Everything but the Carbon Sink

Managing Land Responsibly in a Time of Global Climate Change

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Taking Care of the Giving Earth

Introduction to Landscape Management and Climate Change

Once upon a time, there was the Earth…and she loved a small species named Humans. Every day, the Humans would stroll through Earth’s lands, faces cooled by the shade of her great trees, lungs filled with clean air and the fragrance of foliage, and minds soothed by the calm beauty of her forests, meadows, and lakes. They would wash in her waters, feed from her plentitude, and build homes upon her vast landscapes, where they grew in numbers. The Humans enjoyed their corner of paradise. And the Earth was happy.

One day, the Humans approached the Earth, frowning. “We are not happy,” the Humans said. “We want to become larger and more powerful. We want control, to make changes however we see fit.”

And the Earth replied, “You have my lands—use them as you would to make yourselves happy.”

So the Humans tore down Earth’s trees, burned her fields and covered them with cement and steel. They stopped up her rivers with dams, mowed down her meadows and sprayed them with chemicals that killed the soil and sullied the waters, and sped around in metal boxes that belched smoke and choking vapors. Progress and development ate away at paradise. And the Humans became large and powerful, in control to make the changes they so desired.

And the Earth was happy. But not really.

And the Humans were happy. But were they?
Those who are familiar with the story may find the obvious similarities between this tale and the popular children’s book, *The Giving Tree*, by Shel Silverstein. Now considered a modern classic, the story follows the lives of a boy and the tree who loved him. Throughout different stages of his life, the selfish little boy returns to the tree (that he once loved), and demands that she give him something to ensure his happiness. In the end, he has asked for so much that the tree, whittled down to a pathetic stump, can offer him no more than a quiet place to sit. Most readers are simultaneously saddened by the loss, and angry at the selfishness of the little boy. There was so much more that the tree could have done for the boy had he taken care of her—loved her—as dutifully as she had taken care of, and loved, him.

Of course, it is presumptuous, even incorrect, in thinking that Silverstein meant to represent the little boy as the human species, and the tree as Earth when he wrote the book. However, he did mean to portray the sacrificial relationship between a perpetual giver and a perpetual taker, and this relationship appropriately characterizes the long history of humans and the land.\(^1,2\) In the story, the little boy did not stop to realize that fulfilling his short-term desires destroyed not only the tree, but himself as well; at the end of the tale, he is reduced down to an old man, alone and unhappy. We humans resemble that little boy—we have failed to see how much harm we inflict upon the land, ourselves, and future generations, when we treat the Earth as solely a possession to be exploited (Fig. 1).

One can only wonder: had the little boy in *The Giving Tree* not cut down the tree and stripped it bare of branches and leaves, how much more would he have benefited from the tree’s generous, abundant, and unconditional love? In the same way, we must ask ourselves, how much more would we benefit from respecting and taking care of the land, rather than trying to subdue it according to our own designs? This book focuses on just what valuable inputs the “tree” is able to give, and how we humans, as the little boy, can look past our short-term desires and place in priority the survival and well-being of the land.

This book is not out to spin a story, nor construct a fairy-tale. It strives to deal with the oftentimes grim realities of current environmental conditions. Simply put, we present a series of ideas and arguments that we feel are worthy of your eyes’ and ears’ attention. It’s a very simple transaction, really—we provide the information and argumentation while we ask that you, as the reader, only contribute your open-minded consideration. In our attempts to answer as best as we
can the issues on “taking care” of the land, we hope that you will be informed, challenged, inspired, and ultimately motivated. Because your motivation may find you lying under the shade of a beech tree during one drowsy afternoon, appreciative of your corner of paradise in more ways than one. And maybe the Earth will be happy.

Figure 1. The contrast between the wild forests and the heavily human-altered golf course is dramatic. Have humans sacrificed more than just forests in order to maintain their carefully manicured lawns?

**The Land, the Earth, and Humans**

Humans are a part of nature. The land, all of its features, and every one of its living, nonhuman inhabitants constantly surround and affect even the most wilderness-distanced metropolis. Having been plunged into the landscape since the beginning of human evolution, *Homo sapiens* have interacted closely with the land, particularly by transforming it. This altering of the land goes as far back into the history of human culture as written records and ancient artifacts allow us to observe. From the creation of the awe-inspiring Hanging Gardens of Babylon in 605 B.C., to the painstakingly arranged Zen gardens of 7th century Japanese culture, to the sun-drenched symmetry of the 17th century Versailles gardens of Louis XIV, to the
creation of national parks under the influence of John Muir in the late 1800s, the land has been shaped by all walks of human existence (Fig. 2 - 5). Not only are we humans an inextricable component of the land surrounding us, but also the land has become an inextricable ingredient within our civilization.

However, somewhere along the line, we humans forgot that we are only one part within nature. Just like the shortsighted, selfish boy Shel Silverstein described, humans manipulate and exploit the land in order to satisfy our immediate needs and wants. We don’t stop to realize that we inflict long-term harm upon the land when we create pesticide-saturated, monoculture rice fields or heavily-mowed, immaculate green lawns for recreational purposes. And we surely don’t bother thinking about how such damaged land will negatively affect us—we’re too busy golfing on the green or building houses on coastal dunes.

How can we avoid becoming the boy who destroys his own giving tree? How do we stop ourselves from making the irrevocable mistake of devastating our fields of paradise? Perhaps we need to establish a longer-lasting, more considerate relationship with Mother Nature by removing ourselves from the center of the picture, to the periphery. By acknowledging that the land, the earth, and we are all interconnected, and that taking care of the land means taking care of ourselves and the earth we live in. This requires respecting and appreciating the land and its living organisms—and according to E. O. Wilson, this comes quite naturally to us. Wilson introduces the concept of biophilia—the natural human propensity to establish affiliation with nature, and its other life forms. Wilson declares that “for human survival and mental health and fulfillment, we need the natural setting in which the human mind almost certainly evolved and in which culture has developed over these millions of years of evolution”, and even links nature as a key component within our psyche’s: “How could our relation to nature, on which survival depended minute by minute for millions of years, not in some way be reflected in the rules of cognitive development that generate the human mind?” Whether or not biophilia is true, humans do carry a basic appreciation for nature, and it is this appreciation that should influence our relationship with the land. Then, we no longer remain selfish “takers”, but become stewards of the land. We embrace long-term management of the land, ensuring its health and indefinite longevity, because we enjoy, appreciate, and admire all that it contains. This mentality of appreciative management will in turn benefit, on a grander scale, the earth itself, as well as us, because we live and grow upon the same earth. To demonstrate the rightness of appreciative
Figure 2. The Hanging Gardens of Babylon, built in 605 B.C. by King Nebuchadnezzar for his wife Amyitis, who was homesick for the mountains and forests of her homeland, Medes.


Figure 3. Two Japanese Zen rock gardens, following a tradition founded as early as 7th century A.D. These gardens were meant to restore peace and harmony within a person’s mind.

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Figure 4. The gardens of the palace at Versailles, of King Louis XIV, from the 17th century. Every tree and lawn was carefully managed to maintain strict, geometric shapes.

Figure 5. Yosemite National Park, set aside by President T. Roosevelt in 1890 under the influence of conservationist John Muir. Yosemite was one of the first U.S. national parks.
management, one only needs to sit down and make a mental list of all the benefits—for people and the earth—that accrue through the maintenance of healthy landscapes.

Although the list is too long to include here, the importance of considering how healthy landscapes contribute to the earth and humans cannot be stressed enough. Removing air and water pollution, regulating temperature changes, maintaining biodiversity, providing climatic stability, etc.—all of these landscape contributions greatly benefit the earth and ultimately, us.4 One study in Rwanda Volcanoes Park discovered that the park’s montane forest, only 1% of the nation’s land surface, absorbed 10% of agricultural water, preventing it from becoming run-off.4 Another study looking at the effects of urban forest ecosystems in Chicago highlighted the beneficial gains made by the city due to its 11 percent tree cover. The researchers found that in 1991, the trees in the city of Chicago removed an estimated 17 tons of carbon monoxide (CO), 93 tons of sulfur dioxide (SO2), 98 tons of nitrogen dioxide (NO2), 210 tons of ozone (O3), and 234 tons of particulate matter (with particle size less than 10 microns).5 It seems easy to forget just how much trees can do for the quality of life and the water and air—the same water and air that sustains us. One can only hope that we will not rediscover the value of our trees and natural landscapes when it is too late (Fig. 6).

**More Trees, Less Carbon—A Landscape’s Contribution**

One major benefit made by landscapes, which will be the overall focus of this book, is that they can mitigate the effects of global climate change by removing atmospheric greenhouse gases, particularly carbon dioxide, and storing them for long-term periods. People often overlook the process of removing and storing greenhouse gases by natural landscapes, otherwise known as sequestration, when the controversial issue of global climate change is raised. Emissions from cars and other modes of transportation, burning of fossil fuels for energy and heat, alternatives such as solar-, hydro-, and wind-power—these issues of energy production most commonly fuel the climate change debates, and rightly so.

However, the role that landscapes play in the larger arena of mitigating climate change needs to be recognized, especially during the transition to a non-fossil-fuel based economy. That carefully managed land is able to reduce the greenhouse effect should have been apparent since day one, when jubilant botanists discovered that plants take up carbon dioxide (CO₂) in photosynthesis and store them, thereby helping to reduce the buildup of greenhouse gases in the
Figure 6. The beauty, grandeur, and ecological contributions of trees are oftentimes overlooked, or underestimated. Trees may once again be valuable to us once we’ve destroyed them and are suffering from the consequences of doing so.

atmosphere. Not only do plants take up atmospheric CO\textsubscript{2}, but they also store it as organic matter, keeping it from quickly entering back into the atmosphere. Carbon dioxide is also stored within soils, such as peat within bogs\textsuperscript{6}. Therefore, managing the land in order to maximize carbon sequestration would generally require: 1) more vegetation to take up and store carbon dioxide, and 2) decreased in disturbance of the land, such as deforestation, so that the captured CO\textsubscript{2} remains tightly stored within the plants and soil.

Remember, all things within the earth are interconnected. The American conservationist Aldo Leopold was wise in realizing and reminding others that: “This interdependence between the complex structure of the land and its smooth functioning as an energy unit is one of its basic attributes.… When a change occurs in one part of the circuit, many other parts must adjust themselves to it.”\textsuperscript{7} The land, its inhabitants, and the overarching structure of the biosphere are all affected by climate change. As humans continue to use the land unsustainably, rising atmospheric CO\textsubscript{2} will manifest itself in harmful effects felt by all. On the other hand, when landscapes, through appreciative management, are maintained to maximize carbon sequestration,
the world and its inhabitants, humans included, will be changed for the better. Returning to how trees shape the urban ecosystem within the City of Chicago, the researchers concluded that “the amount of carbon sequestered annually by one tree less than 8 cm (3 inches) in trunk diameter (d.b.h.) equals the amount emitted by one car driven 16 km (10 mi).”

Carbon dioxide that would have circled the globe until taken up somewhere else, can now be stored in the trees that beautify your street.

Sounds like a guaranteed win-win situation.

But let’s face it—human beings hardly ever manage land with carbon sequestration in mind. We’ve got other plans for the land, such as creating that perfect picnic spot in the park, or keeping the backyard as “neat and tidy” as possible. Our appreciation of the land comes from shaping it into the way we like it most. However, is that such a smart way of managing the land? Is it even appreciation at all, or is it just like a little boy who demands that a tree give him happiness through her sacrifice? Even in light of the possible damages brought on by global climate change—to our earth, our land, and even us—will we continue to make landscape decisions that only exacerbate the environmental problems? True appreciation for the land means that we, as the caretakers, must manage it so as to ensure its health and maximize its beneficial contributions to the earth, namely through mitigating global climate change by promoting carbon sequestration. If we do not, we and future generations will pay the costs of poor management. At present, we seem too busy managing things for our own comfort to even notice that the consequences of our poor choices are quite literally raining down upon us (Fig. 7).

Figure 7. Energy-intensive management of landscapes may contribute to harsher climate change effects, one of them being increased precipitation events. What is the point of using extra energy to do what Nature does naturally?

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Landscape Management: The “What’s”, Why’s”, and How’s”

One is attracted to the “paradise” landscape described in the beginning of this chapter because it combines beauty and wildness with solitude and sanctuary. However, beyond the pretty pictures and rustic place of scenery, the landscape quietly sequesters carbon, thereby counteracting some of the harmful workings of fossil fuel use. Poor management, that which increases the release of greenhouse gases, may jeopardize the very existence of our beloved paradise. This should be reason enough for us to want to protect and restore the bounty of the land through careful management.

Unfortunately, it’s not enough for most people.

We intelligent human beings always need convincing; we demand facts, statistics, success stories, logical justifications—the whole works. We need to question those facts and statistics, to see evidence for those success stories, and to work out for ourselves the logic behind those justifications. This book provides “the whole works” for the doubters and skeptics.

Possibly the area garnering the most doubt is the scientific explanation and evidence of global climate change. Since understanding the science behind climate change lays the foundation for all other ideas, Chapter One deals with the questions: what is global climate change (GCC), how do we know it’s actually occurring, and how have humans contributed to it? Together, we look to sources that clearly indicate the occurrence of climate change, namely, the scientific evidence that the earth’s overall temperature is rising. Furthermore, we observe how this rise is closely correlated with the rise of atmospheric carbon dioxide, especially after the Industrial Revolution in the mid-1800s. How carbon dioxide and other greenhouse gases (GHGs) actually cause rising temperature of the earth is explained next. A brief explanation of the carbon cycle, and how excess carbon within the atmosphere leads to warming of the earth (known as the greenhouse effect) clarify the basic nuts and bolts on the issue of climate change. Although much scientific evidence attests to the existence of global climate change, the information we have is riddled with scientific uncertainty. This uncertainty stems from the fact that so many variables are involved in GCC, and that no simple “cause and effect” relationship exists. Furthermore, our current instruments and data-gathering methods still have limitations, while the effects of GCC are not immediate, and will manifest themselves over a long period. However, we argue that this uncertainty should be used to push for more effective preventive measures, rather than become the crutch for inaction.
Because, global climate change is real, occurring, and potentially a great harm to the Earth, we must now ask ourselves: Is this knowledge enough to take action and manage landscapes to promote carbon sequestration? Essentially, why should we even bother trying to make changes through landscape management? Chapter Two deals with these questions by presenting ethical arguments that claim landowners have a moral obligation to manage their landscapes to combat GCC by attempting to maximize carbon storage. Aside from economic considerations, there lies an ethical duty for human beings to protect the land because of its inherent value, and also because humans reside within the land and function as a part of the land. For humans to ignore managing their land for optimal sequestration would be a failure in our moral obligations to the land, and ultimately ourselves. Moreover, ignoring these moral obligations shows our blatant disregard not only for humans living in nations predicted to suffer most from the effects of climate change, but for future generations forced to live in a degraded biosphere. All institutions, businesses, and individuals carry this ethical and moral responsibility. Perhaps institutions, especially colleges and universities, because of their societal role as leaders and educators, are bound even closer to the ethical duty of managing landscapes in an environmentally-conscientious—and appreciative—way.

Who are these institutions? What exactly is an “environmentally-conscientious” landscape? Don’t we already manage our landscapes conscientiously? Can we get a bit more specific here? Dealing with “specifics” and the history of land use comprise Chapter Three. It reveals how human beings have not managed the landscape in an ethical manner, focusing on one specific institution to illustrate what it means to manage a landscape in an appreciative way. Looking specifically at the history of New England landscapes, pre- and post-European colonization, one sees a pattern of landscape exploitation, degradation, and unsustainable alteration—no matter how “good” the original intention for the land set out to be.

Chapter Three illustrates these eventual changes by carefully looking at the history of the Wellesley College landscape, particularly because of its renown for beautiful scenery, extensive preservation of natural habitats, and intent to sustain the original integrity of the land. The chapter presents the vision for the land, held by the college’s founder, Henry Durant, and the ideas and trends that influenced him. Contrary to this original vision for the land, by the 1980s Wellesley College had strayed from managing the land in order to uphold its integrity. The chapter ends by emphasizing the importance of returning to Durant’s original vision by
managing the land according to a long-term plan to preserve and protect it. Managing change can be accomplished through thoughtful human intervention guided by a long-term perspective.

Managing with a long-term goal of sustaining all of the natural elements of a New England landscape requires understanding how each habitat functions. Much of the New England landscape (excluding coastal habitats) consists of six habitat types, each possessing its own set of features and functions. Chapter Four deals specifically with these habitats, focusing on how the carbon cycle functions within each. These habitats include: 1) **Forests**, or lands characterized by a dense growth of trees, and the shrubs, saplings, and other plant forms growing underneath the trees (also known as the understory), 2) **Meadows**, low lands supporting growths of wild grass or cultivated for hay, 3) **Turfgrass** (lawns), areas predominantly sustaining grass, usually mowed short, 4) **Groves**, lands characterized by tree growth, yet lacking the understory growth, 5) **Wetlands**, lands characterized by temporarily or permanently water-saturated soils and conditions, and 6) **Lakes**, or inland bodies of fresh water. By exploring the carbon cycles of each habitat, we reveal that these landscapes can function as carbon sinks—as well as carbon sources. Therefore, careful management is key in keeping these habitats as carbon sinks.

How does one carefully manage landscapes? What needs to be done to ensure greater carbon sequestration than emission? Chapter Five focuses on the actual methods of management needed to maximize carbon sequestration for each of the six habitats. We list several specific recommendations for each habitat that will not only allow the greatest rates of carbon storage, but will also help the habitat remain ecologically “healthy”, sustaining populations of native species of plants and animals. These management recommendations are suitable for any small landscape, becoming a “how-to” guide that promises thriving habitats and numerous benefits in addition to maximizing carbon storage.

The management recommendations we have identified from Chapter Five have costs that must be considered, and therefore Chapter Six focuses upon the economics of landscape management for climate change mitigation. This chapter provides the background information needed for cost-benefit analyses (CBA) to be applied to landscape management recommendations. Applying CBA raises several problems, such as the difficulty of assigning a monetary value to nature and to climate change mitigation, the pitfalls of choosing a discount rate that takes into consideration scientific uncertainty and the long-term benefits accrued by sequestering carbon. The chapter illustrates how CBA can contribute to landscape management
decisions by focusing on three projects, and applying CBA to them. However, while it may be helpful to use economic efficiency as one tool in management decision-making, other factors, such as social responsibility, urgency, and ethical duty may be equally important in coming to management decisions.

The final chapter addresses how to bring about change—now that we’ve covered the science, ethics, and economics of landscape management for climate change mitigation. Chapter Seven provides the essential information on policy-making for environmental efforts, such as landscape management to mitigate climate change, and it highlights existing policies that have been created to combat global climate change. Ranging from international, to national, to state and local policy, the chapter emphasizes how individual and group efforts bring about change in how landscapes are managed. It shows the positive roles that individuals and institutions can have in policy-making, and it reminds us all that action is power. With enough voices, the land can be used to benefit itself and all of us living within it.

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Henry David Thoreau once claimed, “A town is saved, not more by the righteous men in it than by the woods and swamps that surround it.”9 You can become the righteous men—you can protect your woods and swamps, and save not only your town, but the Earth as well. But before we can rally the cry for change, we must first understand the nuts and bolts of landscape management. Knowledge is power, and that knowledge begins with comprehension of the science behind the greenhouse effect and global climate change. The information in this book will hopefully lend strength to your voice. For your voice is needed if humans are no longer to occupy the role of “perpetual taker”, and become the stewards rebuilding and protecting a paradise on the giving Earth.
The Facts of the Matter: 

The Science of Climate Change

The loss of sugar maple trees in New England. The disappearance of small island nations under a warm, rising sea. Severe ice storms in winter. We have all heard the predictions of disasters that will be caused by ‘global warming.’ Global warming is more accurately called climate change, as not all of the Earth would warm, some places will become colder. This chapter is about the facts of climate change, starting with what causes climate change. Are the current predictions realistic? And most importantly, what can we do to slow or stop climate change? In this chapter we will explain: climate change, the greenhouse effect, human responsibility in climate change, and scientific uncertainty about the consequences of global climate change.

Global climate change threatens to harm the environment, natural resources, the human economy and human welfare around the world. But the problem is not yet hopeless. We can help alleviate global climate change, starting in our own backyards. But before we can address how to slow climate change we must first understand the science and systems behind climate change.

Is Earth’s Climate Changing?

The debate over climate change persists in the media and among politicians. But, the consensus among scientists is that climate change is indeed occurring.¹ The Intergovernmental Panel on Climate Change (IPCC), established by the United Nations in 1988, has concluded that human activity has changed the concentration of greenhouse gases in the atmosphere, and that it is very likely the Earth is warming as a result.² Although a small minority of scientists do not accept the evidence for climate change, the scientific consensus represented by three IPCC assessment reports issued in 1990, 1996 and 2001 is historically unprecedented. Despite this
consensus, some still believe the observed changes in the Earth’s climate could be the result of natural climate variation.

