or resolve problems in your own life? Explore the full range of behaviors in modern lives including those outside lawn, garden, and landscape management. How have you or might you expand your use of *systems thinking*? Refer to the figure of *Habits of a Systems Thinker* (figure 2).
- Consider asking how other friends, neighbors, gardeners might be using systems thinking by encouraging them to share their reflections on how they approach problem solving and decision making. Tip: The Center for Courage and Renewal encourages in its *Circle of Trust Touchstones* that when we ask questions of others, we seek to listen without needing to fix or advise them.

EXPLORE MORE

- A list of reliable sources related to this unit is provided in the Selected Resources section.

Donella Meadows Project - Academy for Systems Change
Interested in delving into more on systems thinking? This organization's website offers a wealth of further resources on systems thinking, including several visual representations, recommended books and links to other online resources. **http://donellameadows.org/systems-thinking-resources/**

Unit 2: Knowing Our Garden Systems

Realizing that our gardens are a system and building our observation skills to see the interconnections and interrelationships within our gardens is a great beginning to cultivating sustainable gardening success.

We can start small and find delight in the ongoing discovery process that emerges as our habit of systems thinking expands. For example, we might try an introspective or meditative observational experience where we sit outside or walk around a garden, rallying all the senses - look, touch and taste (taking care to watch out for plant toxicity!), listen, and smell.

Moving towards documenting observations deepens an understanding of changes from season-to-season and year-to year allowing us to discover patterns and trends that better prepare us to make effective and informed management decisions. There is an abundance of options to record your garden system data. As we briefly describe a few methods we know many gardeners already practice, keep in mind the *Habits of a Systems Thinker* described in Unit 1.

- **Journaling** – Garden journals can include photographs, sketches, listings, descriptive text, and calendars. A simple internet search on garden journals reveals there is an array of paper journals specifically marketed to gardeners, including a "gardener's journal" set up as a ten-year perpetual diary - though most any paper notebook can serve as a journal. There are also online social garden trackers and smartphone apps with accompanying websites that offer the ability to include GPS coordinates. The availability of options makes it challenging to provide the most current list here. Investigate on your own including asking fellow gardeners about their favorite tools. Any tool can be effective as long as you are consistent, and it is useful for you.

Garden Journaling Tips

from Karen S. Klingenberger, Consumer Horticulture Educator Emeritus, CCE of Monroe County

- ❖ Your garden journal is a personal document that can help you plan your gardens and enjoy them to their fullest. This should not be a chore but a pleasant past time. Don't fret about making daily entries; focus on significant events such as last frost, first frost, hail…
- ❖ Pick a spot in your yard and take a photo from that same place from season to season and year to year. Placing photos in your journal with the date will help you see what did well and what you might like to change.
- ❖ To help you remember what you ordered or purchased locally from year to year include in your journal your detail receipt and plant tags. A photo or rough hand-drawn map showing where you placed the plants that year could also prove valuable.
- ❖ For the purpose of rotating your annual vegetable and herbs it is important to document their location. Noting planting dates of seeds or seedlings and harvest dates can inform plans for intensive strategies for multiple crops or plantings in a season.
- ❖ Personally, I find the best books to use for journals are lined and spiral bound, 8 ½ by 11 sized with a sturdy cover. My journals are full of drawings, taped-in photos, plant tags and orders and look quite a mess – that works for me. I constantly refer to them when planning for a new growing season and enjoy reminiscing about gardens past.

- **Mapping** - Creating a map of a garden landscape is also a common practice to document a garden system. It can be a sketch or a drawing to scale and feature a few elements on a base map. It may include overlays detailing systems features like soil, water flow, air circulation, light characteristics, and temperature specifics. The key to your success will be finding an approach that best suits your needs and interests. Explore the many possibilities to be inspired and creative.

> **Habitat Network** online forum hosted by the **Cornell Lab of Ornithology** offers features that allow users to map gardens, compile photos and document characteristics.
>
> **www.yardmap.org**

- **Identifying and quantifying garden systems** - Start off by recording organisms found in your garden space. These could include spiders, insect pollinators, wildlife and even domesticated animals. While noting these creatures, take a look at how these organisms are interacting with landscape features and each other. Is there variability in the flowering sequence of plants? How is that tied to insect activity? Next, look at the landscape including water features and the shape of the land. Are there steep slopes or low spots? Are there water drainage patterns and areas susceptible to heavy runoff or topsoil erosion? This practice allows you to produce visuals of trends and patterns which will be valuable in sorting out the complexities in changes, and for thinking in terms of relationships, connectedness, and context. You might also see certain configurations of relationships appear again and again in patterns such as cycles and feedback loops.

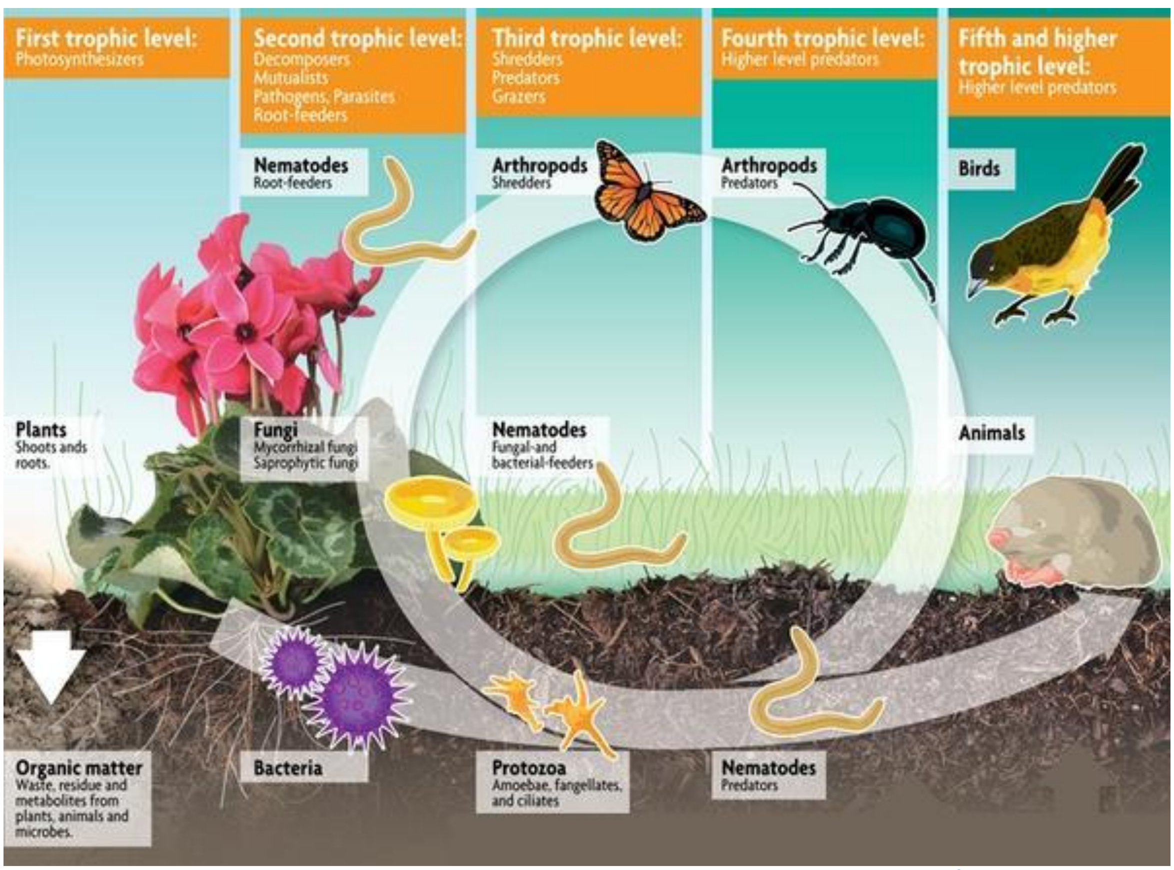


Figure 3: Soil Food Web. Image Credit: John & Bob's Smart Soil Solutions.[4]

Keen observations and systems thinking will enhance our ability to analyze the whole and to appreciate how it is different from the sum of the individual parts. Our deeper understanding of our garden systems is never complete. An on-going effort to recognize connections is an essential foundation for choosing strategies that may maximize gardening success in our changing world. In the next unit, we focus specifically on climate science literacy, finding reliable information and talking with others.

SUMMARY

- There is an abundance of options (such as journaling, mapping, cataloging) for tracking the elements and complexity of your garden system and how it interacts with other systems such as climate and weather systems. Enjoy the ongoing discovery process and how different approaches and observations may deepen your understanding and success.
- The heightened awareness achieved through intentionally observing and documenting changes in our garden landscape will be a powerful tool in cultivating sustainable gardens and contributing to wider community sustainability.

REFLECTION

- Have you used *Habits of a Systems Thinker* (figure 2) as you noticed changes in your community landscape and your specific garden space over the years?
- How have your observations helped you see the interconnections and interrelationships within your garden system? How has that influenced your choices and action in planning and managing your garden?
- Consider what you track and how you track change over time? What has influenced this?
- What would you recommend people new to recording garden observations focus their attention on? And why?
- Consider asking other gardeners these questions as well as comparing notes around specific observations and corresponding management actions. Tip: The Center for Courage and Renewal encourages in its *Circle of Trust Touchstones* that when we ask questions of others, we seek to listen without needing to fix or advise them.

EXPLORE MORE

- A list of reliable sources related to this unit is provided in the Selected Resources section.

Landscapes for Life curriculum aims to show you how to work with nature in your garden. Each topic area (soil, water, plants and materials) includes guidance on mapping your landscape features.

http://landscapeforlife.org

Nature's Notebook is a USA National Phenology Network program in which professional and citizen scientists collect, store, and share long-term observations of plant and animal life stages.

https://www.usanpn.org/natures_notebook

CoCoRaHS is an acronym for the Community Collaborative Rain, Hail and Snow Network. It is a unique, non-profit, community-based network of volunteers working together to measure and map precipitation (rain, hail and snow).

https://www.cocorahs.org

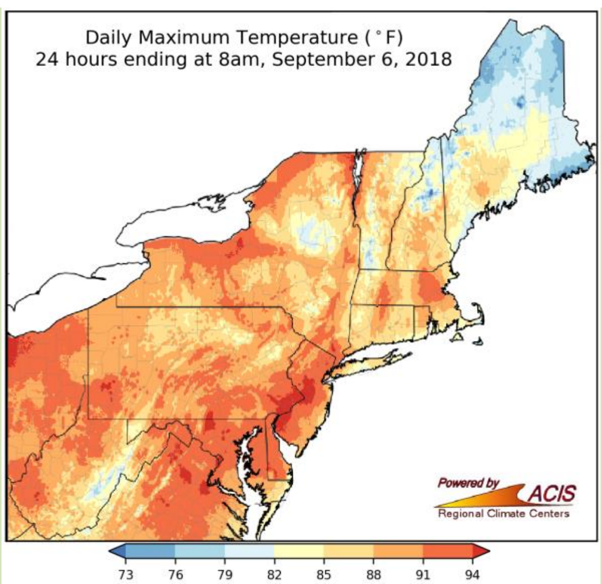
Unit 3: Climate Change Basics

A devoted gardener is thrilled to discover the lavender plants have made it through the frigid winter in Western New York and equally surprised to notice the butterfly bushes have not survived. Puzzles like these have gardeners wondering more about the impacts of weather patterns and weather anomalies on our landscapes. Accordingly, climate scientists and meteorologists are among the essential experts gardeners turn to for guidance.

Defining Weather and Climate Terms

Though weather and climate are both highly complex phenomena they are not the same. **Weather** is the state of the atmosphere at a specific time and place. It is the short-term variations of the atmosphere (from **minutes** to **weeks**). Weather is often referred to in terms of brightness, cloudiness, humidity, precipitation, temperature, visibility, and wind. We commonly talk about the weather in terms of "What will it be like today?", "How hot is it right now?" and "When will that snow storm hit our town?" All of earth's weather depends on the interaction of the sun, which heats the earth and causes air to move as winds; and water, which moves between the oceans, skies and land, forming clouds and precipitation. Meteorology is the study of the atmosphere and weather of the lower atmosphere (below 50 miles) often focused on weather prediction and analysis.

Climate is the prevalent long-term weather conditions in a particular place. Generally, climate is considered the weather in a place over a period of **30+ years**. Climatic elements include precipitation, temperature, humidity, sunshine and wind velocity, and phenomena such as fog, frost and snow. Climate scientists (**climatologists**) study historical records of weather conditions measured or observed at a specific location. This climate data describes the average (or mean) conditions such as high and low temperatures and extremes. Climate data is used to identify anomalies in temperature and precipitation patterns. The hardiness zone and frost-free season maps gardeners use to select appropriate plant material and planting times is based on climate data.