Natural climate variation such as ice ages and the subsequent warming periods do occur, but natural variation in the climate does not explain the ongoing sudden rise in global temperatures. The last little ice age lasted from approximately 1300 - 1850, and peaked in about 1700. The long term climate trend since then, if there were no human interference, would be towards a colder climate. However, the average global surface temperature has increased by about 0.75 degrees Celsius since the late 19th century. The prior 900 years’ climactic events were mainly controlled by solar and volcanic activity, whereas since the industrial revolution temperature increases have been caused largely by human greenhouse gas emissions and deforestation. In figure 1 below we can see the coincidence of the industrial revolution with the onset of the rising temperatures, after a slight delay. The industrial revolution began globally in the late 1700s and average global temperature started to climb in the early 1900s as industrial production, and burning of fossil fuels expanded to a larger scale, and the concentration of greenhouse gases in the atmosphere began to rise.

![Figure 1. Average global temperature, here represented as the differences in degrees C from an average normal baseline of 0, was slowly declining relative to the baseline temperature until the early 1900s. The baseline value was calculated from the average annual temperatures during 1902-1980 in the Northern Hemisphere. An adequate number of accurate temperature measurements was available during this time period for the Northern Hemisphere only.](image)

**The Greenhouse Effect**

The greenhouse effect is caused by atmospheric gases, called greenhouse gases, that trap heat near the surface of the earth. The temperature of Earth is determined by the balance
between inflow of solar energy and the release of energy back into space, as illustrated in figure 2. Greenhouse gases by trapping heat energy and re-radiating some of it back toward Earth, slow the release of heat energy into space and thereby warm the planet. Greenhouse gases are essential to preserving life on Earth, because without them the planet would be too cold to support life. Greenhouse gases include water vapor, carbon dioxide and methane. We cannot perform a controlled experiment on our own planet to test the greenhouse effect so it is useful to look at our two closest planetary neighbors and observe how greenhouse gases, or lack of them, has shaped their climates. Venus and Mars are both, like Earth, rocky planets. Mars is very cold with a mean surface temperature of –63 degrees Celcius, nearly as cold as scientists would expect if it had no atmosphere, because its thin atmosphere traps little heat. Venus on the other hand, with its thick atmosphere rich in carbon dioxide, traps much of the sun’s energy, making the planet too hot for life, at about 462 degrees C.6 Earth falls between these two extremes with

![Image of Earth's energy balance](image_url)

Figure 2: Earth’s energy balance begins with solar energy entering the Earth’s atmosphere. Some energy is reflected by clouds and aerosols before it can reach Earth’s surface (upper left). Solar radiation (upper center) that reaches the Earth’s surface can either be absorbed by the surface or reflected back (lower left). Some of the reflected radiation passes through the atmosphere and out into space. Much of the radiation from the warmed surface can’t escape through the greenhouse gases and is radiated back to Earth as Back Radiation (lower right). The values are in watts per square meter of Earth's surface, and some have a range of uncertainty of as much as +/- 20%.6
a lower concentration of greenhouse gases than Venus and a global average temperature of about 14 degrees C. We can imagine that adding greenhouse gases to the atmosphere is analogous to putting a thicker, more insulating blanket on a planet. When we add more greenhouse gases to Earth’s atmosphere we contribute to global warming. Of the greenhouse gases that humans contribute to the atmosphere, carbon dioxide is the one that is presently contributing most to greenhouse warming.\footnote{7}

**Are CO$_2$ Increases Caused by Humans?**

Carbon dioxide has always occurred naturally in the Earth’s atmosphere. However, recent increases in atmospheric CO$_2$ concentrations result from human alteration of the natural carbon cycle. In the natural carbon cycle, carbon dioxide is used and stored by plants during photosynthesis. Carbon can be stored for long periods of time in woody plant material. When plants and animals respire, they give off small amounts of carbon dioxide, and when plants and animals die and decompose the carbon in their bodies is broken down by decomposers and released into the atmosphere as carbon dioxide. This natural carbon cycle is currently being altered by human activity in several ways.

The two primary human sources of carbon dioxide are the burning fossil fuels and the cutting and burning of forests.\footnote{8} By cutting and burning forests, humans remove a sink for carbon and create a source. When a forest is disturbed, such as by burning, the carbon that was stored in trees returns to the atmosphere in the form of carbon dioxide. Growing forests and other natural habitats can act as carbon sinks, holding carbon in a nongaseous state. Eventually the stored carbon will be released back into the atmosphere in the form of carbon dioxide, but this return can be delayed while the carbon is stored in wood or soils. In woody plants, such as trees, carbon can be stored for years or even centuries.

Humans have already reduced the forested land worldwide by an alarming amount. Almost half of the world’s forests and an even greater percent of grasslands have already been turned into cropland.\footnote{8} At the same time that these sinks are being destroyed, fossil fuel burning has increased substantially, sending more carbon dioxide into the atmosphere even while the natural storage mechanisms for the gaseous carbon have been diminished.
Figure 3: A simplified illustration of the carbon cycle. Carbon dioxide is taken up by photosynthesis and released by plant and animal respiration and combustion. Carbon can be stored for long periods in sediments. Fossil fuels are the transformed remains of plant and animal material stored millions of years ago. Humans are now rapidly sending this stored carbon back into the atmosphere through fossil fuel consumption.

To determine whether human use of fossil fuels and disturbance of natural habitats such as forests is actually increasing carbon dioxide in the atmosphere, scientists have looked for long historical records of the concentration of carbon dioxide in the atmosphere. This has been found in ice cores taken from glaciers, thick sheets of ice thousands of years old, that can be found in Greenland and Antarctica. By measuring the concentration of gases, including carbon dioxide, in air bubbles trapped in the ice, scientists can deduce the atmospheric composition at the time the air bubble was formed. From those data, we know that atmospheric carbon dioxide concentrations are much higher now than they have been for thousands of years. Measurements of CO₂ concentration in the atmosphere before industrialization were about 280 parts per million. Today this level is over 370 parts per million. The burning of fossil fuels and rapid deforestation in round the world are primarily responsible for this recent increase by one third in atmospheric carbon dioxide.

Another way scientists observe global climate change is through satellite observations of ice and snow cover. These observations show annual snow and ice cover is decreasing in the mid and high latitudes of the Northern Hemisphere. Increased flow of fresh water into the oceans
could have dire consequences for regional climates caused by altering the flow of warm water such as the Gulf Stream, in the oceans.\textsuperscript{11}

**Possible Consequences of Global Climate Change**

Although an increase in greenhouse gases causes the global average temperature to increase, the effect on weather patterns will differ among regions. The weather New Englanders have experienced over the past few years might not seem to be getting warmer, but we must remember that day to day weather fluctuations are about 5.5 degrees C (10 degrees F) and that the increase in mean global temperature since the 1850’s has only been 0.75 degrees C. But these few degrees of change could lead to drastic consequences in the future. For example, if the Gulf Stream in the Atlantic Ocean were to slow or stop due to increased fresh water inputs from ice and snow melt in the Arctic, Europe would get much colder because the warm water of the Gulf Stream brings heat and mild weather to continental Europe and the British Isles.\textsuperscript{11} In addition, hurricanes and other extreme weather events may increase in frequency and in intensity because higher temperatures mean there is more energy in the climate system to drive these events. Higher temperatures also lead to greater evaporation rates and increased rainfall and flooding in some places, while other areas will experience draughts and desertification.\textsuperscript{11}

Roger Beale of the Daily Telegraph \textsuperscript{12}
The types of consequences, their intensity, how soon they will occur and their regional distribution are all uncertain. To make sense of this uncertainty, scientists use computer models to try to examine how the Earth’s climate system may be changed, but the truth is that nobody knows exactly what will happen. Because of uncertainty, it is prudent behave cautiously, always seeking to prevent the worst possible consequences of climate change. These consequences could include rising sea levels and consequent flooding of coastal cities and island nations, the melting of ice caps causing a large influx of fresh water into the oceans and altering ocean currents as well as frequent weather disasters such as heat waves, hurricanes, blizzards, and droughts. Though we are not sure what the consequences of climate change will be, figure 5 illustrates possible temperature changes as modeled through the end of the 21st century. The consequences listed under the bars on the right of the figure are informed speculation about the predicted effects of climate change. The predictions of seven different models are displayed on the graph.

The IPCC scenarios in Figure 5 show that the major determinates of future greenhouse gas emissions will be social and economic development and technological changes. The consequences of which the IPCC warns are disturbance and destruction of ecosystems, the spread of parasitic disease around the world, sea level rise, and the loss of land that can be cultivated. However, the IPCC models are lacking an important point about sea level change according to James Hansen. Hansen argues that we are on the threshold of warming needed to melt major terrestrial ice sheets in the Antarctic and Greenland, some thing that threatens to raise sea levels 5-6 meters. The IPCC doesn’t account for the proximity of this calamity because they are only assessed gradual melting, changes in snowfall, and evaporation. Hansen argues that once ice sheets begin melting the positive feed backs could lead to rapid and complete melting of the ice sheets and then the destruction of coastal communities.

Challenges

Climate change isn’t happening only because the production of carbon dioxide and other greenhouse gases is increasing but also because the sequestration of carbon dioxide is decreasing- due to destruction of carbon sinks such as forests. By managing landscapes appropriately we have a chance to increase sequestration of carbon as well as reduce inputs of carbon dioxide into the atmosphere.
Figure 5. Reasons for concern about climate change impacts are related to the types of consequences that may occur. The temperature graph on the left shows observed temperature increases up to 1990 and the range of temperature increases projected after 1990. Each of the seven scenarios projects a different increase in temperature because of the different assumptions about development rates, technology use, population growth, and economic development. Each scenario results in different greenhouse gas emissions and consequently different projected warming. The bars in the right panel display five reasons for concern about the consequences of climate change. White indicates neutral or small impacts or risks, yellow indicates negative impacts for at least some systems, red means negative impacts or risks that are more widespread or of more serious consequence. These possible consequences exclude the possibility of “surprise” or “disaster” scenarios. The B1 and B2 scenarios assume that forested land will increase compared to 1990 levels. The A family of scenarios assume a continued decrease in global forested areas.13

Climate change presents all of us with a great challenge. We need to do more than think about solutions to the consequences of climate change, we should also act to avert the changes before they happen. Those of us in New England are responsible for contributions to climate change because of greenhouse gas emissions and due to serious wetland and forest destruction.15 New England, however, is one of the regions least likely to feel the serious effects of climate change so, why should we mitigate climate change when the consequences may never directly affect us? We will explore the ethical obligations of mitigating climate change in the next
chapter now that we understand what climate change is and what some of its effects may be. Though the effects of our actions may be far away from us in time and space we will see why we still have an ethical responsibility to act to mitigate climate change.
Option or Obligation?

*Applying Ethics to Climate Change*

Donald A. Brown offers a concise summary of the threats of global warming in *American Heat*. He states that due to human activities that produce greenhouse gases,

Oceans are rising, ice caps and glaciers are melting, disease infested mosquitoes are being seen at higher elevations, animals are changing migration patterns, more intense storms... are more frequently killing people and destroying communities around the world, and both droughts and flooding are increasing as the climate models have predicted they should.¹

This summary, offers a glimpse into the potential consequences of changing the chemical makeup of the atmosphere. Systems like the atmosphere, the carbon cycle, and the ozone layer are often called the life-support functions of the Earth. Though these processes can be distant from our everyday lives, they are essential for the survival of species on Earth.

Though humans are altering the environment in numerous ways, issues like climate change that involve these life-support systems, are unique in a few crucial ways. Such problems arise from the sum of numerous small actions, thus the impact from single person can be hard to see or conceptualize. It is not like holding an aluminum can in your hand and having to decide whether or not to recycle it. It is turning on a light switch, driving your car, using paper, everyday activities that have become habitual and trivial and yet contribute to the emission of greenhouse gases. In addition, alterations to these life-support systems are not always immediately felt, and when they are apparent, it may not be by those who are primarily responsible for causing the change. Something is fundamentally wrong with the current situation as our actions are putting those who we do not know at risk of harm and we are potentially depriving future generations of the rich biodiversity we inherited. It is for these two reasons that we must address the moral responsibilities of individuals in relation to climate change.
Tree Hugging: Responsibility, Ethics and the Environment

And so the story goes. For each blessing of modern technology, a corresponding risk comes into being, as the tail of the same coin. With each new invention comes frightful responsibility. –Louis Pojman

Humans are the source of the billions of tons of greenhouse gases causing global climate change. Someone is responsible; the details of who is responsible come from the realm of ethics, which offers a way to mediate the relationship among humans and between humans and the environment. Presently, the way we relate to the environment depends almost exclusively on human needs. According to Pojman, “Environmental ethics concerns itself with these global concerns: humanity’s relationship to the environment, its understanding of and responsibility to nature, and its obligation to leave some of nature’s resources to posterity.” The challenge becomes defining these ethical concerns clearly and applying them to our daily lives. Integrating the environment into the traditional ethical codes of humanity which inform our behavior.

Aldo Leopold’s The Land Ethic is one of the early attempts to extend ethics to include the environment, (including, animals, plants, water, soil, etc). He explains that we are citizens of the land community as opposed to its conquerors. Simply put, “A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it does otherwise.” He stresses the lack of an ethical relationship between humans and the land and claims that humans and the environment relate only through economics. This shallow relationship yields only privileges for humans and no obligations. In Leopold’s mind this type of relationship is bound to become exploitative. If we acknowledge that we have moral obligations to the environment, we should also consider how these obligations can be integrated into personal moral codes.

There are clearly challenges to accepting moral obligations, as Leopold explains they can be seen as limits on our freedom. Introducing obligations to the environment does not mean excluding our human needs, as may be interpreted from Leopold. Mary Midgely, a philosopher who has written extensively on ecological ethics, claims that we can distinguish between the two--obligations to humans and obligations to the environment-- based on the simple fact that we are human. She writes in Animals and Why They Matter, that there are two separate and equally valid types of claims, social and ecological. Rather than joining them as Leopold suggests, we should seek a balance between these two as a way to integrate environmental responsibility into
daily lives without feeling that we have to sacrifice human obligations. She describes our responsibilities to the environment as a whole, “But as beings forming a small part of the fauna of this planet we also exist in relation to that whole, and its fate cannot be a matter of moral disregard to us.” She suggests that our responsibilities to humans may come first, “as social creatures ourselves, we perceive and respond to the consciousness in others in a special way”. Like Leopold she acknowledges that we are members of a larger whole and as members we have responsibilities to the integrity of that whole. She extends Leopold’s land ethic to show that we have obligations to fellow humans as well as obligations to the environment.

In the case of climate change, obligations to humans and the environment go hand in hand. The changing climate will not only affect human welfare, but also forests and coral reefs among many others. Thus our moral obligation is to mitigate climate change wherever and whenever possible. It is important to realize that this responsibility falls on individuals. The sum of individual actions created the problem; individual actions can be the solution.

**Why change is so hard: I don’t think so, not today, not right now:**

If it is clear that actions that mitigate climate change are morally right, why isn’t everyone doing it? Why are people not living out their responsibilities to fellow humans and the environment? There are clearly obstacles that make acting responsibly difficult or unattractive. Pojman explains, “It is hard to get it right. It is hard to live moderately, wisely, and frugally; it’s hard to conserve our resources so that posterity will get a fair share.” In order to initiate any kind of action to mitigate climate change these barriers must be understood. Three of the major barriers are; a general ignorance of the magnitude of the problem and how personal life choices affect it; apathy relating to environmental issues, especially climate change that occurs slowly over a long period and is having little effect on those who cause the problem, and the issues of convenience and economics. These three issues, ignorance, apathy, and economics, have provided constant hurdles for addressing environmental problems.

Perhaps one or more of these reasons is why you are not personally concerned with climate change. Each of these arguments carries some weight, but the present threats of climate change demand that some compromise be reached between the barriers to change and the urgency of mitigating climate change.
But it doesn’t affect me, why should I care? Apathy and Climate Change

Between October 21 and 31, 1998, Central America was hit by most damaging hurricane in recorded history. Hurricane Mitch tore apart economies, infrastructures, homes, and families in a matter of days. The Consultative Group for the Reconstruction and Transformation of Central America offers this summary for Honduras alone:

For Honduras, Hurricane Mitch constituted an unprecedented catastrophe due to the devastation caused, the human and social toll and the losses and damages to its infrastructure and productive system. Nearly one third of the highway network was affected, with the consequent isolation of cities and productive zones; thousands of dwellings were destroyed leaving thousands of families homeless, many of them unemployed and with no source of income; there was likewise a negative impact on future production and exports, economic growth, employment and revenues. According to the National Emergency Cabinet, the hurricane caused the death of 5,657 people (without counting the 8,058 missing), injuring another 12,272 and initially affecting 1.5 million people (of the 6.2 million total population), but with the mitigation of the emergency, this last figure was reduced to 700,000, of which 285,000 remained in provisional shelters until the end of November. The preceding clearly portrays the human and social tragedy that Hurricane Mitch represented for Honduras. With respect to material losses, ECLAC estimated them at around US$3.8 billion, of which US$2.0 billion affected the social and productive capital of the country and the remaining US$1.8 billion on production.8

Perhaps some of the greatest threats that global climate change may present are due to the projected increases in both the frequency and intensity of storms like Hurricane Mitch. Though it is not possible to predict where and when such storms will occur, according to the IPCC they are likely consequences of global climate change.9 Hurricane Mitch might seem an extreme example, but other weather-related catastrophes of varying degrees are affecting people all over the world and doing so disproportionately. These extreme weather events affect tropical regions the most, especially island and coastal communities, and frequently third world and developing nations. Brown explains,

In summary global warming threatens many of the things that humans hold to be of the most value, that is, life, health, family, and the ability to make a living, community, and the natural environment. Therefore, the nature of the risk from global warming is enormous.10

Though they may not presently be close to us, the human lives at risk could one day be our children’s.

Humans are causing climate change, but understanding that other humans also feel the consequences is not always clear. This ambiguity denies the essential reality that humans, no
matter where they live, depend on the environment for their very existence. Apathy towards climate change is not only apathy to the condition of environment, but also to human life. When we alter global life support systems, not only are animals on the endangered species list going to suffer, so are other human beings.

The people affected may not be your neighbors. However, to motivate change a personal connection between daily activities and the global environmental consequences of those activities is essential. Brown even claims that we must trigger distress before change can happen;

To understand the climate change problem well enough to trigger distress at the unethical behavior of those who are causing it, one must understand things that are not immediately evident to the naked eye, such as how the burning of fossil fuels in the United States may affect people who are separated by great time and distance.¹¹

This time and distance should be no excuse for apathy. Peter Singer explains “The fact that a person is physically near, so that we have personal contact with him, may make it more likely that we shall assist him, but does not show that we ought to help him rather than anyone who happens to be further away.”¹² Time and distance do not absolve us of our responsibilities for our actions.

Our actions can make a difference. The apathetic often believe that personal action will never be significant enough to make a difference with such large-scale problems. Firor and Jacobsen explain this mentality in *The Crowded Greenhouse*,

Earth seems so large that many cannot imagine that it can be appreciably modified by the daily activities of ordinary people. To those in the fossil-fuel business, in some ways a romantic enterprise [advancing our technological achievement] it must be incredible to hear themselves branded as polluters who are ruining the climate. To those charmed by the excitement of rural life and unimpressed by the natural world, it seems that any climatic problem will bring forth new technological solutions that do not require changes in their present activities.¹³

Climate change is an issue for everyone, as everyone contributes. Commitments to mitigating climate change can seem overwhelming and require far to great a sacrifice if they to make a difference. This intimidating nature can make people retreat from the issue. This is no the case small changes make an impact. For example if you “Use energy efficient compact fluorescent light bulbs. Each one keeps about 1,500 lbs. of carbon dioxide out of the atmosphere over its lifetime”, or if you “Wash laundry in warm or cold water, not hot. At two loads per week, you’ll
save 500 lbs. of CO₂ annually."¹⁴ Finally, changing the way you manage your landscape can increase the amount of carbon your yard sequesters. It is crucial to realize that the choices for mitigating climate change are diverse and some mitigation will always be better than none.

**Global warming? But I am freezing! How Urgent is the Need For Change?**

In June of 1988, Dr. James Hansen, the then Director of the National Aeronautics and Space Administration (NASA) spoke to the Senate Committee on Energy and Natural Resources about the greenhouse effect, its potential consequences, and the need for political action. He said, “It’s time to stop waffling so much and say that this evidence is pretty strong that the greenhouse effect is here.”¹⁵ Since that presentation, the debates about climate change have not stopped, and the issue remains controversial. Skepticism about climate changes comes in many forms. In, *Trashing the Planet*, Dixy Lee Ray and Louis Guzzo offer one example of skepticism. They contrast examples of recent record cold winters and low temperatures with the record highs in that summer of 1988. They write, “the fact is, there is simply not enough good data on most of these processes to know for sure what is happening in these enormous, turbulent, interlinked, dynamic systems like [the] atmosphere.”¹⁶ These claims about the size, scope, and complexity, of the atmosphere have recruited many followers who are dubious about climate changes and the science behind it.

These criticisms are often used to ignore overwhelming evidence for the greenhouse effect and to resist taking action to mitigate it. According to Brown, “contrary to the understanding of many Americans, much of the science of climate change, including the basics for the conclusion that adding greenhouse gases to the atmosphere will cause some warming is quite sound.”¹⁷ Cold winters, especially record cold temperatures, feed these skeptical notions. Ray and Guzzo claim that we, the public, should remain skeptical until these “cold-spells” can be explained. The term *global warming* has become common knowledge to many Americans, but few understand its meaning. To most, global warming means simply, temperatures should be getting warmer, when in actuality temperature fluctuations in both directions are predicted depending on region. The conception of climate change as global warming seems quickly discredited when things get chilly. In reality the effects of climate change will be very diverse and will necessarily include surprises such as cold spells.¹⁸
In *The Crowded Greenhouse*, Firor and Jacobsen explain, “The climate system is much more complex than even the most elaborate model, so the chance that the model is missing some important factor cannot be entirely dismissed.”[^19] The scientific climate models do not claim to be flawless, but the uncertainty in predictions should not be grounds for complete dismissal of the consequences of climate change. There is a body of evidence that cannot be ignored on the basis of uncertainty and must be taken into consideration. The reality exists that there is uncertainty in predictions made about the magnitude of climate change effects and the rate of change, but there is another known truth that cannot be overlooked. An increase in greenhouse gases will have a negative impact on the life-support system of the plant.

Humans produce greenhouse gases and have the capability to abate the amounts. Ray and Guzzo, climate change skeptics, are correct in pointing out that the climate system is complex and challenging to fully understand, and they even write,

> the alteration of the chemical content of the air by human production of greenhouse gases, however, is something that man can control. And because no one knows the ultimate consequences of the heightened CO₂ might be, it is reasonable and responsible to reduce human contribution wherever possible.[^20]

Brown, in *American Heat*, echoes this claim in regard to uncertainty and writes, “even if one assumes that there is considerable scientific uncertainty about the timing and the magnitude of human-induced climate change, the United States has a strong ethical duty to reduce its greenhouse emissions.”[^21] For both skeptics and the convinced, uncertainty does not seem to be grounds for dismissing our ethical responsibilities to mitigate climate change. If we know that greenhouse gas emissions have the potential to have far-reaching, negative environmental effects, then our failure to reduce emissions is putting people and the environment at serious risk.

Behavior that puts other human beings at risk is an ethical issue, “those who engage in risky behavior are not exonerated because they did not know that their behavior would actually cause damage.”[^22] If behavior is known to be risky citing uncertainty to get out of the consequences is not valid. To avoid putting others at risk it may be necessary even to mitigate a problem that we do not fully understand. The notion of taking action even when the consequences may not be known is often called the *Precautionary Principle*. This idea is a common part of our lives. We all know the phrase, “better safe than sorry”. The precautionary principle links environmental change and ethical responsibility. Even though the negative consequences of climate change are not certain, the Precautionary Principle suggests that acting
to avoid such consequences is prudent and morally right. The precautionary principle need not only apply to government policy, it can also govern everyday life. Uncertainty about the potential effects of global climate change should no longer be grounds for not taking personal or political action to mitigate the effects. If we wait and wait for there to be “enough” evidence, it will be too late.

**Environmental Ethics & Economics: Doesn’t it all come down to the bottom line?**

Economic analysis is often chosen to determine if some action is too costly. Applying economic analysis to global climate change, however can be extremely challenging because is it difficult to place economic value on certain elements of the natural world. A perfect example is the life-support function of the earth. Articulating its dollar is virtually impossible and even implausible, though it has been attempted.23

Cost benefit analysis (CBA) offers one example of the complicated relationship between economics and the environment. Simply stated, this approach assesses the costs and benefits of a certain action or project (see chapter 5). If the benefits outweigh the costs, the action is considered favorable. This seems a very reasonable approach; however, there are certain dangers in using CBA to analyze environmentally related projects and policies. Are the motivations behind the CBA ethically sound? Whose welfare is the concern of the CBA and over what time period? These are important questions, and only a few, that have to be asked before a CBA can be useful in making decisions. Of course, CBA is only one example of economic analysis, but it offers insight into the disjointed relationship between environmental worth and economic worth. In order to make decisions on action we will likely need ways of defining value that extend beyond dollars and cents.

At a more fundamental level than economics are our moral obligations and responsibilities. As Leopold outlined we are members of a larger community and have obligations to the larger whole. He states that humans cannot consider themselves merely as controllers reaping benefits from the greater system, but as responsible members of a land community. Aldo Leopold claims we are one of many interdependent parts. Rachel Carson echoes our role as a member of this larger biological community that we depend on, “The question is whether any civilization can wage relentless war on life without destroying itself.”24
We exist as part of a system and in tampering with that system we tamper with our own lives and the lives of others.

Realization our position as members of this land community and the accompanying moral obligations our approaches to decision making should include more than basic economic analysis. Leopold explains in *Land Ethic*:

> The ‘key-log’ which must be moved to release the evolutionary process for an ethic is simply this: quit thinking about decent land-use as solely an economic problem. Examine each question in terms of what is ethically and esthetically right, as well as what is economically expedient.\(^{25}\)

He attests that our interests cannot purely be economic due to our moral obligations. It seems that in certain cases, moral responsibility trumps economic value. Hence, economics cannot provide a valid excuse for not doing what is morally right. Economics will always play an important role, and the point is not to reject economic considerations completely, but instead to change the way we consider them—to prioritize economics as merely one among several bases for decision making.

**Excuses Aside, We Have an Ethical Responsibility to Act**

It is now clear that issues of uncertainty, apathy, or economics, are not excuses for ignoring ethical responsibility for our actions. Because we understand the potential consequences of climate change we are obligated to put that knowledge to use. Leopold describes one of the penalties of acquiring knowledge,

> One of the penalties of an ecological education is that one lives alone in a world of wounds. Much of the damage inflicted on land is quite invisible to laymen. An ecologist must either harden his shell and make believe that the consequences of science are none of his business, or he must be the doctor who sees the marks of death in a community that believes itself well and does not want to be told otherwise.\(^{26}\)

The current and projected effects of climate change are clearly wounds that may be invisible to many in America, but are no longer invisible to you. By knowing these wounds you have assumed the role of doctor who has an obligation to heal the society that thinks itself well. It should be clear that there this is not a call to change your entire life, but instead to recognize the problem and begin taking steps to be a part of the solution. Rachel Carson explains this challenge, “I think we’re challenged, as mankind has never been challenged before, to prove our
maturity and our mastery, not of nature but of ourselves.” In order for change to occur, we must change ourselves and significant changes may even be small and simple.

These changes we make must be educated and methodic. Leopold writes,

The evolution of the land ethic is an intellectual as well as an emotional process. Conservation is paved with good intentions which prove to be futile, or even dangerous, because they are devoid of critical understanding either of the land, or of economic land-use.

In the following chapters we offer examples and recommendations for how to start making modifications that mitigate climate change. Such actions represent the moral obligation we have to the environment as well as to each other. These guidelines can be applied on both small and large scales, from personal backyards, to institutions managing hundreds of acres. Regardless of size, the following chapters guide you through a landscape poised to make a change. By looking closely at Wellesley College’s picturesque grounds, we can trace the history of a landscape from its original molders to the present and finally, to a future in which landscapes evolve to meet the needs of a dynamic planet and embody our moral obligations to nature and others.
Clockwise from top left: House typical of the country homes built by wealthy Bostonians in Wellesley and neighboring towns; a picturesque autumn vista of Lake Waban; Rhododendron Hollow, Wellesley College; Winding, naturalistic paths, Wellesley College;
Clockwise from left: the landscape integrated with sport and human activity; the rolling hills of Wellesley’s campus, illustrating how buildings were constructed with topography in mind; one of the most wooded, natural areas of Wellesley’s campus; a typical Olmstedian design.
Remembering Our Roots

Around you white pines with single trunks four to six feet across\(^1\) rise 250 feet into the bright blue sky—150 feet taller than the surrounding oaks, hickories and maples. \(^2\) Between the forests, “Quaking bogs,” consisting of thick mats of sphagnum moss and other wetland plants appear to create a solid surface; however, open water exists beneath the mat, such that when trod upon, the bog quakes. \(^3\) Swamps of red maple, alder and willows delineate other wetlands. The forests themselves create a “mosaic of tree stands” tremendously diverse in
Clockwise, starting top left: Red Maple swamp, Wellesley College; wetlands on the shore Lake Waban, Wellesley College; white pines, Wellesley College; diagram of a quaking bog; Jack in the Pulpit, a native wetland plant (*Arisaema triphyllum*).
their composition, even within relatively small areas. The small area that we now call Massachusetts boasts a greater variety of trees than any European nation. Yet everything is not an impassibly dense forest. The forests themselves are open, with only patches of shrubs and saplings. Forests are moist, facilitating the growth of lichens, mosses and epiphytes. In sunlit meadows, an unknown array of grasses and herbs flourish. Wild fruits abound where meadow grades into forest, and the animals that feast in these lands represent an impressive cross-section: turkeys, wolves, lynx, bear, eagles and more. Migratory birds flock overhead, particularly as one nears the coast. The topography of this abundant land, sculpted into rolling hills by glaciers millennia ago, includes kettles, eskers, kames and drumlins. Changes to this scene occur at the hand of nature—hurricanes and forest fires take responsibility for occasionally clearing the land of the lush vegetation.

Where are you? You are standing in New England, just west of present day Boston, but you are looking at a land as it was centuries ago, unaltered by European colonists.

The year now is 2004. The old-growth forests and abundant diversity of flora and fauna have fallen to development. It seems that no space remains untouched, particularly along the coasts and within the sprawling suburbs circling major cities. Colonists felled forests for farmland and timberwood and drained the much contemned swamps. The white oaks, hickories, pines, chestnuts, hemlocks, alders, willows and cedars have all drastically diminished, not only in abundance, but also in size and area of coverage. Generations of people have exerted tremendous effort into conquering the land, from the “dismal swamps” to the dark, feared, wild forests. In the Eastern Massachusetts area in particular, the Wampanoag Native American tribe, after whose chief Wellesley’s Lake Waban is named, turned meadows into farmland and hunted in the area. Farming by the European colonists who replaced them continued for generations, and the great forests were reduced to pastures and plowed fields where soils, which had taken eons to develop, eroded. As eastern farms failed in changing economic times and the upper crust of Boston Society sought refuge in country homes, Wellesley and neighboring towns became the sites of such estates; the land could still sustain hillside orchards, family vegetable patches, and small herds of livestock turned out into the meadows. Centuries came and went, and now the images of wolves and 250 foot pines seem fantastical—not only of another time, but seemingly of another place all together.
While we may feel that the wilds of the first scene are long gone and irrecoverable, the opportunity to reclaim nature still stands before us. Attaining the scale of the “wilderness” that once existed may no longer be possible, but within even small plots, efforts can be made to embrace and nurture the great potential of the land, the potential for renewed diversity and abundance.

**Wellesley**

In the late 1860s and early 1870s, many small tracts of unproductive land along the shore of Lake Waban were patched together by Henry Fowle Durant to form an estate for his young son. It was to be a place of natural beauty—flowering meadows and emerald forests on the shore of a glistening lake. Under his direction, the over-worked land began to be restored to a more three-dimensional form; trees and shrubs began to emerge from the barren farmlands. When his young son died suddenly, Durant and his wife Pauline envisioned a college for women in this picturesque landscape. That campus and school, Wellesley College, serve now as an example of why and how the nature of New England has been preserved and the potential that Wellesley and other small landowners have to manage their property to meet the challenges of mitigating global climate change.

People and institutions annually invest astounding amounts of money into their landscapes—the money spent on landscaping reached $14.3 billion in 2002—primarily for the aesthetic benefits, and there are certainly ways in which this money can be spent preserving both the beauty and the health and biodiversity of the land. In fact, the choices made by small landowners, such as Wellesley College, have much more far-reaching effects that the decision-makers tend to consider. As may be true of many small land holdings, much has changed during the past century, but much from earlier times remains. We will explore the potential that the land still offers, how it can recover from change and how human-initiated change can have an ameliorative effect as well. While pursuing our goal of managing a landscape, such as that of Wellesley College, to mitigate climate change, we also seek to respect the original integrity of the land as well as recognize the needs and desires of the current landowners.
Setting the Stage for Development: The Times, the Visions, the People

Henry Durant’s vision for Wellesley was indicative of a broader understanding of landscapes in the mid to late nineteenth century. Prominent landscape architects nationwide were moving away from intensely manicured, precise gardens into more free-flowing naturalistic designs. Urban areas received special attention, particularly from the notable landscapes architect Frederick Law Olmsted and his son, F.L. Olmsted, Jr. The bleak landscape of Wellesley was not an anomaly of the era; these architects operated when deforestation in New England was near its peak.

In the late 1800s, Frederick Law Olmstead, with an eye for both beauty and function, began transforming such bleak landscapes back into swathes of green. The Boston Fens and Riverway serve as prime examples of his work. Olmsted and his associates managed to turn polluted, degraded city lands into “habitats that enhanced human health safety, and welfare while they reintroduced a sense of the wild into the heart of the city.”\(^{10}\) For once, instead of being filled in and destroyed because people viewed them as useless breeders of pestilence, wetlands were created. These natural elements became part of a city network that incorporated utilitarian elements such as roads and sewers. Overtime, these naturalistic landscapes became so convincing that people began to believe that they were remnants of a “forest primeval” rather than a well-grown garden on a large scale.\(^ {11}\)

Olmsted’s designs gained wide regard, as did A.J. Downing’s vision of a picturesque landscape, one that derives its beauty as much from “a certain spirited irregularity, surfaces comparatively abrupt and broken, and growth of a somewhat wild and bold character.”\(^ {12}\) For Olmsted, the wild, naturalistic landscape served to bring “true nature” to those who would not otherwise have easy access to it.\(^ {13}\) In many ways, this concept is visible in the Wellesley College landscape. Here, students can constantly be heard bemoaning their busy schedules and chaotic life. Yet many students make time to take a walk around the lake—considered a thoroughly relaxing departure from the rest of Wellesley. In the walk around the lake, once you depart the fringe of the wetlands just beyond Paintshop Pond, paths take you up onto forested hills. There, it is hard to believe that the walls of Clapp Library are just minutes away. Olmsted also understood that people needed to be comfortable in their landscapes, and saw green space as potentially having a tremendous effect on the lives of people who operated in these spaces. The outdoors were a place for social gathering, exchange, relaxation, recreation and calm.
A British landscape designer, William Robinson, also influenced the pervading sense of being in natural surroundings at Wellesley. He maintained that gardens need not be small, confined and labor intensive, but rather that the entire landscape could be designed as a garden when one planted perennials, ornamental shrubs and trees that would become self-sustaining in a matter of years.14

By the early 20th century, landscapes nearly everywhere across the United States had begun a sort of homogenization. “Diversity and difference were eliminated because of maintenance procedures, budgetary concerns, safety issues and aesthetic taste; the landscape evolved into a stripped down version of the pastoral, a type of collegiate suburbanization.”15 Wellesley was no different. The homogenization arose in part because of the simplicity and cost-efficiency of maintaining a homogenized landscape and in part because of the increased emphasis on convenience and safety. By the early 1930s, “with energies and attention focused on the spaces of new construction, the surrounding meadows and woodlands began to decline from lack of careful maintenance. Wellesley too fell victim too this. Landscape architect, Fletcher Steele, drew attention to the “impact that a series of small decisions and acts can have on a landscape. Little by little, without intent, the “balance of nature” that was intrinsic to the landscape’s integrity was being altered.”16 Areas that had once appeared distinct from one another, each host to their own variety of species, have now merged into “one amorphous, smooth and generic open space or green space…. This is a trend in campuses across the country as ‘Buildings and Grounds’ has given way to ‘Facilities Maintenance.’”17

Another major cause of the degradation of the integrity of the landscape came with the advent of personal automobiles. In the late 1990s, the Wellesley Alumnae Magazine cited that there were 1,911 vehicles registered to park on campus.18 This change began primarily after WWII, for prior to that, “regardless of the point of entrance, up through the 1940s the various designers and planners relegated the road and the automobile to a secondary role.”19 However, as cars became an increasingly common possession, the campus began to adapt to the cars, covering more areas with roads and parking lots than had ever been needed before. Automobiles have also received blame for causing less walking around campus—by students, faculty and staff—such that they have become less aware of and attached to the landscape.20
**Wellesley: Her Missions, Her Pride, Her Integrity**

In order to understand the contemporary purpose of and vision for the Wellesley College landscape, one should have an understanding of the historical roots of the campus. Henry Fowle Durant, and his wife Pauline, Wellesley's founders, staunchly believed in expanding the educational opportunities available to women. From its opening in 1875 and throughout its 127-year history, Wellesley has remained one of America’s most distinguished liberal arts colleges, continuing as a renowned institution for the education of women. The College’s mission is to "provide an excellent liberal arts education for women who will make a difference in the world." Given the unique origins of the college as an institution designed especially for women, it established specific objectives for its landscape. Historian Elizabeth Meyer notes,

> “In site plans of our campuses, we can often read the history of each institution, its periods of growth, its moments of pedagogical change, its responses to shifts in society, and its attempts to reconcile new technologies… [it] also offers a window into the particular college’s relationships to the land, from the philosophical and symbolic to the pedagogical and functional.”

The way in which we are to perceive the purpose of the Wellesley College landscape today is shaped by the ways in which it has been perceived and thus altered over the course of the College’s history. There is no doubt that the site of the college abounds with intrinsic beauty, and that over time, this beauty has become synonymous with Wellesley itself. Alumna Helen Lefkowitz Horowitz contends “what makes the experience of Wellesley’s daughters different from that of the daughters of other alma maters is that it is framed in the glories of the College landscape.” Such natural beauty is unusual, and with the homogenization plaguing America, it becomes evermore rare.
As such, one purpose of our landscape is to honor this natural beauty and extol its virtues. As a means of doing this, Wellesley designers strove to accentuate the topography, integrating the design of the campus into the glacial hills and dales. The resulting beauty can provide solace and a sense of tranquility to the members of the community. “We hold that the terrain should largely determine the placing and alignment of buildings, wherever the orientation shall permit, regardless of academic regularity…. And that the buildings and groups should grow out of their sties and environment, not impose themselves on them, and that the great and beautiful features of hills, valleys, meadows, groves, and winding roads should be preserved inviolate, and as a setting for architecture akin to them, not rebellious against them.”

Though now extinct, for decades Wellesley once had ceremonies and celebrations intimately tied to nature. There are numerous images in the college archives of students dressed for Tree Day, as well as for celebrations of Flower Sunday, May Day, and Float Day.

Another purpose of the Wellesley landscape seems to be to bestow airs of greatness; people are certainly of the mind that a beautiful campus is likely to be full of lovely, intelligent women. The famous colleges at that time all sported designs that were pleasing to the eye, a combination of gothic architecture and enclosed courtyards, such as at Yale, and vast lawns in some places, notably the University of Virginia. A pre-eminent college should have impressive grounds as well. This notion is amplified when put into a historical context – by keeping elements of the landscape constant, there is a daily visual reminder of Wellesley’s prestigious history, and the greatness of its growth and achievements throughout the decades. By maintaining these visual ties to the past, for example, the rhododendrons in Rhododendron Hollow, dating from the mid-1800s, for example, were presented to the Durants by the Hunnewells, who occupied the neighboring estates in the mid 1800s.

The campus landscape has served as a classroom since the inception of the college, and it continues to do so. From biology students taking water samples in Lake Waban to botany classes touring the arboretum, to tennis classes learning the game on the courts by Billings Hall, there is definitive function to the landscape. Adamant professors have played important roles in shaping the direction of development. Helen Davis maintained that there should be one wild set of plants that is pedagogical, showing the natural growing state of the plant, and another should be ornamental, showing the plant’s contribution to the overall beauty of the campus landscape. The botany and horticulture classes, as well as the organismal biology, ecology and
environmental studies classes all integrate the campus into their curriculum. One of the Art History classes, Landscape and Garden Architecture, taught by professor Peter Fergusson, spends many class periods studying and discussing the campus landscape.