The Northeast Regional Climate Center provides weather station data and climate analyses http://www.nrcc.cornell.edu

All developed countries have weather stations and study climate data for their region. On a worldwide scale, the United Nation's World Meteorological Organization (WMO) analyzes and monitors the state and behavior of the Earth's atmosphere, its interaction with the oceans, the weather and climate it produces, and the resulting distribution of water resources. The WMO publishes the Climate System Monitoring Bulletin and administers the World Climate Data and Monitoring Program.[5]

Using Weather Data and Climate Analyses in Sustainable Gardening

Gardeners listen avidly to the daily weather reports from local meteorologists to figure out the best day for gardening practices affected by the weather. Gardener's keen observations of weather over many seasons are used to time food crop plantings, design flower beds for sequential bloom, and plan refuge plantings for beneficial insects. Though more common among commercial growers the calculation of **growing degree days** (GDD) or the "heat" accumulated during each growing season is a formal way to estimate timing of growth of an organism including bud break, flowering, as well as, when eggs of a particular pest are going to hatch or approximately when vulnerable stages of certain pest will be present. GDD's are a much more accurate method of estimating the timing of events than the calendar method. Japanese beetles do not just wake up one morning and say, "Ooops. June 15th already. Time to get out there." Rather, their emergence is determined by the accumulation of growing degree days. They make an earlier appearance when spring is warm and GDDs accumulate early and appear later when it's cool. Calculating GDD's involves a comparison of daily maximum and minimum temperatures to a lower and upper base temperature for growth of an organism. Use the Climate Smart Farming GDD Calculator at: http://climatesmartfarming.org/tools/csf-growing-degree-day-calculator/ [6]

While growing degree days focus on current weather the US Department of Agriculture (USDA) Hardiness Zone Map uses decades of past minimum average winter temperatures to divides North America into 13 zones of 10 degrees Fahrenheit (figure 4). Plant hardiness zones provides gardeners with information to determine which herbaceous perennials and woody trees, shrubs and vines will survive winters where they want to garden. The information is commonly on tags when you purchase perennial plants and is standard in plant catalogs, though you may see slight differences depending on the source.

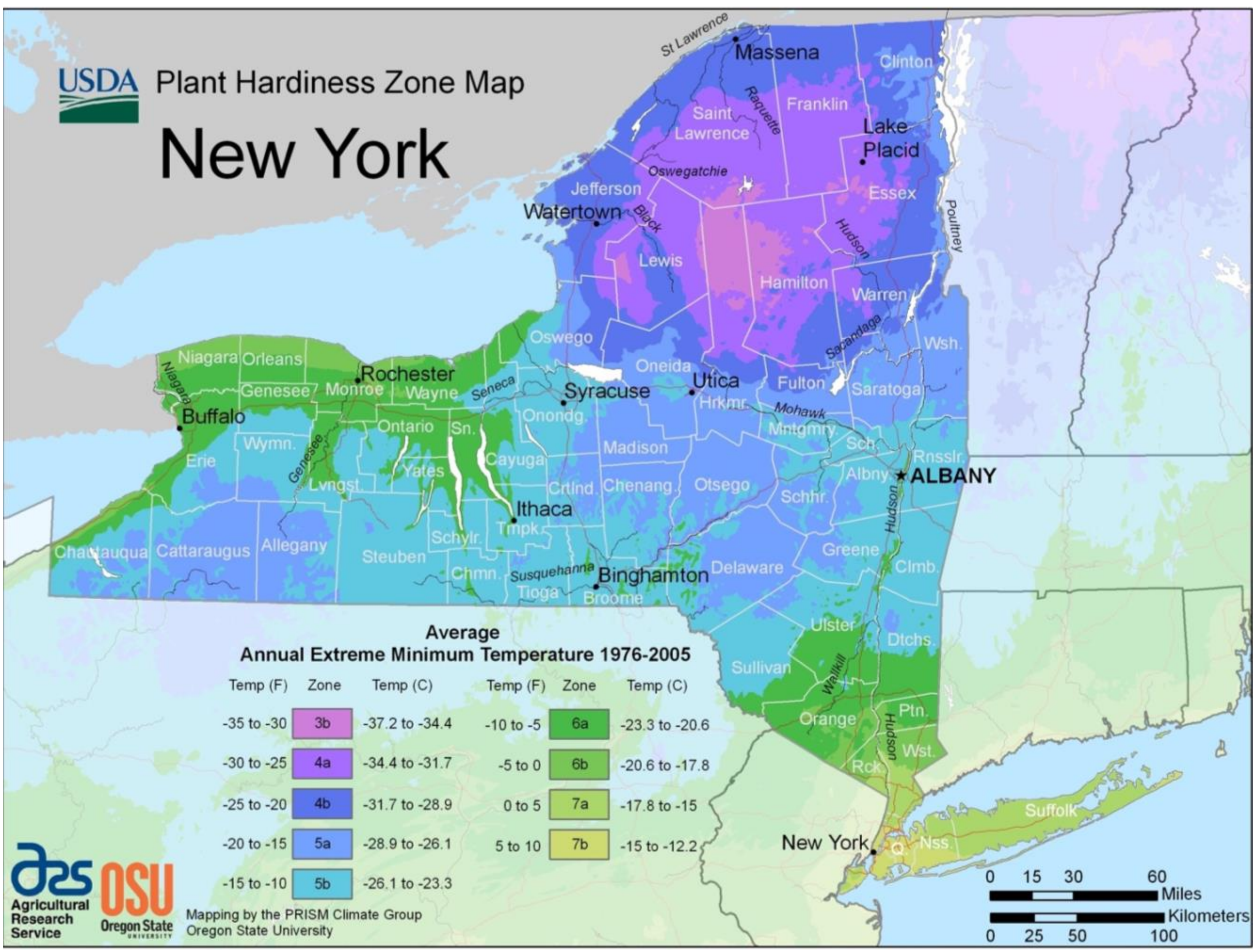


Figure 4: USDA Plant Hardiness Zone Map, 2012. https://planthardiness.ars.usda.gov.[7]

The National Oceanic and Atmospheric Administration's (NOAA) Climate Data Online (www.ncdc.noaa.gov/cdo-web) and their partners like NOAA, Northeast Regional Climate Center at Cornell University (www.nrcc.cornell.edu/) provide access to daily, monthly, seasonal, and yearly measurements of temperature, precipitation. Prediction tools such as these frost maps create from this data. Find additional tools at Climate Smart Farming (climatesmartfarming.org).

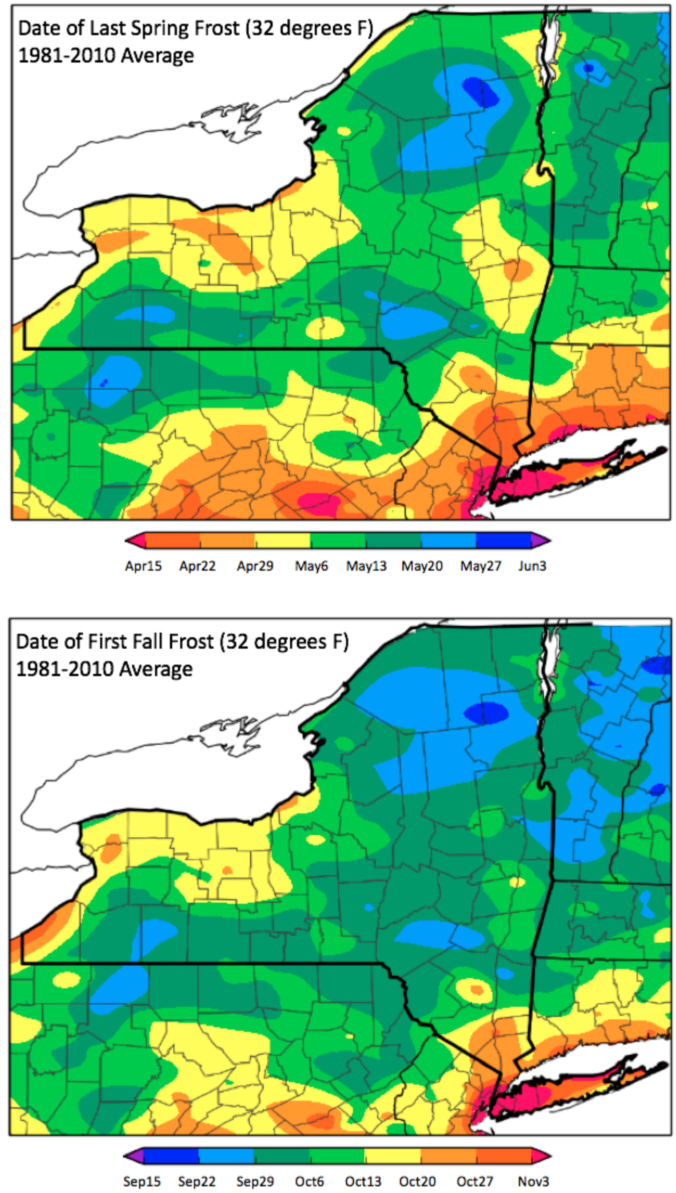


Figure 5: Average last frost in spring and first frost in fall.[8]

Gardeners look to the average date of the last frost in spring to help plan when to transplant plants that are not frost-tolerant. The average date of the first frost in fall helps plan when to plant late-season or fall crops, and when you can expect frost-sensitive plants to finally succumb to freezing temperatures if not covered with sufficient protection. The period between the last frost in spring and the first frost in fall is called the freeze free period or frost-free days. For frost sensitive crops this is the range of the growing season. Gardeners need to select varieties or cultivars with days to maturity or harvest that fit within their frost-free days. And they must hold off planting warm season crops like tomatoes until several weeks after the last frost, when the soil has warmed, and nighttime temperatures are reliably above freezing.

Keep in mind that plant hardiness zones and freeze/frost dates are guides, and no guarantee that winter temperatures or frost-free period will always fall in the range indicated by the maps. A garden site may be a zone higher or lower due to inaccuracies in the map and microclimate impacts. A microclimate is a local set of conditions that differ from those in the surrounding areas. The difference might be slight but sometimes it can be substantial. Microclimates can also be small like a protected courtyard next to a building that is warmer than an exposed field nearby. Or a microclimate may be extensive – a band extending several miles inland from a large body of water that moderates temperatures. Since gardeners need to be aware of microclimates that may make where they garden different from the information found in hardiness zone and frost maps, we encourage documenting microclimate observations and interactions as part of *Knowing Our Garden Systems* in Unit 2.

Microclimates

While plant hardiness zones and freeze/frost maps serve as good guides, maximizing gardening success requires consideration of additional factors that can contribute to a specific garden space being warmer or colder, wetter or drier, or more or less prone to frosts.

- **Large bodies of water**, such as the Great Lakes, the Finger Lakes, Lake Champlain, Long Island Sound and the Atlantic Ocean, tend to moderate air temperatures of adjacent inland areas. Low temperatures in winter are not as extreme, and these areas are less prone to late spring and early fall frosts. Smaller bodies of water have this effect to a lesser extent.
- **Hilltops** that are exposed to winter winds that dry plants out can be particularly hard on evergreens, which cannot replace moisture lost through needles when the ground is frozen.
- **Valleys** may be 10 degrees colder than neighboring slopes and more prone to spring or fall frost as cold air is heavier than warm air so flows downhill and collects in low spots. Similarly, **balconies and rooftops** may escape frosts that kill tender plants at ground level. But cold, drying winds may be an even bigger factor depending on the location, orientation and exposure of the balcony or rooftop.
- **Slopes** facing north are slow to warm up in spring because they receive less direct sun, compared with south-facing slopes. However, plants on south-facing slopes can have blossoms killed by frost when early spring warmth causes plants (fruit trees in particular) to begin flowering prematurely. Similarly, **raised beds and terraces** can warm and drain earlier in spring, especially if they are oriented toward the south.
- **Urban areas** tend to have less extreme low temperatures and frost as buildings offer protection from wind and along with paved surfaces, absorb heat during the day then radiate it back into the air at night. But these excessive warming effects in the summer trap heat and create a scorching environment for plants.
- **Houses** and their surrounding paved surfaces such as patios, driveways and sidewalks would also absorb heat and reradiate it at night, moderating night-time temperatures. Bark on young trees planted on the south or southwest sides of buildings are more prone to cracking in winter. Prevailing winds from the northwest will also create a warmer, more sheltered microclimate on the south and east sides of a house or building. While the north side may receive harsh winds and no sun during the winter, in summer – when the sun rises north of east and sets north of west – these areas can be baked by heat and dried out by the same prevailing winds. Further when wind hits a building, it creates turbulence and higher wind speeds along the wall and around the corners. These areas will not be good places to plant broad-leaved evergreens or other plants that can be dried out by winds.
- **Fences, walls and large rocks** can protect plants from wind and radiate heat, creating sheltered spots. Sometimes, if fences block cold air drainage through your property, the cold air can puddle behind them causing very localized frost damage on near-freezing nights.
- **Soil types** can also affect frost. Heavy clay soils can act much like paved surfaces, moderating the temperature near ground level. Lighter soils that have many air pockets in them can act as an insulating layer on top of warmer subsoils, trapping that heat below ground and are hence more prone to frosts at ground level.

Understanding Warming Trend
We talk about climate shifts in terms of years (30+), decades, and centuries. Scientists study climate to look for trends or cycles of variability including changes in wind patterns, ocean surface temperatures and precipitation over the equatorial Pacific that result in El Niño and La Niña. Observed patterns or phenomena are collectively considered to generate a bigger picture of possible longer term or more permanent climate change.

For 10,000 years the earth has been in a relatively cool, temperate, and stable period. The temperature of the earth is determined by the amount of incoming solar radiation that reaches and is absorbed by various materials on the earth's surface. Our earth is livable because gases in our atmosphere (carbon dioxide, methane, nitrous oxide and water vapor) trap some of the sun's heat that might otherwise escape into the atmosphere. These gases are referred to as greenhouse gases (GHG's). Without this natural insulation, called *the greenhouse effect* (figure 6), the average temperature on earth would be close to 0°F (-18°C) instead of 59°F (15°C), and far too cold to support our current diversity of organisms.