Wellesley’s landscape is unique in its original political purpose of underscoring the “values and aspirations of women’s education.” Even as plans for the college have changed, designers were continuously conscious of a need “to provide for landscape places that instructed, inspired, challenged, cajoled and consoled.” In addition to the instructive and academic opportunities afforded by the landscape, there are four other areas of personal development that tie to the landscape. The Durants were meticulous in their desire to provide grounds for physical growth, and it is said they often walked the campus with the students. Thus, Wellesley was a pedestrian-oriented campus, with walkways and long, winding paths that helped fortify the physical strength, stamina, and overall general health of the students. The addition of the sports fields and the boathouse further accentuate a devotion to wellness. The landscape was also seen as an important factor in the emotional and psychological growth of the students. Being surrounded by a beautiful, harmonious environment can have a soothing effect upon the students, and imbue them with a sense of tranquility; provide spaces for contemplation and relaxation. The campus can also facilitate a certain moral or spiritual growth. Living surrounded by such a beautiful homage to nature, one can forge a connection between the individual and the land. It is the hope that this connection will raise awareness of the intrinsic value of the environment and of the biodiversity it sustains, inspire greater appreciation within the student, and help to build up one’s own identity as a student contemplates how she fits into the greater picture of Nature. Finally, in keeping with the Olmsteds’ belief that the landscape should accentuate social life, the campus landscape is to enhance the sense of community. This sense is fortified through shared appreciation of the landscape, as well as the holding of ceremonial activities upon various traditional areas of the landscape.

Keeping these goals in mind, the overall landscape and architectural design of Wellesley follow these ideas of land and construction:

• Winding walkways and roads that curve through the various forms of landscape in a scenic panorama, thus creating a pedestrian system of movement within the campus.
• Allowing meadows, marshes, and fields to grow in their natural state, with irregular borders, wild-grown plants, and in natural, organic shapes and forms.
• Preserving the forests, the specific tree and plant species, and alternating between different landscape forms: woods abruptly turn into grassy fields that change to shrub hedges that change to manicured lawns, etc.
• Harmonizing the diversity of plants, trees, topographical structures with the architecture.

Over time, the college landscape has developed, fluctuating between attending to the needs of expansion and convenience, and a desire to remain true to the extolled beauty of the campus and a belief that the landscape is worthy of protection in and of itself. Faculty, students, administration and the Board of Trustees all weigh in on how the landscape should be managed; the final decisions integrate issues of safety, beauty, convenience and ecological responsibility. Wellesley College President Diana Chapman Walsh comments, “Anyone who has lived, studied or worked at Wellesley College for any period of time carries experiences of the campus that are vivid and visceral. Every Wellesley alumna knows that her education was greatly enriched by the special beauty of the campus… the landscape [is a] focus of energy and attention …for me and for many of my colleagues in the administration, the faculty and the Board of Trustees.”

Wellesley Today

The question then becomes: Does the purpose of the Wellesley landscape connect to a sound plan for environmental management – can the college retain regard for the environment while remaining true to all that the College landscape embodies? Is there hope for maintaining the integrity of the historical landscape given the demands of the college today and the relative degradation and homogenization of the past decades?
The answer is a resounding Yes! It is absolutely possible. Durant’s designers were proficient during an era of extensive deforestation – and yet they realized the potential of recreating and restoring a bountiful landscape – this potential carries over into today. Just as Olmsted created the Riverway and Fens with a utilitarian purpose underlying the beauty of green space, Wellesley is at this very moment undertaking such a feat. Backhoes are moving earth in the area formerly known as the “Service Lot” which is destined to become known as “Alumnae Valley.” The former parking lot, with the soil having sustained years of runoff from over one hundred vehicles, is going to be recreated as a wet meadow tapering down to the shores of lake Waban. The former Paintshop Pond site—filled with enough toxins that people whispered rumors of it becoming a superfund site—has been (under the oversight of the Massachusetts Department of Environmental Protection) completely reconstructed into new playing fields (under which the waste is contained) and revitalized wetlands that serve as natural habitat, a sink for carbon, and an aesthetic addition to the shores of Lake Waban.

Many environmentalists and landscapers alike equate development with destruction and scorn any further encroachment upon “untouched” lands. What Olmsted would have us recall is that humans cannot only serve as destroyers of nature, but they can also be instrumental in helping to maintain and rebuild it. As Wellesley proceeds to develop, the college must be ever-conscious of its effects upon the land, making every effort to enhance the natural surroundings. In as much as we seek to provide conveniences to students, faculty and staff, we should keep in mind the integrity of the land, the dependent creatures that dwell in its habitats and the many benefits the college and its inhabitants derive from a verdant campus. And if none of these reasons serve to convince, then perhaps it is best said through Wellesley’s mission. Wellesley is a place for women who will and women who do. Part of perpetuating this theme in history is perpetuating responsible social and environmental action.

**Beyond Wellesley**

A critical tenet of A.J. Downing’s writings is that the mosaic-like landscape improves upon the natural landscape. This idea of beauty allows Wellesley to create a variety of spaces, and the principle applies broadly to most small land-holders. Huge forests are not on the scale of possibility for most land-owners, but according to Downing, they need not be to maintain the integrity of the landscape. Thus, even in areas like the Service Lot valley that have been far
more utilitarian than aesthetic over the past years, there is hope for restoration. Author Anne Whiston Spirn writes about the work of Olmsted, Sr.’s work in restoring the desolate lands of the Vanderbilt’s Biltmore Estate in North Carolina,

“The powerful lesson of Biltmore is what human impulse can accomplish given sufficient time, with an eye to restoration and beauty, as well as to utility. One hundred years ago there was no forest at Biltmore, just cut-over woods and infertile fields. Now there is forest. Olmsted had the designer’s faith that he could make something better, not worse. Key to his belief in himself was the ability to envision the future shape of the landscape, to guide it over time, and to imagine human intervention as potentially beneficial, not invariably detrimental. He aimed to demonstrate how human intervention could make a forest more beautiful and more productive, provided one pursued long-term goals and a gradual return on investment, rather than short term goals and maximal profit.”28

Respect for the land as it translates into a respect for the greater environment and well-being of the world around us fits naturally with the goals and needs of Wellesley College, but it does so for many individuals and firms as well. Many people feel a need to maintaining the integrity of the land, and it seems reasonable to extrapolate this into respect for the Earth at large. We feel a sense of responsibility to future generations to leave the land alive and continuously viable. In our quest to create landscapes that imbue physical, mental and spiritual well-being, we must retain as much green space with as great a diversity of topography and habitats as possible. Anyone would concede that it is much harder to achieve relaxation in concrete-filled, lifeless spaces.

The same things that we should minimize because of a concern for pollution and carbon emission—cars, for example—disturb the serenity of the natural landscape. The goals of aestheticism and environmentalism coincide more often than one might expect. More green space leads to more carbon sequestration; fewer cars lead to fewer emissions. And if no other argument is convincing, we must recognize and honor the intrinsic beauty of the land and the world’s environment, taking the measures that we can to insure that the beauty lives on for generations to come.
Carbon budgets, quantitative accounts of carbon gains and losses, can be tailored to assess human impacts on the carbon cycles of systems as large as the biosphere or as small as your backyard (Fig. 1 The carbon cycle). Alteration of the carbon cycle, such as the increasing concentration of carbon as carbon dioxide in the atmosphere, has tangible effects. These alterations are primarily responsible for the greenhouse effect and subsequent climate change.\textsuperscript{1} Since the industrial revolution, humans have been releasing increasing large amounts of carbon dioxide into the atmosphere by burning fossil fuels and altering land use (ex: converting forest to cropland).\textsuperscript{2} The carbon level in the modern atmosphere is now about 30% more than in recent historical times. Stabilizing atmospheric carbon entails mitigating carbon sources and encouraging carbon sinks. Carbon sinks absorb carbon from the atmosphere; a source, on the other hand, releases it into the atmosphere. Carbon sequestration refers to sinks that remove and subsequently keep carbon out the atmosphere for a long period. Such carbon sequestration can be promoted by means of landscape management.

Understanding the nature of carbon budgets and society’s direct effects on carbon budgets is crucial for effective global climate change mitigation. To encourage carbon sequestration, we must first identify the sources and sinks of carbon in a landscape. This chapter explores carbon budgets by habitat type in a small, managed landscape, the Wellesley College campus, and provides a scientific basis for the next chapter’s recommendations for mitigating global climate change through landscape management. We consider six habitat types: woodlands, groves, meadows, turfgrass (irrigated lawns), wetlands, and freshwater lakes.

Calculating carbon budgets can be very complicated,\textsuperscript{3} and therefore, both time-consuming and expensive. A wide variety of techniques exists for quantifying carbon budgets. One method entails using computer models to simulate carbon cycles for a variety of habitats by
accounting primarily for photosynthesis (carbon uptake by plants) and respiration (carbon release by living organisms, including plants and animals). With these modeling techniques, different habitat types can be simulated to reveal how different management choices might influence carbon uptake or release. In the field, biomass assessments can provide insight into above ground carbon storage, and soil analyses reveal carbon storage and release by soil. Sampling carbon dioxide at multiple heights from towers, combined with sophisticated mathematics representing the turbulent flow of air, offers one method for obtaining accurate measurements of carbon dioxide concentrations in the air over a landscape with multiple habitat types. Especially when dealing with large areas with multiple habitat types, a combination of assessment techniques (each specialized for a particular habitat type) offers the best and most accurate way to calculate a budget. Using these types of methods, extensive previous research has established sequestration rates for many habitat types.4

We estimated carbon budgets for the habitats of the Wellesley College campus by using sequestration rates, found in the primary literature, for habitat types similar to those found on campus. The total area for each habitat type was multiplied by the respective sequestration rate, and these estimates were then summed to determine the annual carbon sequestration for the campus landscape as a whole. Finally, we compared these data with annual campus emissions to determine a comprehensive carbon budget for the campus.

**Carbon Budgets: A General Description**

<table>
<thead>
<tr>
<th>General Cycle</th>
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<tbody>
<tr>
<td><strong>Sources</strong></td>
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<tr>
<td>Fossil Fuel Use</td>
</tr>
<tr>
<td>Deforestation</td>
</tr>
<tr>
<td>Decomposition</td>
</tr>
<tr>
<td>Respiration</td>
</tr>
<tr>
<td><strong>Sinks</strong></td>
</tr>
<tr>
<td>Live Biomass</td>
</tr>
<tr>
<td>Dead Organic Matter</td>
</tr>
</tbody>
</table>

- No two carbon budgets are exactly the same.

Carbon constantly cycles through terrestrial ecosystems, aquatic ecosystems, and the atmosphere. Plants act as the main driving force of the carbon cycle. To produce carbohydrates, plants photosynthesize, absorbing carbon dioxide from the atmosphere and releasing oxygen. Animals, ranging from microbes to humans, and plants themselves, "burn" these carbohydrates to fuel biotic processes. This burning process, respiration, releases carbon dioxide. Carbon is also released by respiration during decomposition of dead organic matter (i.e. dead
plants and animals). Respiration returns carbon that was taken up by plants to the atmosphere as carbon dioxide. This is the basic cycle. Specific carbon budgets can vary greatly among habitat types. Differences in habitat type, plant species composition, availability of solar energy, water, and other essential elements affect where carbon is located, how long it is stored, and how fast it is returned to the atmosphere. Consequently, no two habitats have exactly the same carbon budget.

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Carbon Budget: Woodlands

Woodlands have an understory, including woody and herbaceous plants, and are dominated by trees. Carbon enters the forest ecosystem via photosynthesis. It is then stored in the biomass of the plants or in the forest soil. Carbon is released into the atmosphere via plant, animal, and microbial respiration. Most microbial respiration is associated with the decomposition by bacterial fungi of dead plant material. Disturbances such as fire can greatly enhance the rate of return of carbon to the atmosphere. Carbon can also exit the forest ecosystem through animal consumption, harvest, or leaching. Carbon residence time (the amount of time carbon remains ‘locked up’ and separated from the atmospheric reservoir) in forests depends on the lifespan of trees and the retention time in forest soils. On average, residence time for carbon in large trees of a Northern temperate forest is 65 years. Carbon residence time can be reduced by factors such as logging, forest fires, or plant diseases.

Forests act as a net sink for carbon. Forests in the United States sequester from 1,013 to 1,158 kg C/ha/year (Table 1). Variation is mostly due to differences in rates of photosynthesis and seasonality. In the summer, plants sequester more carbon because net primary productivity (photosynthesis) is high. During the winter, on the other hand, photosynthesis is low, and primary production is typically exceeded by respiration. In other words, many trees release more carbon than they absorb when they are not photosynthesizing, such as in the winter. Trees
Table 1. Carbon sequestration (kg/ha/yr of carbon) by common habitat types found in northeastern United States.

<table>
<thead>
<tr>
<th>Habitat type</th>
<th>Description</th>
<th>Carbon sequestered (kg/ha/yr)</th>
<th>Sum area at Wellesley (ha)</th>
<th>Annual sequestration sum (kg C/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lakes(^{10})</td>
<td>Small (&lt;500 km(^2)), meso- to eutrophic lakes</td>
<td>270</td>
<td>42.61</td>
<td>11,505</td>
</tr>
<tr>
<td>Wetlands(^{11})</td>
<td>Temperate wetlands of Northeast U.S.</td>
<td>480</td>
<td>10.42</td>
<td>5,002</td>
</tr>
<tr>
<td>Meadow(^{12})</td>
<td>Cold, humid grassland</td>
<td>400 – 800</td>
<td>4.48</td>
<td>1,792 – 3,584</td>
</tr>
<tr>
<td>Turfgrass(^{13})</td>
<td>Golf course fairway</td>
<td>817</td>
<td>32.94</td>
<td>26,895</td>
</tr>
<tr>
<td>Grove(^{14})</td>
<td>Groves of Northeast and North Central U.S.</td>
<td>850 - 972</td>
<td>22.87</td>
<td>19,439 – 22,229</td>
</tr>
<tr>
<td>Woodland(^{15})</td>
<td>Forests of Northeast and North Central U.S.</td>
<td>1,013 – 1,158</td>
<td>83.88</td>
<td>84,962 – 97,099</td>
</tr>
</tbody>
</table>

with a higher leaf area index (leaf area per unit ground area) tend to be more productive, and therefore, sequester more carbon.\(^{16}\) Tree species differ in the amount of carbon stored in both wood biomass and the soil. For example, the carbon content of the wood of pine trees is 197 (kg/m\(^3\)), compared to 317 (kg/m\(^3\)) for oak-hickory stands.\(^{17}\) The mean carbon density of soils in Oak-Pine forests and Oak-Hickory forests is 6.8 (kg/m\(^3\)) and 8.3 (kg/m\(^3\)), respectively. Furthermore, carbon storage is dependent upon forest age. As trees mature, they grow at a slower pace and rates of photosynthesis tend to decrease;\(^{18}\) however, long-lived species are likely to sequester more carbon over time than short-lived species.\(^{19}\) Each component of a temperate forest makes a separate contribution to the total carbon sequestered: soils (50%); living trees (33%); woody debris (10%); the forest floor (6%); and the understory herbs and shrubs (1%).\(^{20}\)
Sources of CO₂ emissions from forests arise from decomposition, which occurs via respiration by bacteria and fungi. Of all the carbon pools previously listed, woody debris is the only pool that acts as a consistent source of carbon. Fire can release virtually all of the carbon stored in forest biomass. Without disturbance, however, sources of carbon from the forest ecosystem are quite small, relative to the sink components.

How forest carbon sequestration rates will change with the projected rise in atmospheric CO₂ and global warming has been debated. Some studies have shown that organic carbon in the soil under carbon dioxide enriched forests actually increases by 10%. Increased carbon dioxide may also cause an initial increase in plant growth, but scientists disagree on whether such growth is sustainable; it may eventually taper off. Furthermore, if the plants are more frequently nitrogen or water-limited due to changes in climate, increases in plant productivity will not occur and may even decline.

### Carbon Budget: Groves

Groves are woodlands without an understory, and they may also lack a litter-covered forest floor. The ground beneath the trees is typically covered with grass or nothing at all, leaving the soil bare. The carbon cycle of groves functions in a similar way to that of woodlands with a few small differences. Carbon enters grove vegetation as CO₂, taken up during photosynthesis. The carbon is then stored as biomass in the trees (primarily in trunks and large roots) and the grass (primarily in roots). Trees and grass continually process and store carbon over the course of their lifetimes. Dead trees store accumulated carbon until it is released by decomposition or burning. All carbon stored as biomass is eventually released into the atmosphere through plant respiration or decomposition. The latter may be greatly speeded up by disturbances such as premature death (e.g., due to disease) or disturbance.
Furthermore, since groves are an artificial habitat, created by management, dead or dying trees are usually removed before they have fallen.

Figure 3. Grove. Note the lack of woody vegetation under the trees.

Groves are considered carbon sinks and sequester from 850 kg C/ha/yr to 972 kg C/ha/yr.\textsuperscript{26} Although groves sequester less carbon than woodlands due to the absence of understory vegetation and a litter-covered forest floor, these differences in structure also result in fewer sources of carbon.\textsuperscript{27} Soil organic matter is the major carbon sink in groves. Carbon is added to the soil through root exudates, root death, and animal droppings. Grass facilitates soil carbon storage, because grasses can put as much as half of the carbon they fix into their root systems.\textsuperscript{28} Carbon, however, can be lost from the soil through respiration by soil microbes, soil erosion, and surface and ground water run-off. Soil disturbances, such as aeration treatments, compaction due to vehicles, or foot traffic can greatly increase runoff and erosion and, consequently, the export of soil nutrients and organic matter. Animal life in the groves, such as herbivores feeding on tree leaves, contributes to the rapid return of CO\textsubscript{2} to the atmosphere through respiration and may even reduce plant uptake of CO\textsubscript{2} through the consumption of leaves.\textsuperscript{29}
It is important to note that trees planted in yards and around buildings, while not included in the traditional definition of a woodland, function as groves, and therefore, have the potential to mitigate climate change. Trees that surround buildings shade them from the sun, provide evaporative cooling by transpiration, and reduce wind speeds. Each of these effects helps to create a more consistent immediate climate around buildings and therefore lower energy needs for indoor temperature control. This translates into a reduction in greenhouse gas emissions associated with energy generation.30

Climate change has the potential to have a significant impact on groves, but whether this impact is positive or negative has yet to be determined due to differences in the predictions of climate change models. Groves may remain carbon sinks, and their storage capacity may even increase over time as the concentration of carbon dioxide in the atmosphere increases, stimulating growth.31 Increased growth rates of plant species, however, may quickly deplete necessary nutrients in the soil.32 Such depletion of soil nutrients, in combination with increased ozone concentration in the atmosphere and rising temperatures, may then reduce the primary productivity of trees. Also, as global temperatures increase, the optimal climate for growth will shift north for some types of trees. Trees that currently thrive in the Northeast will slowly die and decay, releasing more carbon into the atmosphere, which may or may not be offset by greater tree growth in northern areas. An increased risk of fire during warmer, drier summer months also has the potential to release carbon. Furthermore, respiration rate may rise more than photosynthetic rate in response to rising temperatures, thereby increasing the release of carbon from live plants and decomposition.33 Where precipitation increases trees may expand their ranges into areas previously occupied by other habitats, such as grasslands.34

<table>
<thead>
<tr>
<th>Groves</th>
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<tbody>
<tr>
<td><strong>Sources</strong></td>
</tr>
<tr>
<td>Plant and Microbial Respiration</td>
</tr>
<tr>
<td>Decomposition</td>
</tr>
<tr>
<td>Soil erosion</td>
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<tr>
<td>Disturbances such as fire and mowing</td>
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<tr>
<td><strong>Sinks</strong></td>
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<tr>
<td>Photosynthesis</td>
</tr>
<tr>
<td>Woody Biomass</td>
</tr>
<tr>
<td>Soil</td>
</tr>
<tr>
<td>Grass</td>
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</table>

- Sources and sinks similar to woodlands, but understory and litter absent
- Sequesters less carbon than woodlands, but also has fewer sources of carbon
- Major carbon sink is tree trunks and roots
- Disturbances reduce sequestration
Figure 4. Meadow—a type of unmowed grassland with a high diversity of herbs.

**Carbon Budgets: Meadows**

Grasslands, which constitute approximately 22% of the earth’s land area, sequester carbon as Soil Organic Matter (SOM). Indeed, 90% of the carbon of grasslands is Soil Organic Carbon (SOC). Unlike forests, less than 1% of grassland’s carbon storage is in aboveground biomass\textsuperscript{35}.

Meadows, a type of grassland, take up carbon dioxide through photosynthesis and store most of the carbon in plant root systems. Roots are continually growing and dying as plants forage for soil nutrients and water. As roots die, they contribute directly to the humus content of the soil (thereby increasing SOM). While SOM concentrations are highest in the surface soil, tall-grass systems hold about 40% of their organic carbon below 30 cm.\textsuperscript{36}

Uncultivated grasslands are generally considered carbon sinks, and sequester anywhere from 500-800 kg/ha/year in cold, humid regions,\textsuperscript{37} such as New England. The amount of carbon sequestered, however, can differ among meadows, due to differences in decomposition rates, soil types, and climates.

<table>
<thead>
<tr>
<th>Meadows</th>
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<tbody>
<tr>
<td><strong>Sources</strong></td>
</tr>
<tr>
<td>Decomposition</td>
</tr>
<tr>
<td>Soil loss</td>
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<tr>
<td><strong>Sinks</strong></td>
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<tr>
<td>Photosynthesis</td>
</tr>
<tr>
<td>Soil</td>
</tr>
<tr>
<td>Root Systems</td>
</tr>
<tr>
<td>Plant biomass</td>
</tr>
</tbody>
</table>

- Restored grasslands tend to have less SOM than native prairies
- Restored grasslands sequester more than agricultural sites

Typically, organic carbon tends to increase with increasing soil clay content and annual
precipitation. SOM decreases with rising mean temperatures. In addition, restored grasslands tend to have less SOC than native prairies, but restored grasslands still sequester more carbon than agricultural fields. How long carbon actually remains stored in rich soils close to the surface versus in the subsoil and at what rate carbon sequestration declines with soil age is unknown.

**Carbon Budget: Turfgrass (Irrigated Lawn)**

Irrigated lawns persist only through the support of substantial human effort. Since grass photosynthesizes, one might mistakenly assume that lawns are carbon sinks. The carbon cycle of lawns, however, is complicated by anthropogenic inputs and efforts to maintain this intensively managed habitat type. Continuously mowing the grass and removing clippings eliminates not only carbon, but also vital nutrients, such as nitrogen, from the landscape. This “cleaning” and cutting of lawns also adds gaseous carbon dioxide to the atmosphere directly from petroleum-fueled mowers and leaf blowers. The removal of plant debris from the system and the typically poor quality of soil on which grass is grown require land managers to use an onslaught of products (fertilizers, herbicides and insecticides) to keep lawns looking green and uniform. In 1984, the EPA estimated more synthetic fertilizer was applied every year to American lawns than the entire country of India applied to all its food crops.

Figure 5. Turfgrass lawn that is typically mowed frequently and irrigated.
The carbon cycle of these “industrial lawns” must be viewed from a holistic perspective; while the soil of lawns can serve as a carbon sink, we must also consider the greenhouse gasses (GHG) emitted during lawn upkeep. There are four major sources of emissions in caring for lawns. First, GHGs are emitted when lawns are mowed, aerated, or cleaned with equipment relying on fossil-fuel powered engines. Second, irrigation relies on fossil-fuel energy to pump water. Third, the manufacture and transport of the fertilizers applied to lawns also release gaseous carbon. The final source of CO$_2$ is the respiration of the grass and of the microorganisms that live in the soil, helping to break down organic materials and cycle nutrients. To get the big picture, we need to consider CO$_2$ emitted from these sources as well as carbon uptake by grasses. The energy-intensive maintenance that a lawn demands may often cause a lawn to be a net source rather than a sink.

A recent study found that one form of turf grass, fairways of an irrigated golf course, sequester 816 kgC/ha/year in soil organic matter, where the density of grass was 1.5 g cm$^{-3}$. These scientists estimated that 58% of SOM is Soil Organic Carbon and that, in a turfgrass landscape, this SOC comes from carbon sequestration by grass. They hypothesized that carbon is sequestered largely because of root turnover. The actual process, however, of carbon sequestration in turfgrass systems is not well understood. The history of the lawn is also a factor in carbon sequestration. Lands that have been under previous cultivation, such as agriculture, have a 24% lower SOC in comparison to lawns that replaced natural grasslands. We can infer similar sequestration values to that of fairways for the areas of turfgrass on the Wellesley College campus.
It is unknown how lawns may be affected by predicted climate change. Some scientists have hypothesized an increase in growth rate for most C3 and C4 grasses. In the northeast, if there is increased precipitation there could be less need for irrigation of lawns, but a greater need for mowing as the growth rate of grass may increase with added CO2 in the atmosphere and increased precipitation.

Figure 6. Wetlands are characterized by water close to or at the soil surface hydric soils

**Carbon Budget: Wetlands**

Wetlands are a highly diverse group of habitats characterized by the presence of water close to or at the soil surface, a unique type of hydric soil, and plant and animal communities adapted to water-saturated soils and environments. The carbon cycle of wetlands has characteristics of both drier terrestrial habitats and lakes. In wetlands, carbon enters via: (1) primary producers that take up atmospheric carbon through photosynthesis, and (2) falling litter and other organic matter, as well as surface water runoff and ground water flows that enter the wetland. Flowing water can bring in particulate organic carbon (POC) and dissolved organic carbon (DOC). The carbon entering wetlands from any source may be stored in a variety of ways, including: (1) as dissolved organic carbon within the water and sediments, (2) within the tissue of living biomass (plants, invertebrates, zooplankton, microbes, etc.), or (3) as detritus within the water or soil. It is important to point out the stratified nature of many wetlands—the aerobic water column (or soil layer, depending on the particular wetland) and the anaerobic
water or soil layer, rendered anoxic due to biological activity (especially by microbial respiration) taking up oxygen more rapidly than it can be replenished from the atmosphere.

Carbon is released from wetlands primarily from the aerobic strata through respiration of living organisms, and it may remain dissolved within the water-buffering carbonate system or exit the wetland as a gaseous emission or via water outflow. The anaerobic strata is crucial to the wetland’s ability to retain carbon for long periods. Within the anaerobic strata, carbon is stored as detritus within the sediments, where it may remain for relatively long periods of time due to the slow rate of decomposition under oxygen-depleted conditions. With eventual decomposition, the released carbon may exit via (1) gas emission (e.g., CO$_2$, CH$_4$), (2) water outflow, or (3) it may be recycled back within the carbon cycle when taken up by organisms.

Based upon its structure, wetlands are usually carbon sinks. Capable of retaining significant amounts of carbon for periods of time longer than forests, grasslands, and even lakes, wetlands have a high potential for carbon sequestration for several reasons. They rank among the most highly productive ecosystems known. Carbon can be sequestered above ground in plant biomass, especially within trees and woody shrubs, as well as in sediments (peat). Decomposition is slow due to a lack of oxygen, low pH and cool temperatures within anaerobic sediments or water. Finally, carbon moving into the wetland as detritus or in surface or groundwater flows becomes trapped and retained.

Wetlands, then, can be considered carbon sinks that, if left undisturbed, can greatly contribute to the reduction of atmospheric carbon. Estimates of carbon sequestration by wetlands show that the temperate wetlands of the northeast United States, occupying a size of only 3.0 x 10$^6$ hectares, had soil carbon density of 1,125,000 kgC/ha, and a mean storage rate of 480 kg C/ha/year. Furthermore, wetlands cover only 6% of the world’s surface and yet contain 14% of the terrestrial biosphere carbon pool. However, not all wetlands function as carbon sinks. Due to agriculture, development and other human activities, wetlands are increasingly disturbed. Such disturbances can reverse the wetland’s role from a carbon sink to a source, emitting more carbon (primarily as CO$_2$ and CH$_4$) than is stored. Draining, drilling, and nutrient enrichment of wetlands can promote carbon loss due to decomposition in oxygen enriched soils, decreased primary productivity, and enhanced soil erosion.

Though there is still much debate over the possible effects of global warming upon wetlands. Certain effects may be detrimental to wetland habitats. A general increase in
temperature could lead to: 1) greater plant and root respiration leading to more carbon emitted, 2) increased anaerobic decomposition marked by greater methane emissions, and 3) the melting of permafrost and ultimate loss of carbon sequestration by Northern peatlands. Furthermore, drier conditions within temperate regions will also contribute to increased decomposition of peat and drier conditions would be accompanied by a lowered water table that results in waters becoming more oxidized and therefore reducing peat accumulation. Still another effect of global warming is fluctuating precipitation, marked by extreme precipitation events. Such unstable precipitation could lead to greater runoff from wetlands, thereby increasing the amount of DOC lost from the wetland. In more general terms, global warming would upset the hydrologic balance within wetlands, disturbing the water table and the aerobic/anaerobic strata within the water, as well as creating a positive-feedback cycle of greater temperatures bringing about greater carbon emissions. It is crucial that wetlands be managed in order to keep them as carbon sinks rather than sources.

Figure 7. Freshwater Lake

**Carbon Budget: Freshwater Lakes**

Aquatic carbon cycles differ from terrestrial cycles in the ability of aquatic systems to lock carbon in sediments for long periods, essentially removing that carbon from the global carbon cycle. The rapid accumulation of lake bottom sediments and their long duration in that form make lakes ideal carbon sinks. In reality, lakes can act as either sources or sinks for CO₂.
The imbalance between bacterial respiration and phytoplankton production determines whether an aquatic system is a net source or sink.\textsuperscript{56}

Carbon enters freshwater lakes in multiple forms: as dissolved organic carbon (DOC), particulate organic carbon (POC), and dissolved inorganic carbon (DIC). Lakes obtain DIC by simple diffusion from the atmosphere at the water’s surface and from inflowing ground or surface waters containing carbon from plant roots or soil respiration in drainage areas. DOC and POC enter lakes by land-to-water carbon transfers, in the form of detritus, blown or carried into lakes.\textsuperscript{57} The amount of DOC and POC from terrestrial and drainage area sources directly affects the quantity of CO\textsubscript{2} released by bacterial respiration. However, most of the carbon annually entering lakes is emitted as gaseous CO\textsubscript{2} due to respiration by bacteria or it is taken up by phytoplankton that settle as organic sediments when they die. The contribution of phytoplankton production to sediments is usually limited by the availability of nutrients such as phosphorus and nitrogen.

Lake basins worldwide \textit{collectively} bury \( \sim 70 \times 10^9 \) kg of atmospheric carbon every year.\textsuperscript{58} Lake basins cover only 0.8\% of the surface area covered by oceans, but the amount of carbon that lakes sequester is more than one fourth of the annual atmospheric carbon sequestered by Earth's largest sink—the oceans. Although lake basins collectively act as a major sink, some individual lakes are sources of CO\textsubscript{2}. Are Lake Waban and Paintshop Pond, Wellesley College’s freshwater lakes, a source or sink of CO\textsubscript{2}? Both are small, eutrophic lakes.\textsuperscript{59} In general, the carbon burial rates of small lakes are much higher than large lakes because: 1) relatively large drainage areas translate into higher inputs of terrestrial organic matter and 2) an enhanced nutrient supply encourages the growth of phytoplankton and macrophytes.\textsuperscript{60} Mean sequestration rate of organic carbon for mesotrophic to eutrophic lakes of less than 100 km\textsuperscript{2} in surface area is about 270 kg C/ha/yr.\textsuperscript{61} Lake Waban’s mean sequestration rate of organic carbon may be higher than that estimate due to the luxuriant growth of aquatic macrophytes (predominantly Eurasian water milfoil, \textit{Myriophyllum spicatum}) during the summer.
The contribution, however, of aquatic macrophytes to lake carbon budgets is poorly understood.

Carbon burial rates will be significantly affected by climate change. Increased humidity and rising water levels (leading to greater lake surface areas) would encourage organic production and total carbon burial. Furthermore, a shift from cool to warm temperate conditions would promote water stratification and anoxic bottom conditions that would improve preservation of organic carbon in sediments. Finally, natural or artificial eutrophication of lakes can increase the organic carbon burial rate by up to a factor of four.62

Conclusions

No two carbon budgets are exactly alike. Sophisticated methods exist for quantification of carbon sources and sinks in a landscape. Such methods, however, are expensive and require long term research. If you lack such resources, then simple calculations based on published sequestration rates from primary literature can be used to estimate a landscape’s carbon budget. An excel spreadsheet that will help guide your carbon sequestration calculation is included in the appendix at the end of the book.

Wellesley College is a net source of carbon (Table 2). At present, sequestration accounts for only 0.34% of emissions. Clearly, sequestration cannot balance the carbon budget, but maintaining and even expanding sinks can fulfill moral obligations, respect pedagogical purposes, and may even be cost effective in the long run. Now that we have a clear idea of the quantitative and qualitative nature of our carbon budget, we’re ready to formulate landscape management recommendations for increasing carbon sequestration.

Table 2. Annual Carbon Budget for the Wellesley College landscape of eastern Massachusetts (kg C/yr)

| Total Annual Carbon Sequestration | 149,595  |
| Annual Carbon Emissions: | 36,273,000 |
| Energy | 36,273,000 |
| Transport | 5,681,000 |
| Waste | 1,748,000 |
| Total emissions | 43,702,000 |
| Net Carbon Budget | 43,552,400 |
Control Your Carbon!

Recommendations for Managing Landscapes

Climate change is imminent. Scientists may be uncertain about the exact magnitude of the earth’s increasing temperatures, but a broad consensus exists that the earth is experiencing both global warming and a rise in atmospheric carbon dioxide. Under these circumstances, it is urgent to plan and prepare for the effects of climate change. The most obvious and important step in mitigating climate change is to reduce greenhouse gas emissions, such as carbon dioxide (CO₂) and methane (CH₄). The fight against global warming, however, shouldn’t stop there. Carbon dioxide can also be “captured” by plants via photosynthesis providing temporary storage (up to hundreds of years) for carbon dioxide, potentially decelerating the rate of change caused by greenhouse gas emissions. Water and soil also have the capability of storing carbon dioxide. Various habitats, such as forests, meadows, and lakes differ in their capability to store carbon because of differences in plant, water, and soil carbon storage capacities. Each habitat and its ability to store carbon can work to our advantage. By managing habitats to create optimal conditions for carbon storage, we can increase the amount of carbon dioxide diverted from the atmosphere and, thereby, dampen the effects of climate change.

Woodlands

Forests are not only the most widespread habitat for plants and animals on earth, but also the most diverse. Here in New England, most forests are temperate deciduous forests, where leaves are shed annually in the fall. Dominant trees include Beech (Fagus grandiflora), Sugar Maple (Acer Saccharum), Black Cherry (Prunus serotina), Red Oak (Quercus rubra) and White Pine (Pinus strobus). A healthy temperate deciduous forest usually contains four layers including: the upper canopy, consisting of the dominant older trees; the lower canopy of saplings and understory trees; the shrub layer; and the ground layer of herbs, ferns, and mosses. Dead trees and decaying logs on the forest floor provide habitats for animals and slowly release
Control your Carbon!

nutrients into the soils via decomposition.\textsuperscript{4} Fallen trees and the rolling topography of the land create a high degree of patchiness in environmental conditions, allowing a diverse mix plant communities to thrive. We make the following recommendations for managing woodlands.

\textit{Species and Plantings}

Simple protection of forest land is not enough to create a healthy forest ecosystem. Landscapes change over time.\textsuperscript{5} Invasive species can threaten the stability of native plant communities and destroy wildlife habitat.\textsuperscript{6} Native plants and animals have adjusted to living together and often depend on each other’s existence. Native plants are therefore vital to forest health, and invasive species that may suppress the growth of desired seedlings and saplings should be controlled. If invasive species become dominant within a forest, it may be beneficial to remove the invasive species and replant native trees such as Oak (\textit{Quercus spp.}) and Beech (\textit{Fagus grandiflora}).

<table>
<thead>
<tr>
<th>Woodland Recommendations:</th>
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<tbody>
<tr>
<td>• Control Invasive Species</td>
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<tr>
<td>• Plant and/or select for long-lived tree species with a large leaf area</td>
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<tr>
<td>• Maintain multiple forest strata</td>
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<tr>
<td>• Allow forest debris to remain on forest floor</td>
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<tr>
<td>• Increase soil organic matter by leaving leaves and other decaying material on the forest floor</td>
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<tr>
<td>• Expand the area of forests where possible (Figure 1)</td>
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Figure 1. Some lawns, such as this one at Wellesley College Campus, experience minimal foot traffic and do not function well as places for gathering or relaxing. Forests should be planted or allowed to expand into such areas.
The longer a tree grows, the more carbon it is able to store above and below ground. When planting trees in a forest habitat, select for long-lived tree species that can grow to a large size. Carbon storage is also affected by the amount of woody biomass, the leaf area in the canopy, given that leaves are the site of carbon uptake, and the different tendencies of trees to store carbon below ground in the soil. The greater the leaf area, the more carbon stored. Hardwood trees, such as Oak (*Quercus spp.*), or Maple (*Acer spp.*), typically store more carbon than softwoods like Pine (*Pinus spp.*), Hemlock (*Tsuga canadensis*) and other coniferous trees. Therefore select for hardwood trees with a large leaf area. In New England this would include common trees such as Oak (*Quercus spp.*), Beech (*Fagus grandiflora*), Hickory (*Carya spp.*), and Maple (*Acer spp.*), and also less abundant species including Ash (*Fraxinus Americana*), Walnut (*Juglans nigra*), and Cherry (*Prunus pensylvanica*).

By maintaining multiple strata in the forest ecosystem, carbon uptake and storage can be maximized. The layers of vegetation within the forest increase leaf area for the uptake of carbon and influence microclimatic conditions such as light, temperature, moisture, and wind. Manage for a forest floor that is covered with plants, planting spring ephemerals or groundcover, e.g. Virginia creeper (*Parthenocissus quinquefolia*) as needed. Wildflowers such as trillium (*Trillium spp.*), common wood-sorrel (*Oxalis acetosella*), red columbine (*Aquilegia canadensis*), troutlily (*Erythronium americanum*), and spring beauty (*Claytonia virginica*) greatly add to the aesthetics of a woodland. The forest will sustain itself when multiple generations of species planted occur. Desirable young trees should therefore not be removed to “neaten” the forest and should be planted as needed to provide replacements for older trees. Finally, allow forest debris to remain on the forest floor. Dead wood provides a living space for wildlife in summer and shelter in winter. Decaying vegetation slowly releases nutrients back into the soil and serves as a water reservoir for the forest in times of drought.

Soils sustain plant growth and are a site where carbon is stored. Growth and storage are dependent on a complex and diverse collection of soil organisms, which are vital for soil health. If soil organisms are included in species’ counts, temperate forests are richer in biodiversity than tropical rainforests. For example, up to 3,000 arthropods exist per every cubic inch of productive soil, and a square yard containing a litter layer of leaves 1.5 inches thick may contain 5,000 miles of fungal filaments. Soil is also important for cycling energy and nutrients, including nitrogen, sulfur, and phosphorus, that are required for plant growth.
Maintaining soil health and fertility is essential for both plant growth and carbon storage. Acid rain can cause forest soils to become acidic and removes cations such as calcium, magnesium, and potassium through the process of leaching. Under such circumstances, consider liming the forest floor to create optimal growing conditions for hardwood trees. Also focus on the living components of forest soil, such as bacteria, fungi, and microfauna. Animal life and plant roots form humus, the organic matter in soil where most nutrients become available for plant uptake. Humus also increases the water holding capacity of the soil. In order for soil organisms to thrive, permeable soil crust, stratified soil layers, and the appropriate amounts of organic matter should exist.

**Groves**

Groves are a partial forest consisting of only two strata: old growth canopy and groundcover. The distance between trees is often larger in groves than forests. We make the following recommendations for managing groves.

*Species and Plantings*

Carbon uptake and storage in groves can be enhanced by increasing the amount of vegetation. Plant native, large, long-lived tree species that will cast the most shade and have the largest leaf area possible. Sapling trees can be added to groves where openings in the canopy occur, and trees should be spaced to capture the maximum amount of sunlight. It is advantageous to strategically plant trees of different ages in order to create multiple layers of foliage in the groves to capture the most sunlight and carbon. Younger trees store carbon at a greater rate than older trees, and when an old tree dies, a young tree will be present to take its place. Do not cut down trees unnecessarily, especially large ones that have taken generations to grow to their present size. If trees absolutely must be cut down for reasons such as safety, leave the dead wood in forest
patches to decompose slowly, thereby building soil and providing habitat for native plant and animal species.

The growth of grass in tree groves can be encouraged by building soil organic matter and pH appropriate for both tree and grass species. Grasses increase the carbon storage capacity of the groves because grasses add to soil organic matter via root growth and turnover. Wildflowers, such as Blue Phlox (Phlox divaricata), Dutchman’s-breeces (Dicentra cucullaria), Bloodroot (Sanguinaria canadensis), and Lady’s Slippers (Cypripedium spp.), will not only beautify the landscape, but also aid in carbon uptake.