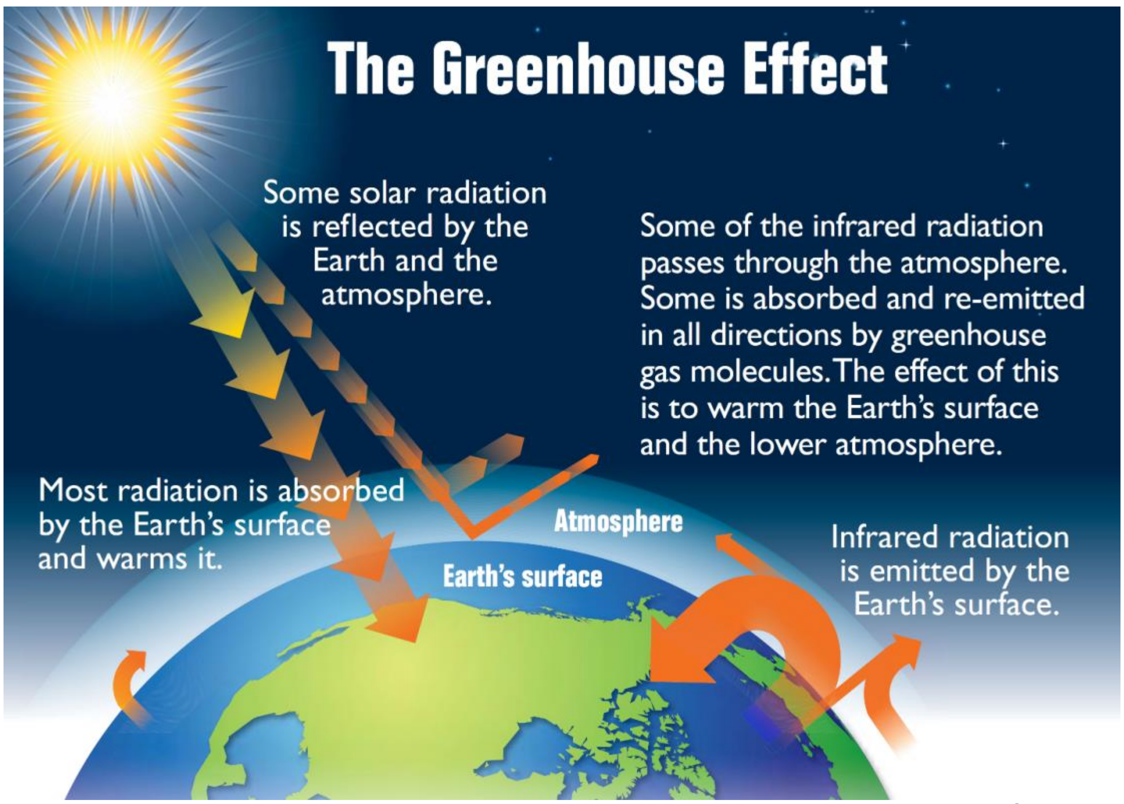


Figure 6. The Greenhouse Effect. Image credit: US Environmental Protection Agency.[9]

Human activity, especially the burning of fossil fuels, is the main cause of the increase and imbalance in earth's atmosphere of the greenhouse gas, carbon dioxide. The carbon budget is the amount of carbon released into the atmosphere by both natural sources, such as decaying plants, or anthropogenic (human-caused) sources, such as the burning of coal and oil minus the amount of carbon absorbed by the ocean, growing green plants, and other carbon sinks (figure 7). The average concentration of carbon dioxide (CO2) in the atmosphere was about 250 parts per million (ppm) in preindustrial times. Now it exceeds 400 parts per million (ppm). This dramatic shift is the key indicator of the amount of greenhouse gases we humans are putting into the atmosphere at record rates. For details on the total national greenhouse gas emissions associated with human activities across the United States see the Environmental Protection Agency (EPA) inventory report (epa.gov/ghgemissions).

Increasing the concentration of a heat-trapping greenhouse gases such as carbon dioxide amplifies or enhances the natural greenhouse which means more heat energy is trapped in atmosphere, making the Earth's surface warmer. Since 1850, the beginning of the Industrial Age, the atmospheric global temperature has warmed about 2 degrees Fahrenheit. The years 1983 to 2012 were the warmest 30-year period of the last 1400 years, and the year 2016 broken all previous records.[10] Similarly, the trend in land temperature anomalies in the northern hemisphere show that annual temperatures in recent decades are departing from the 20th century average regularly in an increasingly positive direction which indicates observed temperatures were warmer (figure 7). As the world has warmed, that warming has triggered other changes to the Earth's climate. Over the last 50 years, the U.S. has seen increases in the number and strength of extreme weather events including prolonged periods of excessively high temperatures, drought, floods, and heavy downpours (figure 8).

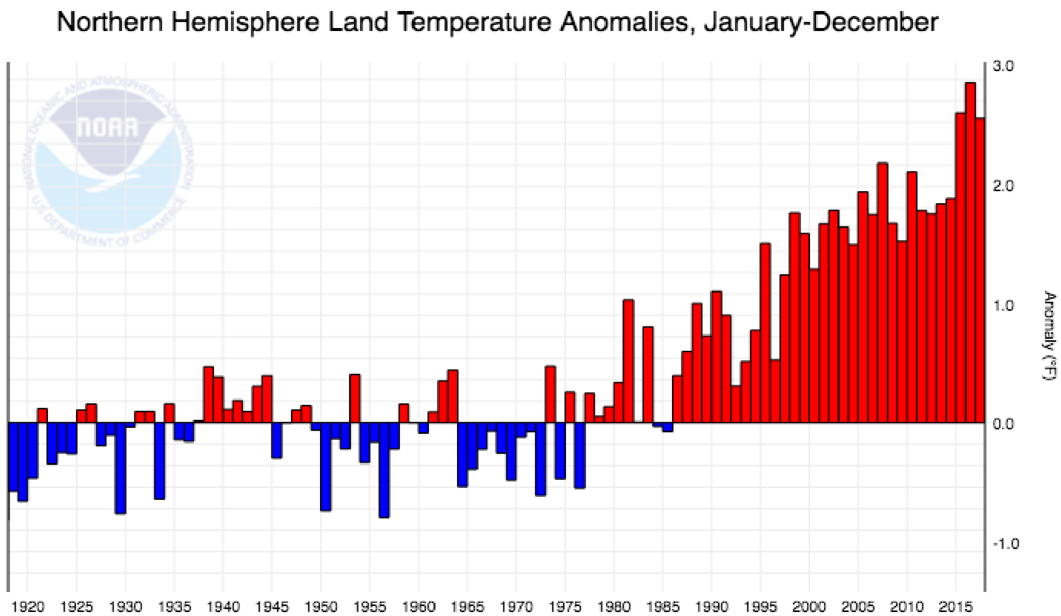


Figure 7: Graph of annual temperature anomalies - departures from the 20th century average.[11]

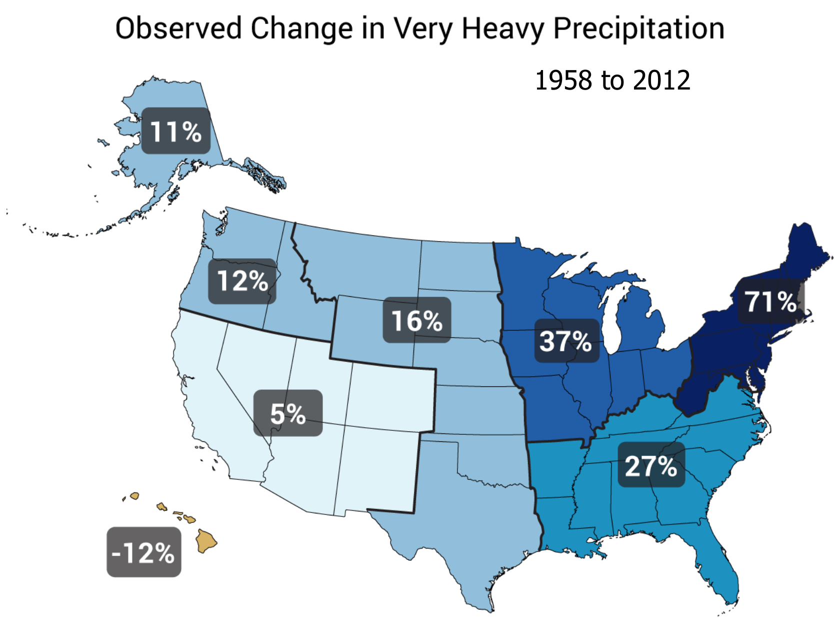


Figure 8: Map of percent increases in the amount of precipitation falling in very heavy events for regions of U.S.[12]

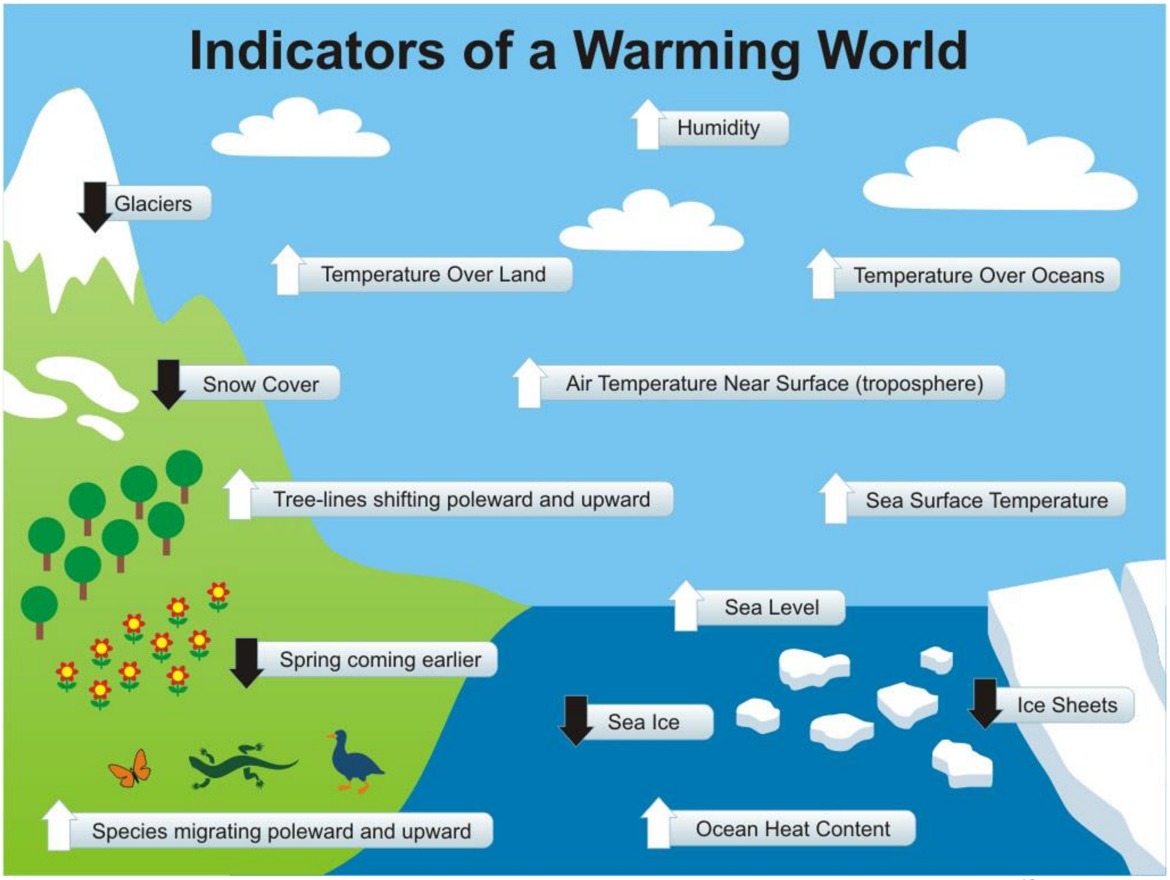


Figure 9: Indicators of a Warming World. Image credit: www.skepticalscience.com[13]

Observing Climate Change Impacts in New York

New York's ClimAID report (2011, 2014), the National Climate Assessment (2014), and other research show that a variety of climate change impacts have already been observed.[14]

Temperature

- The annual average temperature statewide has risen about 2.4°F since 1970**,** with winter warming exceeding 4.4°F. This equals about 0.25°F per decade since 1900.
- Annual average temperatures have increased across the state.

Precipitation

- Overall, average annual precipitation has increased across New York State since 1900, with year-to-year (and multiyear) variability becoming more pronounced**.**
- New York is getting more precipitation in the winter and less precipitation in the summer.
- Between 1958 and 2010, the amount of precipitation falling in very heavy events (downpours) increased more than 70% across the northeastern United States.

Sea-level rise

- Sea levels along New York's coast have already risen more than a foot since 1900**.**
- New York's rate of rise (about 1.2 inches per decade) is almost twice the observed global rate (0.7 inches per decade) over the same period.

Natural resources

- Spring begins a week earlier than it did a few decades ago; the first leaf date is more than 8 days earlier and the first bloom date is more than 4 days earlier than in the 1950s.
- Winter snow cover is decreasing.
- Pollinating bees in the northeastern US arrive about 10 days earlier than in the 1880s.
- New York breeding bird and oceanic fish population ranges have shifted northward over the last several decades.

Observing Signs of Climate Change Impacts in Garden Systems

Gardeners are in unprecedented times. The warming trends observed across all seasons bring uncertainty around stability of temperature averages and ranges (figure 11). Observed increase in frost-free season length and changes in hardiness zones have gardeners questioning how confidently we can rely on frameworks that have provided a foundation to plan and achieve success in our garden settings (figure 11 and figure 12). Our decision-making process now, more than ever, means attaching importance to the increasing number and strength of extreme weather events including prolonged periods of excessively high temperatures, drought, floods, and heavy downpours.

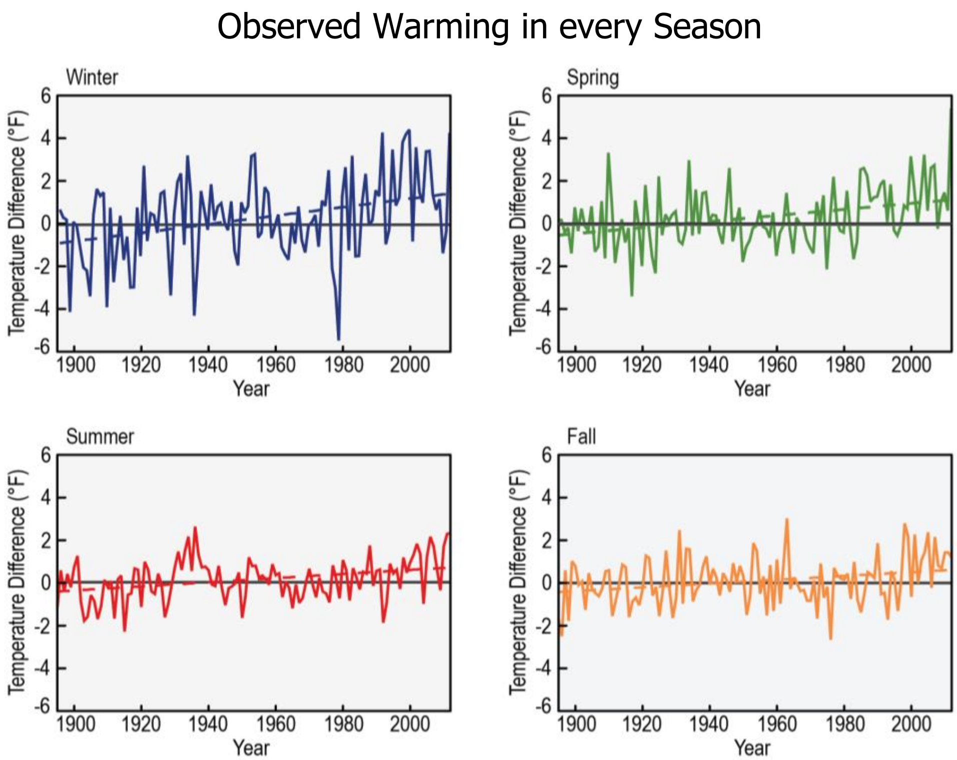


Figure 12: Continental U.S. seasonal temperatures (relative to the 1901-1960 average) all show evidence of increasing trends. Dashed lines show the linear trends. (Source: Updated from Kunkel et al).[15]

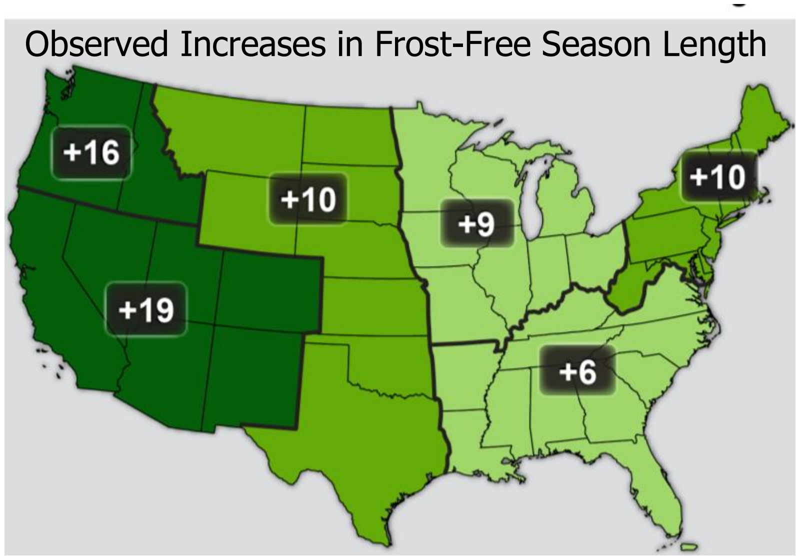


Figure 11: Observed increase in frost-free season length from 1991-2012 compared to 1901-1960. (Source: NOAA NCDC / CICS-NC).[16]

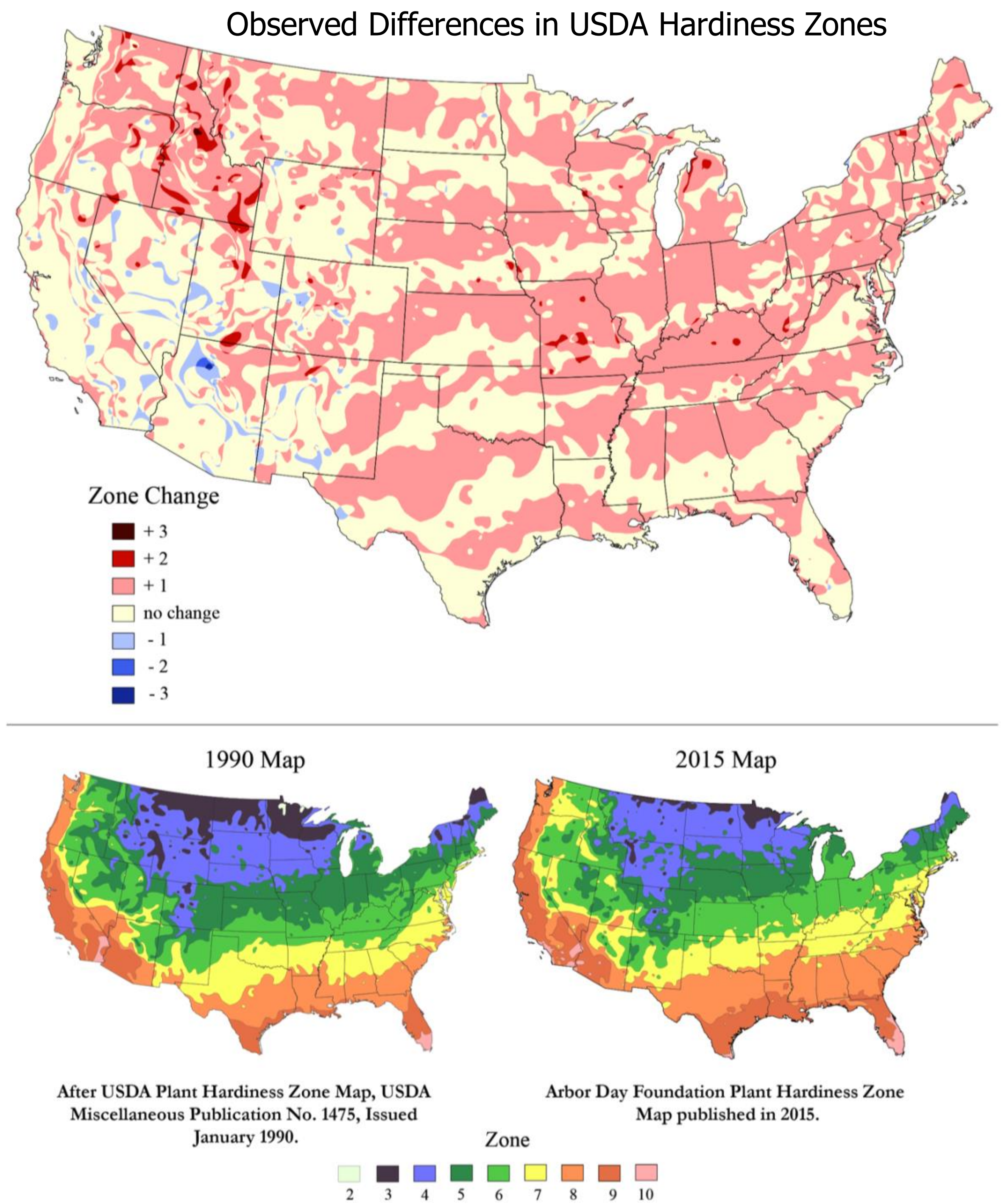


Figure 4: Observed differences in USDA Hardiness Zone from 1990 to 2015.[17]

Our gardening decision-making process must also consider if the current shifts we see in our garden systems can be read as real-world signs of the changes triggered by warming trends and extreme weather. For comparison, here are a few examples of the most common ecological responses to climate change mainstream scientists have documented:

- Local extinctions have already occurred in hundreds of species, including 47% of the 976 species surveyed. Local extinction was significantly higher in tropical species than in temperate species (55% versus 39%), in animals than in plants (50% versus 39%), and in freshwater habitats relative to terrestrial and marine habitats (74% versus 46% versus 51%).[18, 19]

- Leaf and bloom events are generally happening earlier throughout North America. Peak bloom date for the cherry trees in Washington, D.C. has shifted earlier by approximately five days since 1921.[20]
- Wildflower blooms and leaf emergence and at Thoreau's Walden Pond in Massachusetts has shifted more than two weeks earlier.[21]
- Frost and freeze damage threaten plants when an earlier spring is combined with more extreme winter storms (i.e. Nor'easters).[22]
- Chronic and steady reduction in winter chilling is expected to have deleterious economic impact on fruit and nut production as all economically important fruit and nut tree species that originated from temperate regions have chilling requirements that need to be fulfilled each winter to ensure homogeneous flowering, fruit set, and economically sufficient yields. [23]
- Non-native species, especially invasive species are more responsive to climate changes which is facilitating naturalization and invasion.[24]
- Poison ivy plants respond to higher levels of carbon dioxide in controlled experiments by growing bigger and producing more toxic oil. This fuels theories of increasingly big and bad poison ivy in the gardens, woods and parks.[25]
- Many interacting species are shifting their seasonal timing at different rates, leading to changes in synchrony.[26]
- Only butterflies whose populations are stable or increasing managed to expand and thrive as the climate has warmed. [27]
- Range expansion and population increases of white-tailed deer as winters grow milder threaten forests, crops, and suburban landscapes.[28]
- It is generally expected pests (and pathogen) attacks will be more unpredictable and their amplitude larger. Insect–plant interactions will also be less predictable. Further, insect chewing herbivores will consume more leaf tissue as plant nutrition is reduced and many insect pest species will develop quicker while short-lived insect pests may have enhanced population growth and longevity. Relaxed cold limitation could be intensifying the expansion of insect pests into new regions, and a longer growing season in current regions.[29]
- Plants grow more vigorously and produce more pollen than they otherwise would. This is part of the preliminary evidence supporting the World Allergy Organization statement that climate change will affect the start, duration, and intensity of the pollen season and exacerbate the synergistic effects of pollutants and respiratory infections on asthma.[30]

Tapping into our *Habits of a Systems Thinker* (figure 2, Unit 1), expanding our understanding of our garden systems through record observations (Unit 2), and combing this local knowledge with current scientific and technical knowledge will now be the foundation to garden success. Further, it means gardener are well-positioned to be significant community leaders in addressing the management of the challenge of climate change.

Climate Change Vocabulary

Adaptation (to climate change): The process of adjustment to actual and expected climate and its impacts (ex. sea walls to protect a community from rising sea levels). In human systems, adaptation seeks to moderate harm or exploit beneficial opportunities. In natural systems, human intervention may facilitate adjustment to expected climate and its effects.

Adaptive Capacity: The potential of a system (ex. human settlements; ecosystems) to adjust to climate change (including climate variability and extremes) and cope with the consequences.

Climate Change: An alteration in the composition of the global atmosphere that is in addition to natural climate variability observed over comparable time periods and created predominantly by burning fossil fuels, which add heat-trapping gases to Earth's atmosphere.

Climate Impacts: Effects on natural and human systems as the result of the warming climate. These include the increased temperature trends described by global warming, but also encompass changes such as sea level rise; ice mass loss in Greenland, Antarctica, the Arctic and mountain glaciers worldwide; shifts in flower/plant blooming; and extreme weather events.

Celsius and Fahrenheit: A 2°C change in temperature is equal to 3.6 °F.
To convert temperatures Celsius (C) to Fahrenheit (F) multiply °C temperature x 1.8 then add 32. For example, 20.0°C x 1.8 + 32 = 68.0°F and 22.0°C x 1.8 + 32 = 71.6°F.

Enhanced Greenhouse Effect: The concept that the natural greenhouse effect has been enhanced by increased atmospheric concentrations of greenhouse gases (such as CO_2 and methane) emitted as a result of human activities. These added greenhouse gases cause the earth to warm.

Global Warming: The upward temperature trend across the Earth since the early 20th century, and most notably since the 1970s, due to the increase in fossil fuel emissions since the industrial revolution.

Greenhouse Effect: Trapping and build-up of heat in the atmosphere (troposphere) near the Earth's surface. Some of the heat flowing back toward space from the Earth's surface is absorbed by water vapor, carbon dioxide, ozone, and several other gases in the atmosphere and then reradiated back toward the Earth's surface. If the atmospheric concentrations of these greenhouse gases rise, the average temperature of the lower atmosphere will gradually increase.

Mitigation (of climate change): Implementing actions to reduce the sources of greenhouse gas emissions.

Resilience: A capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to social well-being, the economy, and the environment.

Risk: A combination of the magnitude of the potential consequence(s) of climate change impact(s) and the likelihood that the consequence(s) will occur.