Lastly, plant trees strategically so that they protect buildings and parking lots from sun and wind, reducing the energy needed to cool and heat the buildings and cars. Allow some groves, e.g. those not in public areas, to become forests by leaving leaf litter on the ground and encouraging understory growth.

Figure 2. This grove at Wellesley College provides a scenic view from the dorm to the lake. Although this area should not become a forest, management could create a herbaceous layer of wildflowers or low growing shrubs that would not only increase its beauty, but also carbon sequestration.

Meadows

Meadows in northeastern United States have historically existed as temporary ecosystems. They occur as breaks in the forest resulting from human or natural disturbances. Without further disturbance, natural plant succession causes meadows to grow into woodlands within 30-100 years. Meadows that are semi-permanent without management typically occur in areas where rainfall is only 25 to 75 cm/year and that experience periodic fires.16
productivity in meadows is directly related to precipitation and can be severely affected by grazing. The following recommendations are made for meadows:

**Species and Planting**

When starting new meadows, plant as many species as possible, with an emphasis on native species. Meadow grasses are categorized into two groups: warm season and cold season. Cold season grasses, such as Kentucky bluegrass, grow in the spring and fall, but become dormant in summer. Warm season grasses, on the other hand, grow in the summer and are dormant in the winter. Manage to favor warm season grasses because these can become nesting and feeding sites for native animals and birds and some species thrive on marginal soils with little rain. Warm season grasses also have extensive root systems stretching 1.5-4.6 meters (5-15 feet) below the soil surface, adding soil carbon and increasing resistance to drought. Every three to four years grasses renew their root system, increasing soil organic matter.

Choosing when to mow a meadow is one of the most important management tools for controlling species composition. In general, mow only as frequently as needed to control invasive species. Avoid mowing April 1st- July 1st, a time of high productivity for warm season grasses and bird nesting. In order to remove cool season species and provide space for warm season grasses, mow in early to mid-July. Be sure to mow when the ground is dry and leave mulched residues. Never mow below 8 inches in height because lower mowing will kill warm season grasses.

Spot mowing (mowing just a portion of a meadow) is a good way of clearing unwanted plants without severely affecting other plant species. If you are trying to get rid of a particular species like thistle, time mowing to prevent their reproduction. If invasive species are a significant problem, mow twice a year. Mowing more than twice a year will encourage cool
season grasses and create a turf-like habitat. Meadows can develop naturally from lawns, but they can also be encouraged by seeding with annual rye and/or oats plus a seed mix of desired plants. Do not drain wet meadows unnecessarily because wet meadows sequester more carbon than any other type of meadow. Expand the area and number of meadows as possible, because this habitat type requires minimal maintenance.

**Turfgrass**

Turfgrass probably makes up the largest area of the landscape for most small managed landscapes. Although all landscapes require some management, turfgrass is by far the most energy intensive in that it requires regular mowing, irrigation and, in some places, fertilizer and pesticide use. When managed properly to create ideal growing conditions, however, turfgrass has the potential for sequestering a significant amount of carbon (greater than 800 kg ha\(^{-1}\) year\(^{-1}\)).\(^{23}\) Grasses typically allocate greater than or equal to half of the plants’ biomass below ground.\(^{24}\) Therefore management should focus on sustaining grass growth, and thereby, soil rich in organic matter. The following recommendations stress ways in which to minimize inputs, such as water and fertilizer, and disturbances that affect the ability of the lawn to grow to its maximum potential.

**Irrigation**

According to the U.S. Environmental Protection Agency, as much as 50% of water in urban areas goes towards lawn irrigation.\(^{25}\) One way to cut back on greenhouse gas emissions associated with turfgrass is to irrigate as little as possible. When irrigation is necessary, make sure that it occurs at time periods when a minimal amount of water will evaporate, and when water will remain on the vegetation for as short a period as possible, thereby minimizing the growth of fungi on leaf blades.\(^{26}\) For example,
irrigate just before dawn rather than during mid-day. Furthermore, do not apply water at a rate that exceeds the infiltration rate of the soil, as excess water will only cause puddling and runoff. Although water should be applied deeply to encourage deep root growth, only one inch of water is needed to wet soil to a depth of four-six inches. Where runoff is likely, especially in areas of new construction with little established grass, plan for proper drainage.

_Fertilizer and Soil Fertility_

Research has shown that fertilizer benefits weed species more than the desired grass. Therefore, excess fertilization should be avoided, especially nitrogen fertilization. Using too much nitrogen can not only make plants more susceptible to disease and decrease drought and heat tolerance, but excess soil nitrogen can also kill soil organisms that are important in maintaining turfgrass health. Inorganic fertilizers can be minimized when management focuses on building soil organic matter (SOM), also known as humus, that is found in the surface layers of the soil. Organic matter is typically nitrogen rich and will build soil fertility, tilth, and water holding capacity. Furthermore, increased soil organic matter holds cations such as calcium, magnesium, and potassium that are essential nutrients for plant growth. Cations are stripped away from clays and organic matter due to acid rain. These cations can be replaced by liming and retained by mulching grass, leaving it on the lawn. Some plants, such as clover, can increase soil nitrogen by sustaining nitrogen-fixing bacteria that convert gaseous nitrogen (N₂) to ammonia (NH₃), which is then converted to forms that are usable by plants, ammonium (NH₄⁺) and nitrate (NO₃⁻). Organic matter will build most rapidly when soil disturbances that kill grass and expose bare soil are minimized.

_Planting and Mowing_

When replanting turfgrass, use seed mixes containing grasses that are slow growing and lower-growing, to reduce the need to mow. Use the most energy-efficient mowers as possible (electric mulching mowers are ideal), replacing as needed inefficient mowers with more efficient types. Although little attention is paid to small engines and their contribution to greenhouse gas emissions, lawn mowers contribute greater than 10% of all air pollution in many urban areas, and each annually consumes an average of 580 gallons of gasoline. Similarly, the U.S. EPA found that the average gasoline mower emits the same volume of air pollutants in one hour as a car
does driving 350 miles!\textsuperscript{33} Electric mowers, on the other hand, produce less than half the carbon dioxide compared to the average gasoline mower and 2,000 times less air pollutants than even the most efficient gasoline lawn mowers.\textsuperscript{34}

The frequency of mowing can be minimized by allowing grass to grow taller (3-3.5 inches at a minimum). Tall grass keeps the lawn cooler and reduces weed growth. Different grasses are more productive in certain environments, and it is important to choose grass species that are optimum for your area. Grasses employ two types of photosynthesis, C\textsubscript{3} and C\textsubscript{4}. C\textsubscript{3} plants differ from C\textsubscript{4} plants in that they use different enzymes to “catch” CO\textsubscript{2}.\textsuperscript{35} C\textsubscript{3} plants are typically inefficient at capturing CO\textsubscript{2} compared to C\textsubscript{4} plants, but studies show that grassland productivity is highest in cooler environments dominated by C\textsubscript{3} grasses because the potential evaporation is lower relative to water supply and net nitrogen mineralization is higher than in warmer environments where C\textsubscript{4} grasses dominate. On the other hand, it is important to use plants that are best adapted to the climate and require minimal irrigation, fertilizer, and mowing. In particular, C\textsubscript{4} grasses, such as Zoysiagrass are much better suited to handle hot, bright, drier climates than C\textsubscript{3} grasses such as \textit{Poa supina}.\textsuperscript{36} In areas where rainfall is expected to decrease due to climate change, C\textsubscript{4} plants may be most appropriate.

\textit{Soil Compaction and Plant Diversity}

In order to minimize the need for replanting lawns, walkways should be placed when possible in accordance with paths of desire, or the natural pathway pedestrians choose to follow (Figure 3). If creating such paths is not possible, install “green barriers,” -- low shrubs or beds of native wildflowers that people will not want to walk through. Preventing undesired pathways avoids

Figure 3. This social trail on Wellesley College campus was created because the walkway to not correspond to pedestrians’ “path of desire.”
soil compaction that occurs when weight pushes soil particles together and reduces the size of pores between soil particles. Greatest soil compaction occurs under wet and moist conditions, such as right after snow melt. Compacted soil is unable to absorb water, so water flows across the surface of the soil, resulting in soil erosion. Green barriers not only reduce the need for lawn restoration due to soil compaction and soil erosion, but also decrease the area to be mowed (Figure 4).

Avoid pesticide use wherever possible, doing so allows a mix of plant species in lawns. These should include plants such as clover or other leguminous plants that host nitrogen-fixing bacteria. Leguminous plants reduce the need for chemical fertilizers. Plant diversity increases the lawn’s resistance to pests and fungus.

**Lawn to Meadow**

Lawns are suitable for areas of high use, such as paths and playfields, because turf survives under heavy foot traffic. In areas where durability is not required, meadows can reduce maintenance requirements and the environmental damage caused by turf pesticide and fertilizer use. If meadows grasses are too tall, consider managing for a greensward, a low-impact turf that is cut to about 5-7 inches rather than 2-3 inches and maintained by organic methods. In some areas, allow woody plant growth to expand into the edges of lawns and fairways, favoring habitats with greater carbon sequestration.
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Wetlands

Wetlands, one of the world’s most endangered ecosystems, are “the half-way world between aquatic and terrestrial ecosystems.”

Wetlands are typically covered in water or at least experience seasonal flooding. Not only are they important for preventing eutrophication of bordering lakes and streams, but wetlands also support a diverse community of plants and animals. Recommendations for wetlands include the following.

<table>
<thead>
<tr>
<th>Wetland Recommendations:</th>
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<tbody>
<tr>
<td>• Minimize both chemical and physical disturbance</td>
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<tr>
<td>• Do not drain them</td>
</tr>
<tr>
<td>• Prevent excess nutrients from entering wetlands</td>
</tr>
<tr>
<td>• Establish riparian buffers of forests, shrubs, or wet meadows</td>
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</table>

Habitat Management

Since European colonization, the United States has lost 53% of its wetlands. Strong pressures to drain wetlands for agriculture, urban expansion, industrial sites, home sites, and dumps continue to exist. To maximize carbon sequestration and the healthy functioning of wetlands, keep water levels at optimum depths. The optimum differs among types of wetlands. Allow wet meadows to remain water-saturated, so that there will be an accumulation of peat and increase in carbon storage. Avoid any physical disturbance, such as draining, or chemical disturbance that would lead to oxidation of the carbon-rich water and water-saturated soils. One method of preventing physical disturbance to wetlands is to create borders and/or walkways that limit human access.

Management should try to minimize chemical disturbances that cause eutrophication and pH imbalance within the habitat. Although wetlands are a great nutrient sink, excess nitrogen can result in the conversion of ammonium into nitrate by certain microbes. Although nitrate can be used by plants, it is highly mobile and thus enters runoff adding to lake or downstream eutrophication. Runoff of fertilizers from the fields, salts from roads and sidewalks, and pesticides and herbicides that could flow via storm drains into wetlands should be routed away from them. Similarly, erosion and water runoff from wetlands into bordering lakes or waterways should be prevented. Planting riparian vegetation along banks and closely monitoring water levels may prevent erosion. Where possible, try to establish forested swamps that store the most
carbon. Red maple swamps, famed for their brilliant red color in early fall, are the most common type of wetlands in New England.46

**Freshwater Lakes**

Lakes and ponds are lentic, or standing water habitats.47 Lakes can be naturally eutrophic (nutrient-rich) or oligotrophic (nutrient-poor).48 Many lakes and ponds receive water from the surrounding watershed, the area of land that drains towards an aquatic system49, making them vulnerable to nutrient pollution, as well as insecticides and herbicides in lawn or agricultural runoff. Excess nutrients cause plant and bacterial populations, such as algae and cyanobacteria, to explode. When masses of these plants die, they are decomposed by aerobic bacteria, depleting the water of dissolved oxygen and killing fish and other aquatic organisms.50 In the United States, approximately one-third of the 100,000 medium to large lakes and about 85% of large lakes near major population centers have suffered some degree of eutrophication.51 Aquatic communities need clear, oxygen-rich waters to promote the growth of plankton and support fish. The following recommendations support management for healthy aquatic environments.

**Riparian Zones**

Maintain riparian zones around lakes and ponds by ceasing to mow along lake borders and by selectively planting wetland plant species. Riparian zones minimize surface flow into lakes that can carry sediments. They also treat runoff by filtering pollutants, breaking down petrochemicals, and reducing nutrients loads.52 If erosion persists in riparian areas, consider banking the shoreline or reducing public access in the affected area.

Lake Recommendations:

- Establish riparian zones to mitigate shoreline erosion
- Control invasive species
- Promote Integrated Watershed Management

**Control of Invasive Species**

The dominance of macrophytes in lakes discourages phytoplankton growth and a stable, healthy lake ecosystem.53 When controlling macrophytes, it is important to utilize the most effective macrophyte management strategy that will control invasive species, such as Eurasian
water milfoil (*Myrophyllum spicatum*), without harming native aquatic macrophytes. In other words, use control techniques only at necessary locations and avoid manipulating the entire lake.

**Integrated Watershed Management**

Lake management will be most effective when the lake’s entire watershed is considered. Such an approach will be needed to minimize inflow of harmful chemicals and excessive nutrients. Thus, managers should promote integrated watershed management by reaching out to the entire community within with watershed, including children, students, and adults. The community should become aware of problems associated with lakes and learn how to not only reduce their personal impact on lake health, but also how to improve an unhealthy lake and monitor its status.

In order to understand how landscapes function, information is needed about the history of the landscape, including both its physical and biological characteristics. Leslie Jones Sauer, a well-known forest ecologist and landscape architect suggests that, “a monitoring program serves as the voice of the landscape, telling its story, ensuring that our actions are ultimately justified or invalidated by what happens on the ground.” Management has a purpose and should reflect certain goals, such as carbon sequestration. In order to assess the consequences of management, land owners should closely observe and record what is happening within the landscape. A data recording system that is easy to use and permanent, including photographs and narrative, can be useful for identifying best management practices. Consult local scientists and even consider forming a team consisting of interested persons that will be responsible for the monitoring process. Through public events and education, urge the community to take a greater sense of ownership, pride, and responsibility for their landscape.
Using economic arguments, such as cost-benefit analysis, might seem a good way to justify the landscape management recommendations outlined in the previous chapter. After all, everyone wants the most bang for their buck. College administrators and homeowners on a budget are primarily concerned with getting the most in return for the limited financial resources available to them. In our scenario for a small landowner such as a college, the administration would want to know how the potential benefits of managing the landscape to mitigate climate change compare to the expected costs of implementing specific projects, such as converting a lawn to a meadow.

Cost-benefit analysis (CBA) usually involves, as its name implies, comparing the aggregate costs to the aggregate benefits of a decision. CBA is seen by most economists as an extremely good way to determine what allocation of resources is most ideal. It is the most useful tool that economists have developed to make decisions based on overall societal welfare. CBA can be applied to a variety of situations, including project and policy appraisals, while giving equal weight to both positive and negative outcomes. It takes into account more than just monetary costs and benefits, such as opportunity costs and indirect benefits, and it is still relatively simple to understand.\(^1\)

However, applying CBA to the environment and especially to the problem of climate change is not a simple process. It is almost impossible to put monetary value on environmental services or properties. A 200-year-old oak tree is worth different amounts to different people. Also, it is hard to know what effects human actions will have on ecosystems as a whole. Furthermore, there are many ecological processes that are not yet well understood.

The issue of climate change is a prime example or such a stumbling block for CBA. The factors that define the climate change problem are innately different from those that surround other environmental problems. For instance, climate change is a problem with a long time horizon, meaning that while costs to mitigate or adapt to climate change are incurred now, the benefits of our present actions may not become apparent for decades or even centuries. Also,
much is unknown about the eventual outcomes of climate change because we have never before encountered a global environmental crisis.

Cost-benefit analysis may be most useful when applied to specific alternative management options, but even the conclusions that arise from such careful application should be used with caution. CBA is a good place to start when judging which projects should be undertaken or which policies should be implemented. It is important, however, to acknowledge the limitations of the process, especially when dealing with global climate change.

Cost Benefit Analysis
At the most fundamental level, cost-benefit analysis asks the following hypothetical question: Do the potential benefits of an action outweigh the present costs? The decision to invest in a college education is a good example of CBA. Does the potential future salary of a worker with a college degree outweigh the present cost of tuition? For some, the answer may be yes. These students feel that their future salary with a college degree will be higher than without it despite the cost of tuition. For others, the answer might be no. The costs of a college education are higher than any potential income they might make in the future.

Figure 1. “In conclusion, Mr. President, we at Exxon feel that human survival may simply not be economic.”

Figure 1. “In conclusion, Mr. President, we at Exxon feel that human survival may simply not be economic.”

2
As with many economic tools, analysis is not this simple. Uncertainty in measurements and outcomes plays a large role in determining the best choice. Future economic, social, political and environmental conditions are only predictable to a certain extent. Economists, however, are not fortune-tellers; they simply try to make educated guesses about future situations by looking at current trends. For example, while studies show that college graduates earn more than those with only a high school diploma, the hypothetical college graduate above is not guaranteed to find a job with a higher salary than her peers who lack a college education. Such uncertainty is a legitimate concern and must somehow be factored into the analysis. It is usually dealt with by using sensitivity analysis. Such analyses reveal the relative contributions of different parameters to an outcome by varying each parameter by a chosen amount and noting its effect on the outcome. By looking at model outcomes using several values for the same parameter, we can determine how much uncertainty in a specific parameter will influence the outcome.

To find the present value of an action that has long-term costs and benefits, a good economist will also consider a discount rate. This is usually a percentage of the total value of something projected into the future, like an interest rate, but instead of accumulating value, a discount rate causes values to fall. It seems logical that future benefits are worth less in terms of present value. The simple case is that a check for $100 received now is worth more than one that will be received a year in the future, because you could place the $100 received now in a savings account and let interest add to its value. Therefore, the check that you receive in the future is actually worth less than $100. The actual value depends on a number of factors including the interest rates and investment return rates. In the case of the college student, any money she potentially makes in the future is worth less to her now because it can not be used to pay for her education directly. Instead she must take out loans that accrue interest and then use her future earnings to pay off those loans including the interest.

In addition to straightforward monetary costs, CBA must also include opportunity costs—the theoretical costs that come with choosing to take a certain action that precludes other actions. The potential college student must decide whether or not a higher degree is worth forgoing anything else that her tuition might buy, or if she would rather be doing something else with the four years she will spend taking classes. Perhaps more relevant to our questions regarding landscaping, suppose the grounds department only has $500 to spend on mitigating climate change, should they buy a new low-emissions lawnmower or spend the money on planting more
trees on a barren hillside? If they choose to buy the mower, they will have no money leftover to plant the trees. One course of action precludes others.

Economists also take into account benefits and costs that are almost impossible to quantify in dollars and cents. For the college student these intangible benefits could be things such as life-long friendships formed at college or valuable life experiences like spending a semester abroad. Determining these costs and benefits is especially hard when it comes to environmental problems, like threats to biodiversity or improving air quality. There is virtually no market for many environmental goods, which makes it hard to determine how much value people and businesses should place such goods. What is the price tag of a Cardinal that lives in the botanic gardens of Wellesley College? How much is clean air worth? We may not be able to answer these questions directly by putting undisputed values on these things, but we can try.

Techniques such as conducting consumer surveys can be used to see what dollar value the consumer would hypothetically place on the Cardinal. Asking questions like, how much would you pay to be able to take a walk in a park where you would see a variety of bird species can indicate the value of such experiences?¹ We could also look at what choices people have made in other markets, such as the housing market, that might reveal their preferences for environmental goods. If housing in a less industrial part of town costs more, this may be an indication that people are willing to pay more for less polluted air or tree-lined streets.¹ Of course, when using either of these techniques, one must take into account the problem of aggregating individual preferences. Just as people have different tastes when it comes to ice cream flavors, two people will not have the same preferences for an environmental good. The avid birdwatcher will value the Cardinal more than the frequent scuba diver.

**CBA applied to Climate Change**

Besides the problems that come with applying CBA to environmental problems, there are also problems that are either unique to or exacerbated by the issues surrounding climate change. Climate change is unlike any other environmental problem encountered in the past, and it has only just started to be widely accepted by society. Since this is an unprecedented problem, scientists are unsure about the effects of continued warming. Not only will the effects occur in the future, but they are also not absolutely sure whether any effects, positive or negative, will
occur at all. Therefore, the benefits in a CBA of climate change are really the costs, economic or otherwise, that are avoided in the future.