Vulnerability: The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity**.**

Vocabulary Resource: Skeptical Science's Climate Science Glossary: https://skepticalscience.com/glossary.php

Identify Reliable Sources About Climate Change

There is highly politicized condemnation of climate change science; it is important that we use reliable, research-based information in both learning ourselves and educating others. You can ask yourself the following questions when evaluating a source: What indicators do you look for to be certain the information you read is research-based? Where else do you find research-based information that will keep you informed about climate change? For example, the blog realclimate.org is written by a consortium of climate scientists who provide background data and scientific interpretation of the latest climate news. Explore the few additional resources listed below while considering the bullet points list. Use and share this tool a checklist to organize and evaluate resources related to climate change.[31]

- ☐ **Authority** - Who is the author? What is their point of view?
- ☐ **Purpose** - Why was the source created? Who is the intended audience?
- ☐ **Publication & format** - Where was it published? In what medium?
- ☐ **Relevance** - How is it relevant to your research? What is its scope?
- ☐ **Date of publication** - When was it written? Has it been updated?
- ☐ **Documentation** - Did they cite their sources? Who did they cite?

The U.S. Global Change Research Program
USGCRP was established by Presidential Initiative in 1989 and mandated by Congress in the Global Change Research Act (GCRA) of 1990 to "assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change."   http://www.globalchange.gov/

***Climate Master Handbook*, Resource Innovation Group**
This handbook details human activities that contribute to greenhouse gas emissions (GHG) and ways to reduce GHG in the garden and beyond. It is grouped into twelve sections, ranging from Home Water Conservation to Green Building.   http://www.theresourceinnovationgroup.org/climate-educ-lit-pubs

***PBS*, Climate Literacy**
Find resources from a range of public media producers and curators that will help you learn and teach climate science literacy. The structure of this collection is based upon the Essential Principles of Climate Literacy.   https://ny.pbslearningmedia.org/collection/climlit

***The Climate Friendly Gardener,* Union of Concerned Scientists**
This Guide to Combating Global Warming from the Ground Up contains helpful and practical tips on how to reduce your carbon footprint in the home garden. It features "five steps to a climate friendly garden," ranging from keeping your soil covered to creating a climate-friendly lawn.   http://www.ucsusa.org/food_and_agriculture/what_you_can_do/the-climate-friendly-gardener.html   Videos of Climate-Friendly Gardening in Action   http://www.ucsusa.org/food_and_agriculture/what_you_can_do/climate-friendly-gardening-videos.html

Talking About Gardening in a Warming World with Others

Gardeners are often the first to notice changes in seasonal temperature patterns and impacts of extreme weather events on landscapes. Not surprisingly, garden-based educators and volunteers are increasingly called upon to offer guidance on the topic of climate change as part of community education efforts related to gardening. As peers, gardeners, play a vital role as agents of change within our networks and the broader community.

Figure 13: Master Gardener Volunteers provide outreach to public audiences. Photo credit: CCE Wayne County.[32]

For those of us who would like to participate in engaging the public, there is an accompanying facilitator's notebook to this course book, found at climatechange.cornell.edu/gardening. It emphasizes conversations that allow people to process the emotional responses – such as worry, curiosity, etc. – that emerge in gaining understanding about climate change and inspires the use of scientific evidence through background information, engaging questions and hands-on activities. The facilitator's notebook included the list of **Principles of Climate Change**[33] developed by Columbia University's Center for Research on Environmental Decisions to help guide instructors toward meaningful, respectful discussions about climate change.

Cornell Cooperative Extension and researchers at Cornell University are developing a course on climate change that seeks to enhance both an understanding of the science behind the challenge and communication strategies about the topic. This course –entitled *Climate Change Science, Communication, and Action* - will be released in late 2017/early 2018. Learn more from Cornell University's Civic Ecology Lab https://civicecology.org.

The Debunking Handbook
Global Change Institute
University of Queensland, Australia

This is a quick, reader-friendly guide to understanding how myths persist and how to effectively debunk them. It will prove helpful when conversing with skeptics and deniers.

https://skepticalscience.com/docs/Debunking_Handbook.pdf

In the next unit, we examine the **Sustainable Garden Audit** as a method for considering various climate friendly garden management actions that support our mitigation and adaptation efforts.

SUMMARY

- Climate is the prevalent long-term, 30+ years, weather conditions in a particular place. Weather is often referred to in terms of brightness, cloudiness, humidity, precipitation, temperature, visibility, and wind.
- Gardeners use frameworks grounded in weather and climate to guide gardening decision making process.
- Human activity, especially the burning of fossil fuels, is causing the increase and imbalance of greenhouse gases in the atmosphere. The result is the earth is warming at an ever-accelerating rate with consequences such as extreme weather.
- Climate change impacts being observed in NYS and the Northeast region include warming temperatures across the seasons and increases in the number and strength of extreme weather events including prolonged periods of excessively high temperatures, drought, floods, and heavy downpours.
- For gardeners, climate change impacts bring increasing uncertainty to our gardening decision-making process.
- Garden-based educators and garden volunteers are increasingly called upon to offer guidance on the topic of climate change and it is important that we use reliable, research-based information in both our learning and conversations with others. *The Gardening in A Warming World* Facilitators' Notebook offers many resources on how to approach educating others about this complex and important topic.

REFLECTION

- Does climate affect your everyday life? Elaborate on specific examples. Consider the many ways that climate is a part of our daily lives- eating, working, playing traveling and more. Be sure to think about climate – not weather. Clarify the definitions of each.
- What changes in your life do you foresee as the temperate climate we have been so used to begins to warm? Explore how it might specifically impact your gardening practices. Explore the full range of quality of life scenarios that could unfold - from the negative to positive.
- What types of changes have you noticed in your garden over the years? Evaluate the links among your observations and the climate change impacts in New York State. Connect your personal observations with insights others have collected through scientific monitoring, research and modeling. Continue or begin recording and reflecting on observations as well as discussing them with others.
- The National Oceanic and Atmospheric Administration (NOAA) and National Science Foundation (NSF) support the website http://climateinterpreter.org/. This resource provides invaluable information on climate change communication. Browse the site and jot down any points or information that you might find helpful in talking about climate change with others; find an opportunity to test these concepts in a friendly conversation. Did certain kinds of information or values improve your ability to share important facts about climate change?

EXPLORE MORE

- A list of reliable sources related to this unit is provided in the Selected Resources section.
- See page 34 for our list of **Community Focused Climate Change Programs.**

Climate Learning Network

Find training models, news, and discussion forums designed to help extension educators incorporate climate change into their existing programs and become Climate Literate.

http://climatelearning.net/e-learning-modules/

UNIT 4: Climate-Friendly Sustainable Garden Audit

Gardeners are on the leading edge of climate change impacts and so are well-positioned to be significant community leaders in addressing the management of this challenge. To date, the response to manage the climate crisis is a two-pronged approach through mitigation and adaptation. Actions to **mitigate climate change** are those activities which reduce emissions to stabilize the levels of heat-trapping gases in the atmosphere. Actions to **adapt to climate change** are those help us adjust to actual and expected impacts. Gardeners who cut down the need for gas-powered mowers and fossil-fuel based fertilizers by replacing high maintenance lawns with alternatives mitigate the causes of climate change by reducing greenhouse gas emissions. Gardeners who include a more diverse mix of plants in gardens including plants tolerant to drought or typically grown in higher zone are employing adaptive strategies.

Our **Sustainable Garden Audit** focuses on mitigation and adaption actions in these major practices:

1. Organic material waste management
2. Soil health and nutrient management
3. Water management and conservation
4. Pollinator protection
5. Garden design and plant selection
6. Equipment and material selection

Our **Sustainable Garden Audit** builds the foundation for identifying and evaluating mitigation and adaption actions associated with gardening using *Habits of a Systems Thinker* (figure 2) such as:

- ✓ Consider the elements and interactions in your specific garden system
- ✓ Identify the impacts of actions on the system as well as other systems
- ✓ Identify the linkages of climatic events
- ✓ Consider possible unintended consequences of specific actions
- ✓ Document trends over time

There are no single solutions. Practices are interrelated, and one strategy influences the other. We will need to hold uncertainty in the face of unpredictable changes to our garden systems. Though tracking our efforts though will be essential to contributing to our communities' greater resiliencies.

> Integration of local knowledge with additional scientific and technical knowledge can improve disaster risk reduction and climate change adaptation. Local populations document their experiences with the changing climate, particularly extreme weather events, in many different ways, and this **self-generated knowledge** can uncover existing capacity within the community.
>
> From the 2012 Intergovernmental Panel on Climate Change report
> *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*

1. Organic Material Waste Management

Plant residues such as those from mowing, pruning, weeding, and food waste are organic materials. Organic materials are carbon-based compounds and consequently part of the carbon cycle. Specifically, the sequence of the carbon cycle where plants capture carbon dioxide (CO_2) gas from the air and convert it to carbohydrates (starches and sugars) along with other carbon compounds that become the tissues of the plant. When the plant dies microorganisms cause the plant tissues to decompose, which releases CO_2 into the atmosphere.

In our gardening systems, **humus** (the stable, long lasting remnant of decaying organic material) is the soil organic matter. Soil organic matter is an important part of **soil health** as it serves as a reservoir of nutrients and water, aids in reducing compaction and surface crusting, increases water infiltration into the soil, supports many beneficial microbes and insects, and can sustain plant growth with little or no synthetic fertilizer.[34] Building up and maintaining the organic matter in soils also serves to **sequester carbon in the soil** that would otherwise be in the atmosphere as CO2 gas.

Take inventory of everywhere plant waste is being generated in the lawn, garden, landscape and even the kitchen. Then consider for each source of waste whether it is staying in place for decomposition, being composted in another on-site location, traveling off-site for composting, or traveling off-site to be put in a landfill. With knowledge of the sources and destiny of organic material waste, think through linkages and consequences of these actions.

By way of example, let us briefly consider **grass clippings and fall leaves.** Leaving grass clippings in place returns the nutrients and organic material they contain back to the soil. The same is true for mulching fall leaves in place. If there is too much fall leaf litter for it to be mulched sufficiently to fall between grass blades, consider moving the leaves to an on-site **compost** pile to decompose to humus. This organic material can be incorporated back into your garden and would also keep the cycling of nutrients and organic material on-site. However, when there is not enough composting space for timely decomposition, then transporting off-site is needed. Transporting off-site will likely consume fossil fuel but if the organic material will be composted off-site that is better than burying it in a landfill where organic material undergoes anaerobic (without oxygen) decomposition that produces the greenhouse gas **methane**. **NOTE:** Remember that methane is a much more powerful heat-trapping gas than CO2.

Best Practices
Organic Material Waste

- ☐ Leave grass clippings in place.
- ☐ Mulch fall leaves and leave in place.
- ☐ Compost yard plant waste.
- ☐ Compost kitchen plant food waste.
- ☐ Check the availability of local municipal or commercial compost options for yard and kitchen organic waste that cannot be composted on-site for whatever reason.

Municipal leaf pick-up systems where leaves are kept in a compostable paper bag on the curb until pick-up is a good ecological practice; the longer open leaf piles sit exposed to rain on impermeable surfaces, the greater the chance they will leach nutrients into the runoff that can negatively impact water quality. A more in-depth examination of your specific variables may reveal additional interactions or connections that will impact the best climate-friendly sustainable solutions for your organic material waste.

2. Soil Health and Nutrient Management

Most gardeners know the value of **healthy soil** as a living ecosystem with a health that can be actively supported through specific techniques. In addition to its function in supporting a healthy garden, it is of great importance to our warming world. Soil sequesters carbon, stores water and reduces greenhouse gas emissions, thereby making it a great asset in working to mitigate the effects of climate change.[35] Soil carbon sequestration is a major focus of international efforts to curb greenhouse gas emissions, such as the 4 per thousand initiative, which seeks to increase the amount of carbon in the soil in order to mitigate the effects of GHG emissions and improve soil quality.[36] Learn more at: http://4p1000.org/.

As mentioned in the Organic Material Waste Management section, cycling of decaying organic material is important to soil health. The **soil food web's** primary consumers or decomposers, mainly fungi and bacteria, digest pieces of fallen plant material while secondary consumers, such as mites and protozoa, feed on the fungi and bacteria and release nutrients that can be absorbed directly by plants. Higher-level consumers, including earthworms and ants, feed on the secondary consumers and will release nutrients that fuel plant growth.

Maintaining a **suitable habitat** for these interactions is key to fertile soil. Work to keep living plants growing in the soil as often as possible; provide a continuous and variety of food sources by growing as many different species of plants as practical; cover the soil at all the times to minimizes variation in the soil environment including temperature and erosion; and limit equipment or foot traffic in the garden especially when the soil is wet to minimize soil disturbance and compaction.[37,38]

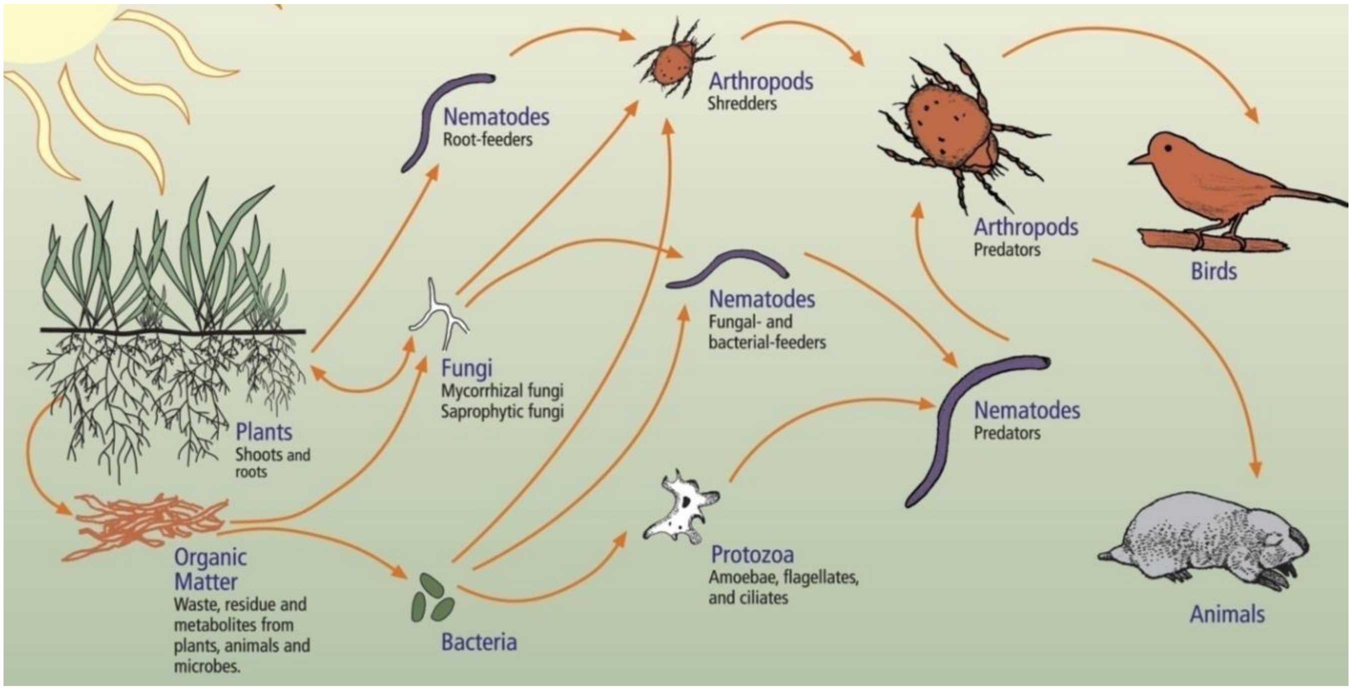


Figure 5: Soil Food Web. Image credit: USDA-NRCS.[39]

Low or no-tilling or turning the soil less is one way to build up soil organic matter (**carbon storage**). The aeration that happens with tillage accelerates microbial breakdown of organic matter and the release of carbon dioxide (CO2) into the atmosphere. Rather than use tillage to address soil compaction, plant cover crops with deep root systems which break up compacted layers and add organic matter to the soil. Earthworms have also been noted to till the soil as well as leave behind vermicasts which attracts decomposers like fungi and bacteria. While this works in most backyard and community garden systems, do recognize that earthworm invasions in forest ecosystems are a concern.

Cover cropping or integrating legumes (beans, peas, clovers) in gardens or lawns is also a way to minimize dependency on supplemental nitrogen. Through legumes' symbiotic relationship with nitrogen-fixing bacteria in their roots, they convert atmospheric nitrogen gas into ammonium. Synthetic nitrogen fertilizers are very energy-intensive to manufacture, and the process and their transport emits CO2. Cover crops can also aid in conserving soil moisture and preventing erosion.[40] More on cover crops at http://covercrop.org/.

Organic sources, such as manures and compost, should also be used strategically and sparingly since whether we add organic nitrogen sources, or synthetic ammonium or nitrate fertilizers, some nitrogen gas is lost to the atmosphere during natural biological process that are part of the **nitrogen cycle** (figure 10 in Unit 3). In addition to nitrogen (N), phosphorus (P) and potassium (K) are the nutrients required by plants in the highest quantity. Other nutrients are usually adequately available when the pH is in the recommended range for the specific plant. Because N levels fluctuate depending on soil conditions and biological activity, soil testing provides a good measure of the availability of P and K but not N. A plant's needs and soil test results should then serve as the basis for deciding if supplemental nutrients are needed.

Climate-friendly sustainable solutions promote soil health and supplement nutrients which meet specific plant needs. Be sure to **examine and monitor** the specific interactions or connections among the strategies you employ in your garden. Get a clearer picture of soil fertility and plant needs before applying compost or fertilizer or lime. Cultivate soil health with **low input tactics** described in the organic material and soil sections above, which includes minimizing tilling. Match plants with **soil pH**. If supplemental nutrients are needed, never over-apply (this includes too much compost)**.** Over **fertilizing** can lead to excess plant growth, which can lead to greater susceptibility to diseases. With **pesticides** (which include insecticides, herbicides, and fungicides), first understand the identity and life cycle of the pest in order to choose the most efficient and effective management strategy. Most **pests** can be tolerated at some level by plants that are strong and healthy. Also learn to live with some weeds, nibbles in leaves, as well as leaf spots and leaf galls. Focus on cultivating plant health and learning to scout for insects and diseases which may warrant action above a specific threshold. Creating a **welcoming habitat** for **beneficial insects** such as lady beetles, ground beetles, lacewings and hover flies will also limit the need for pesticide inputs.

Best Practices Soil Health and Nutrient Management
☐ Grow plants in the soil as often as possible. ☐ Grow many different plants. ☐ Minimize soil compaction. ☐ Rotate annual plants. ☐ Integrate legumes. ☐ Keep the soil covered all the time. ☐ Use cover crops. ☐ Till or turn the soil less. ☐ Attract and contain earthworms in the garden. ☐ Measure pH and choose appropriate plants. ☐ Add nitrogen sources to meet plant needs. ☐ Identify plant nutrient needs. ☐ Test soil for current available nutrients.

3. Water Management and Conservation

Water is important to all facets of ecosystems including humans who depend on a reliable, clean supply of drinking water to sustain our health; and plants that need water to fuel transpiration and growth. The **water cycle**, also known as the hydrologic cycle, describes the continuous movement of water on, above, and below the surface of the Earth as well as between states of liquid, vapor, and ice. Warming temperatures associated with a changing climate increase the rate of evaporation of water into the atmosphere, which will dry out some areas, and fall as excess precipitation on other areas. Our current climate predictions for the Northeast include more rain on rainy days and more frequent large **rainfall events**. A large amount of rain in a short period of time can increase surface runoff, thereby influencing flooding risks and diminishing groundwater storage, and washing away valuable topsoil. Adding this to rising rates of evaporation of water further increases the likely greater frequency of summer drought.[41]

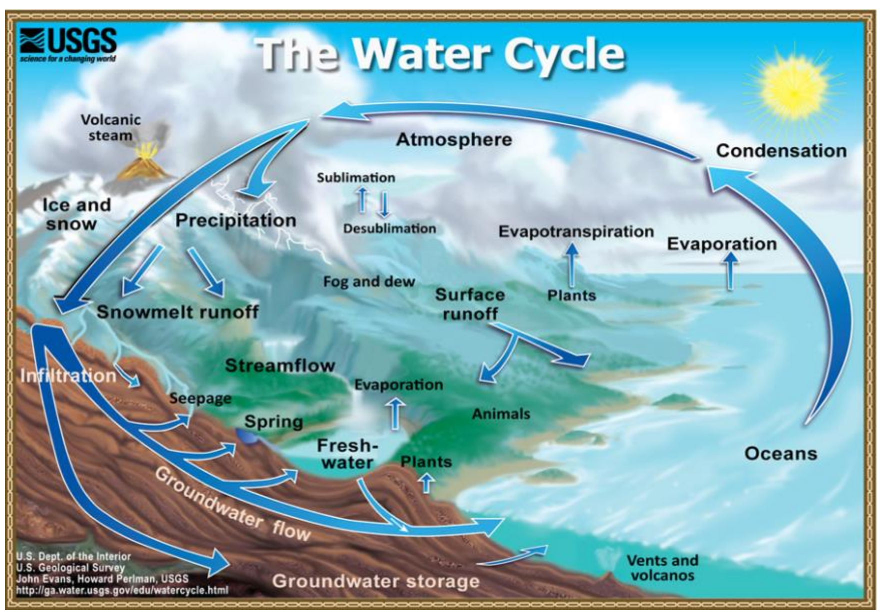


Figure 6: The Water Cycle. Photo credit: U.S. Dept. of the Interior, U.S. Geological Survey.[42]

Gardeners are among the many water managers challenged to meet water needs without exacerbating the pressure on water resources. Nationwide, **watering of lawns and gardens** is estimated to account for nearly one-third of all residential water use, totaling nearly 9 billion gallons per day with as much as 50 percent loss to evaporation, wind, or runoff.[43]

An essential part to managing and conserving water is building a deep understanding of what is happening with water in your **garden ecosystem**. As part of observing and documenting your garden system, consider how you might map or otherwise record elements related to water supplies, rainfall, flow of runoff and other infrastructures. It is also important to know how much water the plants in your garden ecosystem need to thrive. Plant stress from too much or too little water can fuel increased susceptibility to pests and disease.

Strive to work with nature and grow plants **adapted to your conditions** and well suited to the local climate. This may include selecting drought or flood resistant varieties for garden areas prone to prolonged dry or wet periods. Additionally, recognize that the water needs of plants vary depending on their stage of growth. Established plants generally require less water than newly planted vegetation that has not yet developed deeper root systems.

Water needs of plants can also vary seasonally. For example, **drought stress** is rarely lethal for most Northeast lawns. Cool-season grasses slow growth under drought conditions. They may even turn brown but are likely not dead as they will survive on a fraction of an inch of water over a several-week period. During active spring and fall growth cool-season lawns need no more than one inch per week at a rate where all the water is soaked up with no puddles forming or running off.[44]

Rule of thumb: Though one to two inches of water per week is a common recommendation for many actively growing landscape plants including vegetable, trees and flowers; combine this rule of thumb with your on-site personal observations to maximize potential success.

Addressing soil compaction, using raised beds, covering soil with mulch or adding soil amendments to improve drainage or water holding capacity are modifications that may have impacts you didn’t at first consider. A raised bed can aid soil drainage but also can dry out faster. Mulch material placed on the soil surface can reduce moisture evaporation and lower soil temperatures around plant roots. A simple **rain gauge** is a great tool to help gardeners track how much water plants are receiving from rainfall. **Tensiometers** (soil moisture probes) are more precise pieces of equipment that are used for measuring soil water and determining irrigation needs. They are most practical for a larger landscape.

Hand watering and drip or micro-irrigation will conserve water by allowing gardeners to direct the application where it is needed.[45] Applying water slowly will encourage infiltration and reduce runoff. Less frequent, deep watering also encourages deeper root growth to areas where the soil stays moist longer. If supplemental water is determined to be necessary at a specific time and location, be sure to use no more than is needed and minimize your use of potable water. The extraction, treatment, distribution, and use of water followed by the collection and treatment of wastewater requires a lot of energy. Though non-potable water is not safe for drinking it can be a resource for watering landscapes and gardens. Further, captured rainwater will reduce the volume of water going into storm sewer systems. Active rainwater harvesting collects water in a rain barrel or cistern where it is held for reuse. Be sure that local laws permit rainwater or other active water harvest collection systems like air conditioner condensate and grey water.

Passive rainwater harvesting diverts water overland to vegetated areas for immediate use. Terraces, rain gardens and bio-swales might be integrated into the garden and used to slowly convey and disperse the water throughout the garden.

Bio-swales and rain gardens are also one of the most effective ways to minimize surface runoff. When rain hits the ground, it starts moving according to the laws of gravity. Some seeps into the earth to replenish groundwater storage and the remaining water flows downhill as runoff. Runoff keeps rivers and lakes full of water, but it also changes the landscape by the action of erosion that moves bits of rock or soil from one place to another. In addition to water, rocks and soil runoff can also move pollutants such as fertilizers, herbicides, insecticides, animal waste, road salt, fluids from vehicles and more. Impervious surfaces like compacted soil as well as walkways and driveways made with concrete, blacktop or stone are a primary cause of elevated storm water runoff as they allow runoff to gather volume, speed and pollutants.

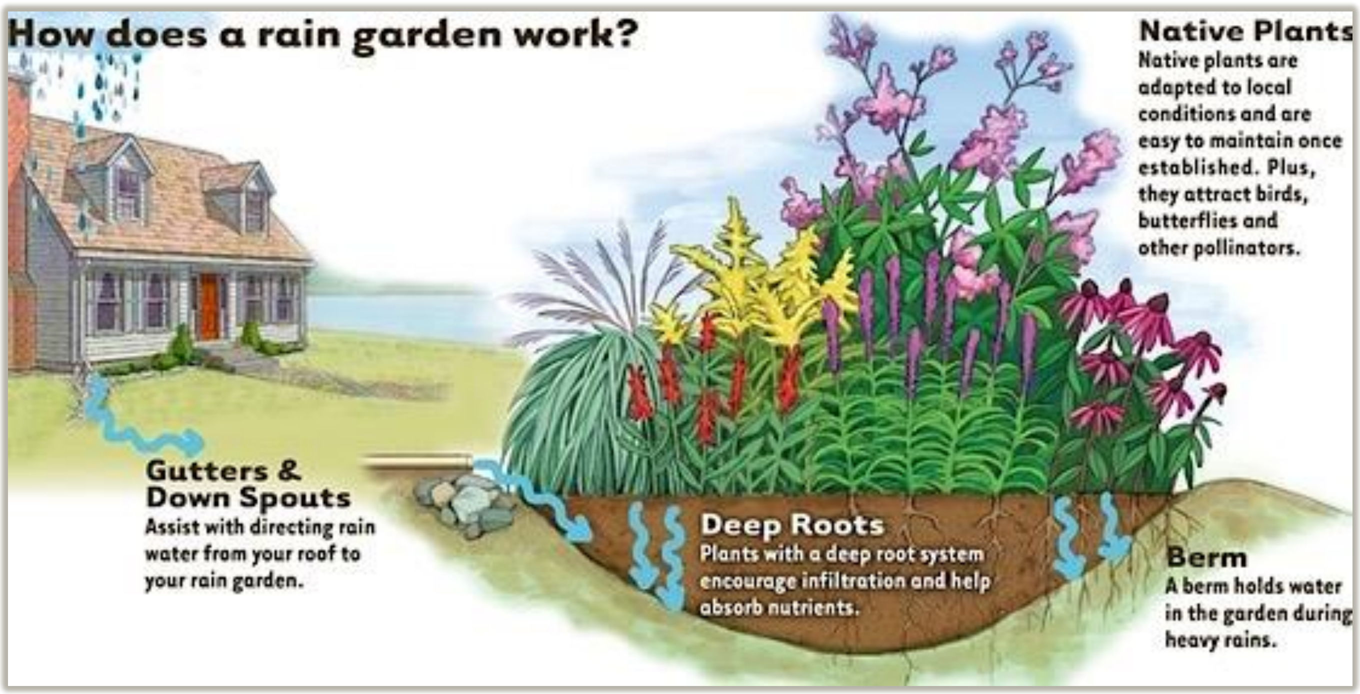


Figure 7: Rain garden illustration. Photo credit: Cornell Cooperative Extension Ulster County.[46]

When you are addressing soil compaction, consider plans that incorporate **green space and porous surfaces** in patios, pathways and driveways. Natural vegetation buffers along waterways and wetlands absorb and cleanse storm water.