![Diagram of the "Chain of Causality"](image)

Figure 1. The "Chain of Causality"

Uncertainty plays an unusually large role because climate change has a long chain of causality (Fig. 1). There is uncertainty within each link and the uncertainties themselves are unusually large. While the calculation of the change in atmospheric concentration due to carbon emissions seems like a straightforward task (a), it is difficult to know what effects natural carbon sources and sinks will have (b). In the next link (c), the heat-trapping greenhouse processes themselves are subject to other factors besides greenhouse gas concentrations, making it difficult
to associate certain concentrations of gas with a certain increase in temperature. The third link between temperature increases and physical effects (d) involves many different components that are hard to model accurately. Weather patterns, for example, are only predictable to a certain extent. Even if weather patterns were known in general terms, it is still next to impossible to determine what effect those changes will have on humans and wildlife (e). Finally, in order to apply CBA, these changes need to be given a monetary value. While some effects, such as the construction of a sea wall to counteract rising sea level, can be measured relatively easily, others, such as loss of biodiversity are almost impossible to quantify.3

Another problem associated with uncertainty lies in the complexity of ecosystems and our interactions with them. We have a limited amount of information about the effects of human interference on the climate system. While we may think we are doing the right thing by regulating carbon sources or increasing the capacity of sinks in order to halt global climate change, we could be setting the stage for a different kind of ecological disaster by disrupting poorly understood processes.1 The creation of new carbon sinks may have unexpected impacts on the environment.

The absence of impact data is another problem that researchers must contend with when modeling climate change. Aaheim et al. write, “Unlike almost all other environmental externalities, in the case of climate change it might be argued that there are few directly relevant actual data, and that predictions of physical impacts are based entirely upon the predictions, judgements and models of scientists.”3 Climate change does not have any environmental precedent, so we must rely on reasonable assumptions and educated predictions.4

The long time frame of climate change is another problem for CBA. Factors that generally do not change in the short run, such as population densities, will have a tendency to change over an extended period of time. For example, people living in low-lying coastal areas may choose to move when the sea level begins to rise, so any benefit that would accrue through protecting those populations would cease to exist.3 Also, CBA is usually applied to scenarios that take place over the course of 25 years or less. Significant effects from increasing atmospheric carbon concentration are not expected to occur until 100 years from now, meaning that benefits from mitigation actions taken now may not accrue until 100 years from now. It is estimated that the effects can also be expected to last for another 250 to 300 years.5
This last problem with the time horizon is especially important when discussing the discounting of future benefits. It is clear that we need to acknowledge the potential effects of long term environmental problems, but the customary discount rates for events that occur in the distant future are relatively high (5-10%), making any future benefit appear negligible.\textsuperscript{5} This makes sense under most circumstances. For example, if you would not receive the $100 check we discussed above for another 100 years, as opposed to just one year, you would probably not take the time to factor it into your present income at all. The check is basically worthless to you now. Therefore we must devise a new system to choose a logical discount rate that adequately assesses future benefits, but at the same time recognizes the potentially immense impact of climate change on the environment.

Valuing benefits in environmental CBA also creates a problem. Because the most direct benefits are ecological benefits, and more quantifiable economic benefits are usually lacking. Also, in the case of climate change, most of the benefits are in the form of avoided costs.\textsuperscript{3} This means, by acting to prevent climate change now, we must address the question, what future adaptation and repair costs are avoided? For example, by limiting GHG emissions now and stemming sea level rise, future coastal populations will not have to bear the costs of erecting seawalls.

Most GHGs are joint products, meaning that the costs and benefits of emissions reduction are often tied together with other environmental and economic goods. For example, if more trees are planted on Wellesley’s campus, not only is more carbon sequestered, but the quality of the air also improves and therefore human health in the area improves. A study by Alfsen, Brendemoen and Glomsrod found that when the joint products of carbon reduction are taken into account (reduction in environmental damages, health damages, traffic congestion, etc.), the benefits compensate for any economic cost.\textsuperscript{6} These types of indirect benefits have been valued anywhere from $1 to $10 for each dollar of direct benefits related to climate change mitigation.\textsuperscript{3} If such joint product benefits are taken into account, we can safely assume that they would double the direct climate benefits.

**CBA for Wellesley’s Landscape**

Now we will look at some examples of cost-benefit analysis for projects aimed at mitigating climate change by using Wellesley College’s landscape. These projects are: reducing
sediment flow into Lake Waban, reforesting a small grassy hillside and turning a secluded lawn into a meadow. It is important to note here that we are assuming Wellesley is an isolated community. The benefits and costs discussed are restricted to those that affect the campus and its population of students, staff and wildlife. Global, even regional, impacts, because they are anticipated to be small, are ignored.

In the previous chapter, we recommended landscape management practices that would enhance carbon sequestration on the campus in a variety of habitat types. According to Hanley et al. carbon sinks remain one of the “wild cards” in searching for low-cost, flexible solutions to the climate change problem. They cite studies that show that carbon can be sequestered for as little as $25/ton. However, they also recognize that uncertainties exist when measuring the amount of carbon sequestered.\(^1\) Other authors bring up problems related to the long time frame associated with climate change.\(^3\) For example, carbon sequestered in trees only remains as biomass for a fixed number of years depending on the lifespan of the trees.\(^7\) Ecological processes beyond human control, such as forest fires, or other disasters, have the potential to release massive amounts of stored carbon back into the atmosphere. However, barring any unforeseen disasters, the nature of Wellesley’s landscape seems to make it an ideal candidate for the creation of additional carbon sinks.

Because it is hard to put a value certain types of environmental benefits, the best way to handle the valuation of the carbon sinks created by the changes in landscape management that we propose is to find a dollar value for each additional kilogram of carbon sequestered, otherwise known as a marginal value. Other studies equate this value with some percentage of gross domestic product (GDP)\(^3\) so it is not out of the question that the value for Wellesley College should be some percentage of the income that the college makes each year. However, an even simpler method would be to reverse a carbon tax. Studies estimated the carbon taxes need to stabilize greenhouse gas emissions at anywhere from $100 to $400.\(^5\) One particular study estimated that a tax of $250 would be necessary to reduce long-run U.S. carbon emissions to 20% below their current level. If individuals or firms are taxed at a rate of $250/ton of carbon emitted, we can infer that the same parties should receive $250 for each ton of carbon sequestered.\(^8\) Therefore, each ton of carbon is considered to be worth $250 to Wellesley College.
In choosing an appropriate discount rate for our analysis, we follow the recommendation of William Kline, author of *The Economics of Global Warming*, who concludes that 1.5% is an appropriate discount rate for the benefits from present mitigation actions. He comes to this conclusion in several ways, but the intuitive method is the easiest to understand. Suppose you were trying to determine how much a dollar 200 years in the future is worth now. At what value would you be willing to take a dollar from your future offspring in order to make yourself better off now? Fifty cents? Five cents? If you looked back in history to the Revolutionary War era, does it make sense for your ancestors to take a dollar away from you to make themselves better off by one cent? Obviously, the answer is no. Living standards have not progressed far enough in the past 200 years to justify your great-great-great grandfather taking one dollar from you if it was only worth one penny to them. However, if it was worth ten cents to them (equivalent to a discount rate of 1.15%), they might be justified in doing it.\(^5\)

*Figure 3. View of Lake Waban from Wellesley College campus.*

**Diverting Sediments from Lake Waban**

One of the most striking features of the Wellesley College campus is Lake Waban, which also acts as a significant carbon sink (See Chapter 4). One of the recommendations suggested in Chapter 4 was reduce the flow or organic material into the lake. One way to accomplish this would be to install a storm drain treatment center to reduce sediment flow into the lake. Such a device can prevent up to 80% of inorganic sediment and organic material runoff from entering
the lake, resulting in cleaner lake water, fewer algae blooms and less carbon dioxide emitted from the lake. The net result is that the lake acts as a sink instead of a source for CO$_2$, sequestering up to 10,800 kilograms of carbon per hectare annually, which is equivalent to 12 tons.$^9$

The treatment center cost to the college would be about $85,000 including the installation fee. In addition, the grounds department estimates that in order to maintain the trap, two workers would have to devote one day a year to removing sediment from it, resulting in $460 per year for maintenance.$^{10}$ If a eutrophic lake is capable of sequestering 12 tons of carbon per year, and we use the value for carbon from above, this results in benefits of $3000 at a 1.5% discount rate, outweighing the yearly maintenance costs, but not the initial installation costs. It would take 34 years to reclaim the total cost of the drain in carbon sequestration. However, if we suppose the joint products of a cleaner lake are equal to the value of carbon, then the initial investment would pay for itself in 16 years.$^{11}$

In the specific case of Wellesley College and Lake Waban, however, state laws require the installation of sediment traps when older storm drains are repaired or replaced. Therefore, it can be argued that the cost of the sediment trap and its maintenance are sunk costs, or costs that the college incurs anyway. Therefore only benefits in this analysis are meaningful.
Converting a Lawn to a Meadow

A meadow sequesters about the same amount of carbon as a mowed lawn, but meadows require much less management. Therefore, it seems beneficial to turn a secluded lawn into a meadow. In an analysis of this change, a variety of costs must be taken into account, including seeding or transplanting costs, opportunity costs and maintenance costs. Completely reseeding the lawn with meadow species would cost over $20,000 based on recent estimates from similar projects on other parts of campus. The cost is high primarily because the seed is expensive. A less costly option would be to transplant grasses from another established meadow, and the least expensive option would be simply to stop mowing the area and allow meadow herbs and grasses to take over the area. This last option, however, might lead to many unwanted invasive species, meaning that whatever cost of planting is avoided would be made up in maintenance costs. Maintenance costs themselves are estimated to be about $920 per year assuming one worker spends three days a year working on invasive species control and one day a year mowing the area. Therefore, total costs range from $1,000 to $21,000 for the first year of the lawn to meadow conversion.

In this particular area of campus, opportunity cost also plays a part because the land has been designated as the potential site of a new residence hall. Because a new meadow will take anywhere from three to five years to establish itself, if construction of the new building occurs within or just outside of that time frame, any initial expenditure would be lost. However, if the construction does not start until a much later time, then the meadow would have time to grow and sequester a significant amount of carbon. Another cost to consider is the loss of aesthetic value. Many would argue that a meadow is less pleasant to look at than a finely manicured lawn. Even if the residence hall described above were to be built in such a way that the meadow is preserved, some students might be displeased with the new landscaping.

A meadow sequesters 400 to 800 kilograms of carbon per hectare per year while a lawn sequesters about 800 kilograms, resulting in $110 to $220 worth of carbon for a meadow and $220 worth of carbon for a lawn, using the assumptions described above. At 0.43 hectares, this meadow can sequester $48 to $95 worth of carbon. The same area can sequester $95 as a lawn. Additional mitigation benefits accrue as joint products for the meadow, since it has to be mowed much less often than a lawn and does require irrigation or fertilizer. The grounds department estimates that they mow a meadow once per year and up to once per week for a lawn. By
mowing less often, we would be emitting less carbon as well as saving labor hours. After applying the discount rate, the total benefits of the meadow come to $94 to $187.\textsuperscript{13}

Comparing the costs to the benefits, indicate that the lawn probably should be converted into a meadow, because the meadow has the potential to accrue $94 more carbon-related benefits than a lawn each year. At this rate, it will take only 11 years before the benefits offset the initial costs if the lowest cost method of establishing the meadow is used.\textsuperscript{14} The timeline for the construction of the residence hall will ultimately determine if the conversion is made. If the construction does not start for another 11 years or later then a greater initial investment is warranted because there would be time to get more carbon storage benefits. However, if construction begins within the next 11 years, we should look to maximize the short-term benefits that primarily include the reduction in mowing costs and related emissions.

![Figure 5. Hillside on Wellesley College campus proposed for reforestation.](image)

*Re-Forresting a Hillside*

Forests sequester at least 30% more carbon than mowed lawns, so another possibility is to turn a lawn back into a forest. A small hillside that was once covered by trees, is now home to struggling patches of grass intermingled with bare soil, lichens and weedy herbs. The rest of the hillside is still covered with trees, saplings and shrubs, including white oaks, eastern hemlock and rhododendrons. With the exception of some strategically placed bark mulch, the forest floor
is also left alone by the college grounds crew. It seems logical that we should simply extend this
forest patch to cover the barren hillside. CBA, however, may come up with a different result.

This is by far the most labor-intensive recommendation we have looked at so far and the
cost of the materials, while not on the same scale as an $85,000 storm drain, will still be
relatively expensive. We estimate that we will need 5 large sapling trees at $500 each, 10
smaller saplings at $200 each, 50 shrubs at $75/shrub and finally 50 herbs at $6 a pot, for a total
of $8,550 for the raw materials. Transport and delivery is estimated at $100. It would take 3
workers about one week to do the planting. This comes to a total of $3,450. We expect
maintenance to be intensive for the first five years after installation due to watering needs and
control of invasive species, falling to very little maintenance thereafter. If we estimate that this
maintenance will take one worker two days a week for three summer months during the first five
years, the costs are $27,600.16 This brings the grand total to $39,600.

Benefits include carbon sequestered, as it is obvious that a forested hillside will sequester much
more carbon than a sparsely vegetated hillside. In fact this particular lawn has an area of 0.1 ha and
therefore has the potential to sequester 30 more kilograms of carbon annually as a forest than as a
lawn. Applying our carbon valuing system, this change yields only $8.25 in benefits. In addition, the
hillside would no longer have to be mowed, saving labor and gas, as well as reducing carbon
emissions. We will use the estimation for joint products and double the dollar value of the carbon
benefits to find the total benefits, which results in $16.50. Joint products you will remember include
such things as the aesthetic value of a wooded hillside. Comparing the costs to the benefits of the
project at a 1.5% discount rate indicates that the college should not reforest this hillside, unless the
costs were covered by a gift to the college specifically for the purpose of restoring the area. In this
case, since the money is earmarked for a particular project, the college does not have to consider
whether or not the benefits outweigh the costs.

**Conclusions**

CBA is a useful mechanism for evaluating these projects, but it is only a tool. It presents
the necessary information, aggregate costs and aggregate benefits, in a manner that is easy to
understand. However, complications arise, such as the opportunity costs in the lawn to meadow
project, which make actual decisions harder than they appear on paper. In these cases, individual
circumstances and preferences will dictate the subsequent course of action. CBA is a starting
point, and should not be used as a paramount decision-maker. As you have seen, individuals may have moral obligation to mitigate climate change (Chapter 2) and institutions may have pedagogical reasons for doing so (Chapter 3).

**Climate Change as a Global Problem**

It is important to keep in mind that climate change is a global problem. Changing weather patterns, a diversity of regional climates and geographies, and development differences between countries means that the benefits and costs of climate change mitigation are going to be spread around the world. Some parts of the world may have to bear more of the cost and reap fewer benefits, while others will reap more benefits for less cost. The cost-benefit analyses conducted above were limited specific projects within a small landscape, a college campus that covers only 500 acres. Therefore, it can be argued that what is best for Wellesley may not be best for the rest of the world. The college can be seen as concerned mostly with short term costs and benefits due to the 4-year student turnover. Administrators are concerned with providing the best experience for current students, while recruiting for the next two or three classes. For the most part, none of them are looking 200 years into the future to see the concerns of the class of 2200. They are concerned with more immediate problems, like building a new student center to bring the campus up to date in order to continue to compete with other institutions.

![Figure 6. Climate Change Talks](Image)

Figure 6. Climate Change Talks.
On a small scale, actions that would mitigate climate change are at least partly favored by CBA. Wellesley College will be resistant to investing a lot of money, time and energy into a project that will not see results for 200 years when they can invest the same money into improving student housing or dining options, enticing applicants and more revenue now. Potential global impacts from climate change, however, may be on such a large scale, that action is warranted because it is morally right no matter what the current numbers indicate. This means that the college should do everything in its power to mitigate climate change, including creating and enhancing natural carbon sinks, regardless of the cost. This may be an extreme scenario, but it does not negate the fact that any cost-benefit analyses undertaken by institutions like Wellesley College or by individuals in the context of the climate change should also include some measure of the global, or at least regional, impacts of their actions.
Climate is changing and consequences are unpredictable and potentially severe; thus, the question is no longer should we do something but what should we do to mitigate climate change. In previous chapters we have discussed land management strategies and the use of CBA in deciding which projects to undertake in order to increase the carbon sequestration of our landscapes. Yet, none of us -- private landowners, business entrepreneurs, or college administrators -- work alone in the world. We live in a society governed by laws and policies. While we may have decision-making power over the land we own, these policies create the context in which we make our decisions; they can encourage or discourage actions that result in the emission and sequestration of greenhouse gases.

In the world today however there are few policies aimed at mitigating climate change. Such a dearth of public policy asks us, as land managers and active citizens, to look beyond managing our own land and use our influence to bring about such policies. By doing so, we can increase awareness of carbon emissions and mitigation factors, reducing the accumulation of greenhouse gases in our atmosphere.

First we need to define what a policy is, and then focus on the complexity involved in climate change policies. Then we can examine policies or policy proposals at various level of government and explore avenues through which we can support or create these policies. We’ll look at the Kyoto Protocol, an international accord with the goal of mitigating climate change. Then we’ll explore suggested national policies like the BTU taxes and finally we’ll focus on state and local laws and their malleability. The goal of the chapter is to understand the basics of climate change policy, and highlight opportunities in which we, or our affiliated institutions, can support the creation of climate change policies.
What is Policy?

There is no singular definition or description for policies but they can be characterized by their scope, membership, level of formality, and enforcement mechanisms. A policy can be international, national, state, or local in scope. For international policies, countries are usually the members, whereas at a local level individuals make up the membership. There are formal policies that function as laws in states organizations, such as car emissions guidelines. There are also informal policies, like mission statements that organizations use to guide decision-making, such as a commitment to ethnic diversity.

Formal and informal policies can have enforceable punitive repercussions from fines to loss of membership privileges within the institution. Some policies however are committed to voluntarily and are without a mechanism of punitive justice, such as the Kyoto Protocol, which will be discussed later in the chapter. A belief in the policy, peer pressure, and/or the maintenance of a reputation between countries and allies are pressures that keep members bound to the policies they voluntarily ratify even in the absence of punitive enforcement.

It is important to remember that policies can have both direct and indirect effects. Some policies that affect climate change are explicitly about reduction of greenhouse gas emissions. Others that, for example, work to improve public transportation, or create bicycle lanes and traffic signals like those in Cambridge, England, can have an impact on carbon emissions even when this is not directly stated in the wording of the policy itself. Thus, we as private citizens and institutions have many avenues through which we can promote policies that potentially mitigate climate change.

Policy has a long process it undergoes before it becomes effective in law. First the policy has to be put on the governmental or legislative agenda. Then it has to garner enough support to come before a committee where policy makers formulate its wording and justify its regulations. Afterwards it is presented to the legislature, and most likely amended. If it passes, the processes of implementation, monitoring, and sustaining the policy begin.

During this long process it is often public support and citizen lobbying that brings attention to the issue and keeps the policy alive. The Nixon administration changed its indifferent attitude towards environmental protection because public support was highly in favour of creating regulations to clean up the environment. The furor that public interests groups and
citizens created drove the administration into creating the Environmental Protection Agency (EPA) and policies like the Clean Water Act. Thus, Active citizenry -- your activism -- is essential in the creation of environmental policy.

**Complexity of Climate Change Policy**

Creating and enforcing policy, especially environmental policy is difficult. Conflicts concerning time horizons, constituency wants and needs, and consequences of climate change make effective policy a juggling act. Moreover, regulations need to employ cost-effective solutions (though we asserted that climate change mitigation should be undertaken despite the costs). They also need to be on the same spatial and temporal scale of the ecological systems they are meant to govern, meaning that if a policy is trying to protect a watershed it needs to be enforceable throughout the region, even if the watershed crosses state lines. Yet often, legal responses have created narrow and inflexible policy with excessive costs or ones that actually cause environmental harm indirectly.

Climate change policy is especially difficult to draft due to its causal, spatial, and temporal complexity. Causal complexity refers to the numerous factors that drive global warming, such as the countless sources and sinks for multiple types of greenhouse gases, not just CO₂. How can we draft policies that are comprehensive enough to address these interrelated factors, yet can be passed politically? Advocates of incremental, piecemeal policies over a comprehensive policy say that small changes are easier to support politically. Yet, piecemeal
regulation may ignore the full scope of the problem, miss lower-cost synergistic options, or produce unintended effects. In the United States, federal regulation has focused on separate laws for pollution control of air, water, and land. These laws were also passed one at a time. In consequence, restrictions on one medium – air, water, or land -- at a time has shifted disposal of wastes and pollution into the others.

Climate change policy is complex spatially because the climate change problem results from a global pool of greenhouse gas sources and sinks, these gases travel and affect climate worldwide. Simultaneously, there is immense regional variability in expected change in weather patterns, their effect on ecosystems, the costs of climate change mitigation, and the ease of implementation. For example, if a comprehensive policy asked only for a global neutral carbon budget, then one country could continue to produce greenhouse gas emissions with impunity and engage in deforestation while another country preserved enough forest to sequester the carbon. On a global scale, the carbon budget is neutral, but on a regional level wildlife (especially endogenous species) will have been driven to extinction and people will be facing consequences of environmental damage.