Rain gardens and bio-swales are modeled after natural ecosystems and are designed to use plants, soils, mulch and microbes to slow and treat storm water runoff. They also can reduce the likelihood of downstream flooding and replenish groundwater supplies. Rain gardens are strategically located in low areas and can be any size or shape. Bio-swales are shallow vegetated channels that can be used to direct surface runoff to rain gardens or other areas where the water can be absorbed.[47]

On the flip side, **xeriscaping** is a method of gardening that focuses on water conservation by designing a garden to include a wide range of plantings that are drought resistant, and the creation of landscapes that require very little irrigation. For example, gravel and mulch are used to create the spacing between planting beds, rather than grass turf. Xeriscaping is used extensively throughout the Southwest US where drought conditions prevail.

Northeast Drought Monitor

This tool provides a glimpse into the Northeast's current drought conditions. It offers an easy visual of what's happening in your area. This map is updated weekly and is a collaborative project between the National Drought Mitigation Center at the University of Nebraska-Lincoln, the United States Department of Agriculture, and the National Oceanic and Atmospheric Administration. The **Cornell University Climate Smart** Farming website offer other great tools and information as well.
http://climatesmartfarming.org/tools/us-drought-monitor/

Best Practices:
Water Management and Conservation

- ☐ Understand what is happening with water in your garden ecosystem.
- ☐ Choose plants suited to site conditions.
- ☐ Recognize that plant water needs vary.
- ☐ Make observations of plants, soil and rainfall before supplemental irrigation.
- ☐ Limit water use, especially potable water.
- ☐ Minimize surface runoff.

4. Pollinator Protection

Over 80% of the world's flowering plants rely on **pollinators** for successful reproduction**.** Pollinators include species of ants, bats, bees, beetles, birds, butterflies, flies, moths, and wasps. **Pollination** is the transfer of pollen, in and between flowers of the same species, leading to fertilization and successful seed and fruit production for plants. Wind and water play a role in pollination but often it is an unintended consequence occurring when an animal visits flowers to eat or sips nectar and pollen grains attach themselves to the animal's body. When the animal visits another flower for the same reason pollen can fall off and thus fertilize the other plant.[48] This process ensures that a plant will produce full-bodied fruit and a full set of viable seeds.

The **North American Pollinator Protection Campaign** notes that worldwide, roughly 1,000 plants grown for food, beverages, fibers, spices, and medicines need to be pollinated by animals.[49] However, there is evidence that pollinating animals have suffered from loss of habitat, chemical misuse, introduced and invasive plant and animal species, and diseases and parasites. Additionally, earlier flowering and leafing is one of the most **potentially disruptive plant responses** to warming. This is generating concern that climate change will create a mismatch in timing and current pollination relationships as plants and pollinators show different responses to warming.[50] Our gardening practices need to include recognizing and protecting pollinators as our gardens and **ecosystems will not survive** without them.

Figure 8: Monarch butterfly on Aster spp.
Photo credit: Jennifer Stengle, CCE Putnam County[51]

Northeast Growing Degree Day Calculator

Growing Degree Days (GDD) are a measure of heat accumulation; this is relevant to gardeners because it can provide important information on plant maturation and insect development. Cornell's climate smart farming program offers a GDD calculator that allows you to input your address and get details for your specific location. The Cornell University Climate Smart Farming website offer other great tools and information as well.

http://climatesmartfarming.org/tools/csf-growing-degree-day-calculator/

Observing Pollinators in Your Garden

Take note of the animals in your garden ecosystem including potential pollinators. What are their daily and nightly seasonal patterns and relationships? Do they spend time on the garden plants you already have? Do you always have plants in bloom? Certainly, this could be a challenge if space is limited. This could also be the motivation needed to transform your lawn into a more valuable pollinator habitat.

Figure 9: Monarch butterfly caterpillar on butterfly weed. Photo credit: Jennifer Lerner CCE Putnam County.[52]

Further, there is a need to continually evaluate how **bloom patterns** are changing with our warming world and how they will need to change to maintain continuous bloom. Do you have plants in bloom at night? Moths and bats pollinate night-blooming flowers. Are there plants in bloom you have never seen pollinators on? In breeding some modern hybrid flowers, especially those with "doubled" flowers, the pollinator attracting pollen, nectar, and fragrance features can be lost. Do you see them returning to a place that might be nesting sites? Or visiting water sources?

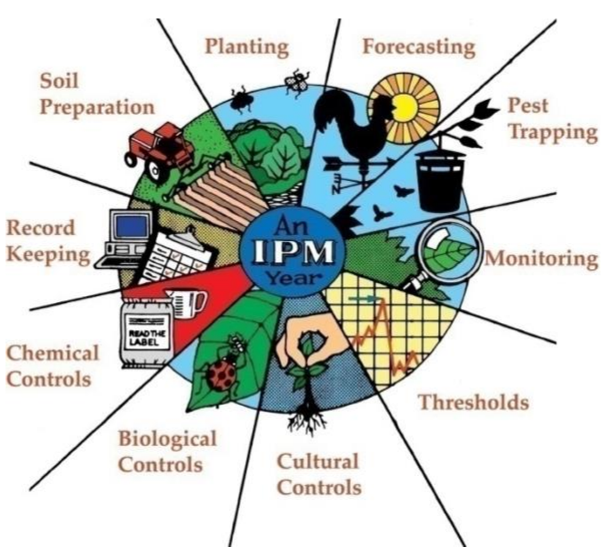


Figure 21. An IPM Year.
Used with permission from the New York State Integrated Pest Management Program.[53]

If you find that you need to manage a pest in your lawn, garden, landscape or home do consider using an IPM (integrated pest management) approach to ensure that the pollinators are given protection and can do their job to keep our gardens and ecosystems thriving. IPM promotes safe, least-toxic solutions in the management of a wide range of pests including insects, fungi, bacteria, viruses, weeds, and wildlife. IPM rarely relies on one tactic. It brings together, or integrates, a range of biological, organic, cultural, mechanical, and chemical options to prevent pests entirely or reduce them to levels you can live with. Find our NYS Pollinator Protection Plan on this site: https://nysipm.cornell.edu/environment/pollinators

5. Plant Selection and Design

Since plants are most often the focal point of garden landscapes and conversations among gardeners, we can often enter the plant selection process with a one-function garden mindset, for example, concentrating on a vegetable garden, a native plant garden or a tree for shade. For climate-friendly sustainable garden success we need to open up a new way of gardening that focuses on how pieces of the garden connect to each other. We need to see more than the plants and recognize that in **natural ecosystems** nothing does just one thing. We mentioned in previous sections rain gardens, bio-swales, and gardens that provide resources for pollinators. Might plants in these gardens also provide food for humans, be native to the region, attract beneficial insects and provide shade? Cultivating a whole ecosystem instead of a garden might seem a bit overwhelming so start small. Can you imagine which place you'd like to start with this approach in your garden?

Growing more food? There's no need to create a separate vegetable garden if you can fit vegetables into annual and perennial garden spaces. Or add annual or perennial flowers or herbs to the vegetable garden to attract beneficial insects. It's been estimated that food travels an average of 1,500 miles from farm to grocery store, amounting to roughly 50,000 lbs of CO_2 emissions.[54] By producing homegrown healthy food, you'll also be reducing greenhouse gases.

Changing hardiness zones may mean that crops just on the verge of hardiness in areas of NY state will become increasingly easy to grow, such as stone fruits and watermelons. Gardeners may have opportunities to experiment with growing new crops or increasing the season length for others. However other crops- such as cabbage and apples –may not be as successful as they have been in the past. Gardeners may also want to try out crops adapted to heat and drought stress, given projections of hotter, drier summers.[55]

Figure 10: Pounder Vegetable Garden. Photo credit: Cornell Botanic Gardens.[56]

Or maybe you want to **reduce gas emission** by minimizing lawn and turning to alternative groundcovers? Or incorporate some (or more) native species and drought resistant plant species into a new or existing garden bed? Might you plant more trees to capture carbon? In addition, leafy species (deciduous trees and shrubs) on the south and west sides of homes provide summer shade and warm winter sunlight, while planting evergreens on the north side and shrubbery along the foundation can protect homes from winter winds. In selecting plants appreciate that **new climate conditions** are already shifting plant hardiness zones and there are many unknowns including the variability of plant responses to environmental changes. **Prepare for unpredictability** by including a diverse mix of plants and choosing trees and shrubs that do well across many zones. A wide variety of plants can also help preserve **genetic diversity** and provide opportunity to experiment with new species.

Plants can also assist in sequestering carbon. Specifically recall the aspect of **the carbon cycle** where plants capture carbon dioxide (CO_2) gas from the air and convert it to carbohydrates (starches and sugars) along with other carbon compounds that become the tissues of the plant. When plants respire they break down these carbon stores in their tissues and release CO_2 back into the atmosphere. The amount of CO_2 taken up by the plants through photosynthesis is generally far greater than that lost through respiration. This results in a large net gain of carbon by plants in their tissues over the course of their lifetimes. Maintaining healthy living plants serves to **sequester carbon** that would otherwise be in the atmosphere as CO_2 gas. Though plants species vary in their ability to accumulate and store carbon, adding more plants to your garden is a good thing when you choose plants that are suited to your site conditions and avoid invasive species.

Prohibited and Regulated Invasive Species

There are some species of plants and animals that have been introduced and cause harm; it is best to avoid them in our gardens and landscapes. There are plenty of native and non-invasive plant species to use in gardens and landscapes. Check with your local Cooperative Extension for guidance. **NYS Department of Environmental Conservation** provides a prohibited & regulated plant list. **http://www.dec.ny.gov/animals/99141.html**

Best Management Practices
Plant Selection and Design

- ☐ Understand your site and regional climate.
- ☐ Choose plants suited to local conditions.
- ☐ Include a diverse mix of plants.
- ☐ Recognize and do not plant invasive species.
- ☐ Start small and follow your passion as you cultivate your garden ecosystem.

6.Equipment and Material Selection

The National Gardening Association reports that U.S. households spent $29.1 billion on their lawns and gardens in 2012 (National Gardening Survey).[57] As we strive to maximize climate-friendly sustainable gardening practices, it's important to evaluate our **dependency on tools and products**. Every time we are tempted to introduce an input to our garden system we should be asking: 1) why is this needed? and 2) exactly how much is needed?

For example, most gardeners would agree that gas-powered blowers and weed whackers are not needed; mulch leaves in place or rake and hand pull weeds. Opinions on gas-powered lawn mowers are less obvious. If it's not possible to shift to a push or electric mower, then gas-powered mowers should be serviced regularly, including keeping the mower blade sharp as this reduces gas consumption by up to 20%. Keep the grass above 3 ½ half inches, mowing only often enough to avoid piles of grass clippings. This might be every 5 days during the flush of top growth in spring, not at all during summer drought and every 7-14 days the rest of the growing season.[58]

Remember that **containers, lawn furniture and hardscape materials,** when added to our gardens, are important to include in the evaluation process, as transportation of materials adds to the accumulation of greenhouse gases in our atmosphere. How can new purchases be minimized by using existing and salvaged materials for garden construction, like bricks and stone?

In fact, we need to **thoughtfully critique** all aspects of organic waste management, soil health and nutrient management, water management, pollinator protection and plant selection through the lens of what materials are cycled within the system and what materials are being added. Then we can strive to work with the nature of the site to minimize inputs that need to be manufactured and or transported to the site. When we do decide a specific input is needed, such as mulch to cover the soil while waiting for plants to fill in a space, then we can consider the origin of the mulch and how it was transported to our garden. Few will disagree that eliminating the need for manufacturing and transporting new products in all aspects of cultivating a garden is a **challenge**. However, it is the foundation for climate-friendly sustainable gardening.

SUMMARY

- Gardeners are on the leading edge of climate change impacts and so are well-positioned to be significant contributors to self-generated knowledge that can uncover existing capacity within the community.
- There are no single solutions. Practices are interrelated, and one strategy influences the other.
- Plant waste in the lawn, garden, landscape and kitchen might staying in place for decomposition, be composted in another on-site location, travel off-site for composting, or travel off-site to be put in a landfill.
- A healthy soil habitat is a great asset in mitigating the effects of climate change. Low input tactics like minimizing tilling and not over applying supplemental nutrients promote soil health.
- An essential part to managing and conserving water is building a deep understanding of what is happening with water in your garden ecosystem and then using strategies that minimize potable water use and runoff.
- Warming temperatures may create a mismatch in timing that disrupts current pollination relationships. A diverse plant portfolio can support pollinators' full needs for food and shelter throughout their entire life cycle.
- Plants assist in sequestering carbon that would otherwise be in the atmosphere as CO2 gas. Plants species vary in their ability to accumulate and store carbon though plants suited to your site conditions and not invasive will require less maintenance.
- Every time we are tempted to introduce an input to our garden system we should be asking why is this needed and exactly how much is needed?

REFLECTION

- How have your approached to each of the following areas of gardening: organic material waste management, soil health and nutrient management, water management and conservation, pollinator protection, garden design and plant selection, equipment and material selection? Consider how your current actions already align with climate friendly sustainable gardening? How might you modify your approaches to ensure success gardening in a warming world?
- Consider the diversity of plants in your garden? How does this plant portfolio support the soil health, water conservation, pollinators, and other aspects important to your garden system success? Ask other gardeners what they are growing and explore growing guides like the follow for inspiration around diversify your plant portfolio with your local site conditions in mind.

- ☐ Woody Plant Database: http://woodyplants.cals.cornell.edu/home
- ☐ Flower & Vegetable Growing Guides: http://www.gardening.cornell.edu/homegardening/index.html
- ☐ Vegetable Varieties for Gardeners: http://vegvariety.cce.cornell.edu/main/login.php
- ☐ New York Invasive Species: http://nyis.info/
- ☐ Alternatives to Invasive Plants: www.nysipm.cornell.edu/nursery_ghouse/invasive_plants.asp

EXPLORE MORE

- A list of reliable sources related to this unit is provided in the Selected Resources section.

National Climate Assessment
One of the major likely outcomes of climate change will be increased precipitation accompanied by flooding. The U.S. Global Change Research Program has regional centers that provide information that will help you to think through other aspects of home and community you might want to audit, alongside your garden. http://nca2014.globalchange.gov/report/regions/northeast

Select Resources

Unit 1: Systems Thinking for Sustainable Gardening

Circle of Trust Touchstones
http://www.couragerenewal.org/touchstones/
Donella Meadows Sustainability Institute
www.donellameadows.org/systems-thinking-resources
The Handbook of Sustainability Literacy
http://arts.brighton.ac.uk/stibbe-handbook-of-sustainability
The Systems Thinking Playbook
www.lindaboothsweeney.net/thinking/habits
The Iceberg Model of Systems Thinking (2-minute video)
https://www.youtube.com/watch?v=9I5YvLm5KXI
What the Bleep Do We Know? (feature film available for downloading)
http://whatthebleep.com/

Unit 2: Knowing Our Garden Systems

Landscapes for Life
http://landscapeforlife.org/
Nature's Notebook USA National Phenology Network
https://www.usanpn.org/natures_notebook
CoCoRaHS - Community Collaborative Rain, Hail and Snow Network
https://www.cocorahs.org/Content.aspx?page=aboutus

Unit 3: Climate Change Basics

Climate Assessment: Report for Policy Makers - Intergovernmental Panel on Climate Change
http://www.ipcc.ch/
Climate Change - U.S. Environmental Protection Agency (EPA)
http://www.epa.gov/climatechange
Climate Change - NY State Department of Environmental Conservation
http://www.dec.ny.gov/energy/44992.html
Climate Change Communication - Yale Project
http://environment.yale.edu/climate/
Communication Climate Change
http://climatenexus.org/communications-climate-change/
Climate Interpreter- NASA & National Science Foundation (NSF)
http://climateinterpreter.org/
Climate Literacy: The Essential Principles of Climate Science - NSF
www.globalchange.gov
Climate Masters Handbook
http://www.theresourceinnovationgroup.org/climate-educ-lit-pubs
Common Sense Climate - Index National Oceanic and Atmospheric Administration (NASA)
https://data.giss.nasa.gov/csci/
Connecting on Climate: A Guide to Effective Climate Change Communication
http://www.connectingonclimate.org/
Cornell Climate Change
http://climatechange.cornell.edu
The Cultural Cognition Project at Yale Law School
http://www.culturalcognition.net/
The Debunking Handbook - Global Change Institute, University of Queensland, Australia
http://www.skepticalscience.com/docs/Debunking_Handbook.pdf
Evaluating Resources - University of California Berkeley Library
http://guides.lib.berkeley.edu/evaluating-resources

Greenhouse Gas Emissions - Environmental Protection Agency (EPA)
https://www.epa.gov/ghgemissions
NASA scientists react to 400 ppm carbon milestone
https://climate.nasa.gov/400ppmquotes/
National Climate Assessment (2014, U.S. Global Change Research Program)
http://nca2014.globalchange.gov/
NOAA weather and climate maps
https://www.climate.gov/maps-data
NOAA, Northeast Regional Climate Center at Cornell University
http://www.nrcc.cornell.edu
Real Climate: Climate Science for Climate Scientists
http://www.realclimate.org/?wpmp_switcher=desktop
Responding to Climate Change in New York State Synthesis Report, NYSERDA
http://www.nyserda.ny.gov/climaid
The Science and Impacts of Climate Change (Cornell professor - Art DeGaetano lecture)
http://www.cornell.edu/video/art-degaetano-climate-change-science-impacts
Skeptical Science
http://skepticalscience.com/Welcome-to-Skeptical-Science.html
U.S. Global Change Research Program, Assess the U.S. Climate.
http://nca2009.globalchange.gov/
What We Know About Climate Change
http://whatweknow.aaas.org/

Unit 4: Climate-Friendly Sustainable Garden Audit

The Climate Friendly Gardener - Union of Concerned Scientists
http://www.ucsusa.org/food_and_agriculture/what_you_can_do/the-climate-friendly-gardener.html
Cover Crop Guide - Decision Tool - Cornell University
http://covercrops.cals.cornell.edu/decision-tool.php
Earthworms in the Forest: Blessing or Curse?
http://www.cornell.edu/video/earthworms-in-the-forest-blessing-or-curse
Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation
http://www.ipcc.ch/report/srex/
Pollinator Network at Cornell
https://pollinator.cals.cornell.edu/pollinator-conservation
Pollinator Partnership
http://www.pollinator.org/involved.htm
Pollinators – USDA
http://www.fs.fed.us/wildflowers/pollinators/index.shtml
Rain Barrels: A Step-by-Step Guide for Building & Installing
http://cceonondaga.org/resources/how-to-build-a-rain-barrel
Soil – USDA Natural Resource Conservation Service
http://www.nrcs.usda.gov/wps/portal/nrcs/site/soils/home/
Soils and Climate Change – Rutgers University
http://climatechange.rutgers.edu/docman-list/affiliate-publications/446-healthy-soils-and-climate-change-final/file
Soil Management – Cornell Garden-Based Learning
www.gardening.cornell.edu/soil
Sustainable Gardening in a Changing Climate, Dave Wolf, Cornell University
https://www.youtube.com/watch?v=zzom1kysGYo
The Water Cycle for Schools
http://water.usgs.gov/edu/wateruse-total.html
Water-Energy Connection

www3.epa.gov/region9/waterinfrastructure/waterenergy.html
Weed Suppressive Ground Covers Brochure
https://ecommons.cornell.edu/handle/1813/42430
The Xerxes Society for Invertebrate Conservation
http://xerces.org/

Recommended Books

The Climate Friendly Garden - Janet Morielli
Collapse - Jared Diamond
Don't Even Think About it: Why our Brains are Wired to Ignore Climate Change – G. Marshall
The Gardeners Guide to Global Warming: Challenges and Solutions - Patty Glick
Grow More with Less, Sustainable Garden Methods - Vincent A. Simone
Hot: Living Through the Next 50 years on Earth - Mark Hertsgaard
The Long Summer - Brian Fagan
The Permaculture City - Toby Hemenway
Thinking in Systems: A Primer - Donella Meadows

Community Focused Climate Change Programs

Adaptation Planning for Coastal Communities
https://coast.noaa.gov/digitalcoast/training/climate-adaptation.html
Adapting to Climate Change: short course for land managers
https://www.fs.usda.gov/ccrc/sites/default/files/hjar/credits.html
ANREP's National Network for Sustainable Living Education http://www.anrep.org/people/initiatives/nnsle/
Antioch University New England Center for Climate Preparedness and Community Resilience
http://www.communityresilience-center.org/education-and-training/weathering-change-webinar-series/
Barnegat Bay Shellfish Restoration
http://ocean.njaes.rutgers.edu/marine/ShellfishVolunteerTrainingProgram.html
Bay wise Program https://extension.umd.edu/baywise
Clean Air Partnership http://www.cleanairpartnership.org/projects/municipal-adaptation-training-program/
Clean Energy Communities Program https://www.nyserda.ny.gov/cec
Clean Energy Corps https://ag.umass.edu/clean-energy/extension-services/clean-energy-corps
Climate Academy https://training.fws.gov/nctcweb/catalog/CourseDetail.aspx?CourseCodeLong=FWS-ALC3193
Climate Adaptation Academy https://climate.uconn.edu/caa/about-the-academy
Climate change science, action and communication https://civicecology.org/course-cc/
Climate Learning Network eLEarning Modules on Climate Change
http://climatelearning.net/e-learning-modules/
Climate Ready Great Lakes
http://www.regions.noaa.gov/great-lakes/index.php/project/climate-ready-great-lakes/
Climate Smart Communities Program http://www.dec.ny.gov/energy/76483.html
CoCoRaHA https://www.cocorahs.org/
COMET MetED climate change resources
https://www.meted.ucar.edu/training_detail.php?topicSorting=2&module_sorting=titleAsc
Community Resilience Action Network of Erie
http://www.greeneriepa.org/get-involved/erie-county-community-resiliency-workgroup
Community Resilience Building/Municipal Vulnerability Preparedness Program
https://www.communityresiliencebuilding.com/crbworkshopguide
Connecticut Institute for Resilience and Climate Adaptation (CIRCA) https://circa.uconn.edu/
CT NEMO/CLEAR Nonprofit education program for municipal officials
http://nemo.uconn.edu/training/index.htm
Decision Analysis for Climate Change
https://nctc.fws.gov/NCTCWeb/catalog/CourseDetail.aspx?CourseCodeLong=FWS-ALC3196

DEEP CT Webinars http://www.ct.gov/deep/cwp/view.asp?a=4423&q=571260&deepNav_GID=2
ecoAmerica Path to Positive Communities https://ecoamerica.org/communities/
Energy Masters
https://www.arlingtonenvironment.org/wp-content/uploads/2012/01/2017-18EnergyMasters-CommunityVolunteerOption.pdf
Energy Navigator volunteer Tompkins County http://www.getyourgreenbacktompkins.org/navigators/
Forest Adaptation Planning and Practices https://forestadaptation.org/node/646
Incorporating Climate Adaptation Strategies in Comprehensive Planning
http://www.coastaltraining-wa.org/Climate-Training-Series
Lake Champlain Sea Grant Sustainable Landscape Stewards
https://www.uvm.edu/seagrant/sustainable-landscape-stewards
LEAD Fellows https://cardi.cals.cornell.edu/programs/lead-ny/current-class
Local Government Climate Adaptation Training
https://www.epa.gov/communityhealth/local-government-climate-adaptation-training
Maine's Municipal Planning Assistance Program
http://www.maine.gov/DACF/municipalplanning/technical/climate.shtml
Master Watershed Steward Program https://extension.psu.edu/programs/watershed-stewards/about
National Network of State-local Sustainability Organizations (N2S2O) http://nnsso.com/
NOAA Digital Coast https://coast.noaa.gov/digitalcoast/
PACE Land Use Law Center http://www.law.pace.edu/our-programs
PREP-RI http://prep-ri.seagrant.gso.uri.edu/
Program for Resource Efficient Communities - Community Environmental Education
http://buildgreen.ufl.edu/cecampus.htm
Resilient MA http://www.resilientma.org/
RiverSmart Communities https://extension.umass.edu/riversmart/
Rutgers Environmental Stewards http://envirostewards.rutgers.edu/county-programs/
Signs of the Season: a New England Phenology Program
https://extension.umaine.edu/signs-of-the-seasons/training/
Sustainability and Environment Course http://www.globalcompetencecertificate.org/course-registration/
Sustainable Floridians Program (SM) http://brevard.ifas.ufl.edu/communities/sf_course.shtml
Sustainable Jersey http://www.sustainablejersey.com/nc/events-trainings/
The CLEO Institute https://www.cleoinstitute.org/cleo#clttop
The Resource Innovation Group: Transformational Resilience http://www.theresourceinnovationgroup.org/
Understanding Climate change impacts on water resources
https://www3.epa.gov/owow/climate_change_and_water_resources/story_html5.html
US Climate Resilience Toolkit https://toolkit.climate.gov/#tools
Woodland stewardship education http://extension.umd.edu/woodland
World Bank City Climate Planner Certificate Program http://cityclimateplanner.org/

Concluding Remarks
"We are all adrift in the same boat -- and there's no way half the boat is going to sink." --Argentine climate negotiator, Raul Estrada-Oyuela
Cultivate with your peers an on-going conversation. As we are confronted with the seriousness of climate change, we need to review ways to process and explain the complexity of this topic, identify our own vulnerability in the face of the volatile changes caused by climate change, and learn more about the benefits and techniques of sustainable gardening. Most of all, let us come together mindfully to support our community of gardeners. There is a wide variety of effective gardening practices that can inform our efforts to meet the challenge of gardening in a warming world.

Endnotes

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