Finally, temporal complexity and uncertainty complicate formulation of climate change policy. How do we create a policy flexible enough to change over time? Can we create an optimal schedule for reducing carbon emissions and increasing sequestration rates? Climate change may be more or less serious, with consequences of a different kind than currently predicted. While climate change policy and action needs a long time horizon in which to balance out costs and benefits, it simultaneously needs to be flexible.²

Causal, temporal, and spatial complexities endow climate change policies with particular characteristics. These policies operate on the precautionary principle, which simply means they function according to the precept “better safe than sorry.” While there is uncertainty about the specific effects of climate change for various reasons, we can make policies based on the best information available. With such a complex problem, it is nearly impossible to draft “the perfect” climate change policy. Yet, because reversing the effects of climate change is much more difficult and perhaps more costly than preventing GHG emissions in the first place, forward thinking policies with long time horizons are in our own best interest.
Climate change is a global problem; thus successfully dealing with this problem will require the commitment of many countries. The Kyoto Protocol is the result of a movement to create an international accord with the goal of mitigating climate change. Based upon the United Nations organized Rio Earth Summit of 1992, a nonbinding agreement to stabilize GHG emissions, the Kyoto Protocol was created December 1997. Under the Protocol, industrialized nations committed themselves to reaching a target level for GHG emissions by the years 2008-2012. The Protocol asks the United States for a seven percent reduction in GHG from 1990 levels by 2012. Target levels differ based upon the wealth of each country (measured through GDP) with the assumption that richer countries not only produce more greenhouse gases but also have a lower cost of reduction. Developing countries had no obligation to reduce their GHG emissions because industrialized countries produced most of the greenhouse gases. Once the industrialized nations had reduced their emission then, with technological and financial help, emerging markets would begin their reduction.

The Kyoto Protocol included a variety of mechanisms to increase its flexibility over time such as international carbon trading, joint implementation, and the Clean Development Mechanism. International carbon trading is a way for firms in various countries to reduce their abatement costs by buying and selling greenhouse gas emission units. Thus, countries that have the ability to reduce their GHG emissions have an additional incentive to do so; they can generate income by selling their extra carbon trading units to a country with high abatement costs. The downside to this scheme is that there is no incentive for any country to reduce below their target rate.

Joint implementation is another way to reduce carbon emissions in a cost-effective manner. A firm in one country sponsors a project to reduce emissions in another country. Both countries decide upon the amount of emission that would be reduced. The sponsoring country then earns a carbon credit, which adds to their carbon budget and reduces costs of domestic reduction. The second country is one step closer to reaching their target without any immediate, direct cost to themselves.

The Clean Development Mechanism is another example of a flexibility mechanism in the Kyoto Protocol. It gives emission credit to firms in an industrialized nation for the equal amount of reductions that result from the firm’s investment in another country’s business. With this
mechanism, unlike joint implementation, it is hard to measure if the investment actually led to emission reductions because the money is given for a specific project.\textsuperscript{4}

The Kyoto Protocol has faced much criticism. It has been called unrealistic and unenforceable. Several suggestions about how to modify the treaty to increase its effectiveness have surfaced, but few have been incorporated into the treaty.\textsuperscript{5} Alternatives, such as an international carbon tax, have also been offered at the policy negotiation table. In one such proposal, a uniform tax rate would be imposed in all countries targeting the supply end of the fossil fuel market. If the raw product—fossil fuels—were taxed then all processes and products created from the energy produced would incorporate this tax. Studies show that a 7\% reduction in the United States would need a $50 - $150 carbon tax per ton. Natural gas prices would increase by 35\% - 40\% and the price of coal would double, making it unlikely that a carbon tax policy could be passed.\textsuperscript{6} Of all the alternatives however, the Kyoto Protocol is the only seriously supported international climate change policy.

The Kyoto Protocol has not received much support from the United States. First, the Protocol was slighted by the Bush administration in the early 1990s. Then, during the Clinton presidency, the United States signed onto the treaty but the administration invested little in the promotion of Kyoto. Congress also withheld the necessary funding to pursue the climate science
research and policy analysis that was needed to reach Kyoto’s target emission level. In March 2001, early in the George W. Bush presidency, the United States broke its commitment to the Kyoto Protocol. The United States would not accept a plan that would “harm our economy and hurt American workers.” Uncertainty around climate science was cited as evidence against global climate change, and he said that caps on carbon dioxide emissions would significantly increase electricity costs for the nation’s consumers. Since then President Bush has asked corporations for voluntary reductions in emissions. The United States’ withdrawal from the Kyoto process served as a catalyst for international action. In July 2001, the Kyoto Protocol was adopted by 178 nations (notably excluding Russia), mostly due to the flexible position the European Union took ensure its acceptance. As of today, no move has been made to commit the United States to the Protocol once more.\(^7\)

Despite the United States’s lack of commitment to the Kyoto Protocol, individuals can set personal goals to meet Kyoto Protocol emission guidelines within their community or home. Already small citizen groups and private institutions have taken up the commitment. Tufts University, in Massachusetts, has developed a climate change initiative in which they are trying to meet the 7% reduction for all university related GHG emissions, which, given the university’s
growth rate, is a 30% cut in projected GHG emissions. To achieve this goal, Tufts has undertaken numerous creative projects and programs. They have added solar paneling to two dorms, and are currently constructing an energy efficient residence hall. They have switched to low energy fluorescent bulbs on over 90% of the campus, implemented ZIP cars on campus, and implemented computer energy conservation initiatives. They also have a staff position that works to coordinate and support these activities. Tufts is not the only university to have made such a commitment. Over thirty universities have student groups dedicated to realizing the Kyoto Protocol goal in their university. Lewis & Clark College has actually achieved its goal of a 7% reduction from 1990 emission levels.

Most universities and community institutions, however, do not have such an initiative in place. A disgruntled and active membership, be it students or community members, could bring about a climate mitigation plan. Adopting a mission statement that simply recognizes climate change and the institution’s part in the process would be a good beginning step, and would lay the foundation for future mitigation schemes. By taking an active role in promoting the ideals of the Kyoto Protocol, individuals create a climate change constituency that could sway legislators, while overcoming the political inertia that uses uncertainty in climate science as a way to continue with the status quo.

United States Policy: An absence of policy

The United States has no comprehensive, coherent policy concerning climate change. While there is a $2,000 tax break on hybrid vehicles, there are larger tax breaks for those who purchase SUVs for business reasons. Moreover, Congress defeated an amendment in 2003 to impose a 5% increase in fuel efficiency for SUVs; they are still quite the gas-guzzlers. In terms of climate mitigation, the SUV tax break negates any possible benefits of the tax break on hybrid cars. While the United States has strong environmental policies such as the Clean Air Act and the Clean Water Act, there is no federal mandate on emission levels for greenhouse gases.

National policies have been proposed to address climate change. One such policy was the BTU (British Thermal Units) tax proposed by the Clinton administration. Under this tax regulation, fuel sources, such as coal, natural gas, liquid petroleum, nuclear electricity, and hydro-electricity would be taxed 25.7 cents per Million Btus (British Thermal Units), which is a measure of the heat content of a fuel. Furthermore, an additional 34.2 cents per Million BTU
was to be imposed on refined petroleum products, raising the overall tax to 59.9 cents. Solar and wind energy were tax exempt. Like a sales tax, the more an individual or firm consumes, the more they would have to pay. It was an attempt to discourage consumers from excessive use of fuels that emit greenhouse gases when burned. When Clinton proposed the tax, it became the center of controversy. Though many environmental organizations supported it, deeming it to be a necessary first step to combating climate change, there were critiques of the proposal as well. These criticisms ranged from accusations that the tax would paralyze the economy to predictions that the tax would be a great burden for economically disadvantaged households. The BTU tax proposal was defeated by the legislature.

Since 1993, when the BTU tax was proposed, there have been no major pushes for a national GHG reduction plan. With the current Bush administration, it does not look like there will be a new policy proposed. Thus, citizen action is needed to drum up pressure for a coherent set of subsidies, tax breaks, and regulations to achieve reductions in GHG emissions. If enough voters call for action, policy makers will respond by placing climate change initiatives on the national agenda. Through self-education, community awareness, and lobbying you can help raise awareness of the need for integrated, national climate change policies. Such a movement is a long-term goal; however, valuable endeavors can be undertaken now. By pursuing good landscape practices, promoting institutional commitments to GHG reduction, and working for state and local policies that support GHG mitigation, you begin to create the atmosphere that moves society toward addressing climate change.

**State and Local Policy: Within Your Grasp**

In the absence of a comprehensive national environmental policy, states can be the innovators in finding methods to mitigate climate change. Using their authority over areas such as transportation, utilities, land use and wildlife protection, they can create programs that lessen carbon emissions or increase sequestration. Thus state models are often the most innovative climate change policies being formulated. Also, at the state level, policies have generated less controversy than when proposed on a national scale. For example, fifteen states including Massachusetts have set target rates for emission reductions. States have also managed to require mandatory GHG reporting, an initiative that has been controversial at the national level. In addition these states have taken a more active interest in quantifying the amount of carbon
sequestered by various ecosystems and in encouraging such sequestration. Heartland states like Nebraska have created committees to study sequestration potentials, Tennessee has a no-tillage agricultural training program and Oregon has managed to protect many of its forests, important for their carbon sequestration potential.\textsuperscript{17}

It is obvious that States have a great ability to create innovative policy, and often, local towns within a state can add amendments to the overarching policy. Since state and local legislative institutions and policy makers are accessible individual voters, you, can affect these policy decisions with a success and speed unavailable to national policy. Through town meetings, state lobbying, petition campaigns, and local action campaigns, state and city policies can be amended. Moreover, you could run for a public position on the local level, or you could serve on a city or state-wide taskforce dealing with water supplies, land management, drought control, education, and the like. It is at this local level where citizens can realize the greatest amount of direct political power.

Take for example the Massachusetts Wetlands Protection Act. Established in the late 1970s, the act recognizes the importance of wetlands as a rich habitat for plants and wildlife, and as a resource for citizens. Wetlands can sequester carbon, reduce flood damage, and mitigate the dangers of toxic chemicals in the environment. While the state EPA oversees appeals to the Act, each town can create bylaws and amendments that tailor the act for the town, and the towns enforce their regulations.

In Massachusetts, 40% of its cities and towns have passed their own bylaws that add protections to those afforded by the Massachusetts Wetlands Protection Act. Some municipalities have extended wetland conservation to include a 100-foot buffer zone around the 100-year flood plain.\textsuperscript{18} This additional area allows towns greater jurisdiction over the wetlands. Moreover, while the wetlands regulations protect the land, they offer no protection to the wildlife on those lands. Thus Bedford, a city in southern Massachusetts, corrected this oversight by requiring that construction in flood plains not compromise the health of the wildlife or the land. It also does not allow more than 25% of its 100-year flood plain to be imperious surfaces. The town of Brewster has prohibited construction on entire flood plains. By keeping the waterlogged soil from disturbance, these towns have inadvertently also increased the sequestration abilities of the wetlands.\textsuperscript{19} State laws and local bylaws are the most immediate way individuals can create change, and they allow local areas to tailor laws to their needs.
As you have seen, climate change policy can be addressed at multiple levels of government. While complex to craft, it is important that we create these coherent policies. The Kyoto Protocol is an attempt to create such a policy on the international level. Yet, without the support of the United States and Russia, it becomes less effective and enforceable. Nationally, there is an absence of a well-formed, comprehensive policy, though they have been proposed. Moreover, there is no foreseeable creation of such a policy. It is at the state and local level where environmental laws are passed and enforced; it is at this level where individuals most easily influence them as well. At each level of government however it is essential to have a political constituency that supports policies aimed at mitigating climate change. You can be part of that constituency. By taking an active role in supporting such a policy, you encourage its creation and strengthen its effectiveness.
Conclusion

Managing to mitigate climate change

Global climate change is the greatest environmental challenge of our time. It presents complex scientific problems, challenges our moral commitments to others and nature, and it cannot be solved by unilateral action. It will affect all nations, peoples and environments far into the foreseeable future. Mitigating such a multi-dimensional, long-term problem will be difficult, but the vast majority of scientists and policy makers worldwide agree that it is necessary.

Climate changes are due to human activity changing the composition of atmosphere. Most importantly, the concentration of carbon dioxide is increasing due to the burning of fossil fuels and the loss of habitats that sequester atmospheric carbon—grasslands have been transformed to cropland, forests to pasture, wetlands to rice paddies. Never before in the history of Earth has a single species had the power to affect such global changes, and it is not clear that we now have the needed wisdom and leadership at the national and international level to alter our behavior for the good of the Earth, ourselves and future generations.

The fundamental carbon cycle of the biosphere is being altered, and hence it is this cycle that has been the focus of our attention. A focus on the carbon cycle, however, does not preclude other priorities. A landscape mosaic of wetlands, forests, meadows and lakes—a restoration of carbon sinks within the landscape—also reduces air pollution, muffles the sound of traffic, stores freshwater, sustains populations of wildflowers, cools the surroundings, and calms the mind. Restoring carbon sinks is, therefore, the right thing to do for the land and ourselves.

It is heartening that individuals, institutions, towns and states have recognized the seriousness of global climate change and are acting responsibly to mitigate it. We suggest that all individuals of developed countries, that have and continue to emit the largest amounts of greenhouse gases, find ways to reduce their contribution to global climate change. Our findings for Wellesley College indicate that the focus of our efforts to address climate change will have to be on
reducing sources of greenhouse gases. However, all landowners, and particularly those like college
and universities involved in education, can also restore, maintain and enhance carbon sinks. In fact,
enhancing carbon sinks, unlike changing sources of energy, can begin immediately. Mowing and
irrigating less, planting a long-lived tree, allowing meadows to flourish, and protecting a wetland
can begin now—from decisions made today. We can start, literally, with our own backyards.
Simply begin by asking where can I plant another tree, shrub or wildflower and how can I maintain
the land with a minimum of effort and disturbance to natural processes.

Humans have always manipulated the landscape to suit particular purposes. In the case of
Wellesley College, the vision and foresight that created its natural landscape of forested hills
separated by wet meadows can now be extended to include carbon sequestration. It is easy to fall
into complacency due to economic constraints, lack of immediate, tangible consequences, and
apathy, but we need to keep in mind our moral obligation not to put other people or ecosystems at
risk. You can begin to meet those obligations by assessing a landscape's ability to sequester
carbon—creating a carbon budget—that reveals ways to reduce the overall emission of greenhouse
gases from the habitats it includes. Faced with various choices of projects to pursue, you can
employ economic tools such as a cost-benefit analysis to choose the best option. While there are
many reservations in applying CBA, it does help you to identify the expenses and advantages of
any particular course of action. In the end however you may choose to manage to mitigate climate
change despite the cost, because it is the right thing to do.

Yet, we need not end our efforts to mitigate climate change at the boundaries of our land.
There is a dearth of effective international, national, and local climate change policy. As a
landowner and concerned citizen, you can work to create policies at various levels of government,
which promote reduction in greenhouse gases and protect and restore natural habitats. Using a
landscape-level focus you can work beyond your home to do your part in mitigating climate
change.

Our earth is truly a “giving tree.” It sustains us and myriad of other fascinating creatures.
Yet, history and science make it clear that we cannot expect it to keep producing a bounty of
goods no matter how we use or abuse it. Like the boy in Shel Silverstein's “The Giving Tree," if
we take too much from our earth without respect for its ecosystem processes and regenerative
needs, we could end up with little more than a stump to sit on. But there is a different way to
live. By acknowledging and valuing the ecological roles of the tree, we can harvest its fruit and rest in its shade while the costs of our development drain into its roots, trunk and branches.

*I think we’re challenged, as mankind has never been challenged before, to prove our maturity and our mastery, not of nature but of ourselves.* – Rachel Carson

1
Endnotes

Chapter 1: The Giving Earth


Chapter 2: The Facts of the Matter


**Chapter 3: Option or Obligation?**


25. Leopold, “Land Ethic”.


**Chapter 4: Alders to Asphalt**


Chapter 5: Counting Carbon


   The range for woodland sequestration rates was calculated by dividing the total flux of Northeast and North Central forests by the total area of the respective forests (as found in Birdsey and Heath’s 1995 study).


19 Methods for calculating carbon sequestration in forests involve remote sensing space-crafts and forest inventories. Forests were defined using remote sensing land covers under the normalized difference vegetation index (NDVI). Inventory data were used to calculate above-stump and total biomass. Using both methods assured that NDVI totals only included forested regions.


The annual carbon sequestration rate of groves was estimated by multiplying a percentage (84%) of the total annual carbon sequestration rate of woodlands, as found in Birdsey and Heath’s (1995) study. Groves were assumed to sequester approximately 83% of woodland’s annual sequestration rate because woody debris, forest floor, and understory herbs and shrubs each contribute, respectively, 10%, 6%, and 1% to total carbon sequestration by a woodland, as stated in Turner’s 1995 study.

27 Birdsey and Heath (1995) used the following methods to calculate carbon storage in groves. They acquired base year data, such as vegetation volume, growth rates, and mortality rates, from national compilations of forest inventory statistics. From this data they used a variety of models, including soil models by Burke, et al. (19??) and Post, et al. (19??), to estimate the carbon stored in each part of the forest: trees, understory, forest floor and soil. This method involved multiplying the volume by certain empirically derived conversion factors to obtain the amount of carbon stored by a tree of a specific volume. Growth rates for vegetation (i.e. changes in biomass volume) were similarly converted to reflect the change in carbon storage over time. Soil carbon was linked to regional temperature and precipitation differences (Birdsey and Heath, 1995).


33 Nicholas Rodenhouse. 5 May 2004. Personal Communication.


46 Online. Internet. 4 May 2004. Available: [www.co2science.org](http://www.co2science.org)


49 Important to note is that the carbon sequestration of wetlands is still poorly known, in part, due to imprecise measurements of DOC and POC in waters and soils, rates of primary productivity, and standing crop biomass. It is difficult to accurately determine just how much carbon each aspect of the wetland environment contains due to the varied and dynamic nature of these habitats. However, in some studies, model simulations have been used in order to estimate how much soil carbon would have to be lost by a wetland to shift if from a carbon sink to a source. These models, though helpful, provide only hypotheses about the source-sink status wetland habitats.


Chapter 6: Control your Carbon!


8. Smith, *Ecology and Field Biology*, 613


10. Sauer, *The Once and Future Forest: a guide to forest restoration strategies*, 151


17. Smith, *Ecology and Field Biology*, 570


20. Sauer, *The Once and Future Forest: a guide to forest restoration strategies*, 335


27. Creighton, *Greening the Ivory Tower*, 110


31. Smith, *Ecology and Field Biology*, 66


34. Bressor, “Electric Lawn Mowers”

35. Smith, *Ecology and Field Biology*, 86-89

36. Smith, *Ecology and Field Biology*, 570

37. Smith, *Ecology and Field Biology*, 76

38. Smith, *Ecology and Field Biology*, 76


41. Smith, *Ecology and Field Biology*, 653

42. Smith, *Ecology and Field Biology*, 653

43. Smith, *Ecology and Field Biology*, 653


45. Sauer, *The Once and Future Forest: a guide to forest restoration strategies*


52. Sauer, *The Once and Future Forest: a guide to forest restoration strategies*, 102


55. Sauer, *The Once and Future Forest: a guide to forest restoration strategies*, 132

**Chapter 7: Banking Carbon**


9. 40ha*270 kg/ha/yr

10. 2*$230/worker/day

11. $85,000/((3000*2*.985)-$460)

12. 4 days* $230/day

13. ($47.30*2*0.985) to ($94.60*2*0.985)

14. 11*(benefits of meadow)-(discounted benefits of lawn)-(costs of meadow) = 11*($186.36-($94.60*.985))-1000

15. $230/day * 2 days *12 weeks *5 years


**Chapter 8: Beyond the Backyard**


5. McKibbin, W. & Peter W.

6. Goulder, L & Brian N.


11. Rosencranz, A.


18. A flood plain is the strip of land adjacent to a river that is covered when water overflows the banks during rainfall.


**Appendix**

**Carbon Sequestration Worksheet**

<table>
<thead>
<tr>
<th>Habitat Type</th>
<th>Carbon Sequestration Rate by Habitat Type (kg C/ha/yr)</th>
<th>Habitat area (ha)</th>
<th>Annual sequestration (kg C/yr)</th>
<th>(a x b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Woodland</td>
<td>1013 - 1158</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grove</td>
<td>850 - 972</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meadow</td>
<td>400 - 800</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lawn</td>
<td>817</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wetland</td>
<td>480</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lake</td>
<td>270</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Sum of values in this column = total annual carbon sequestration by your landscape</th>
</tr>
</thead>
</table>