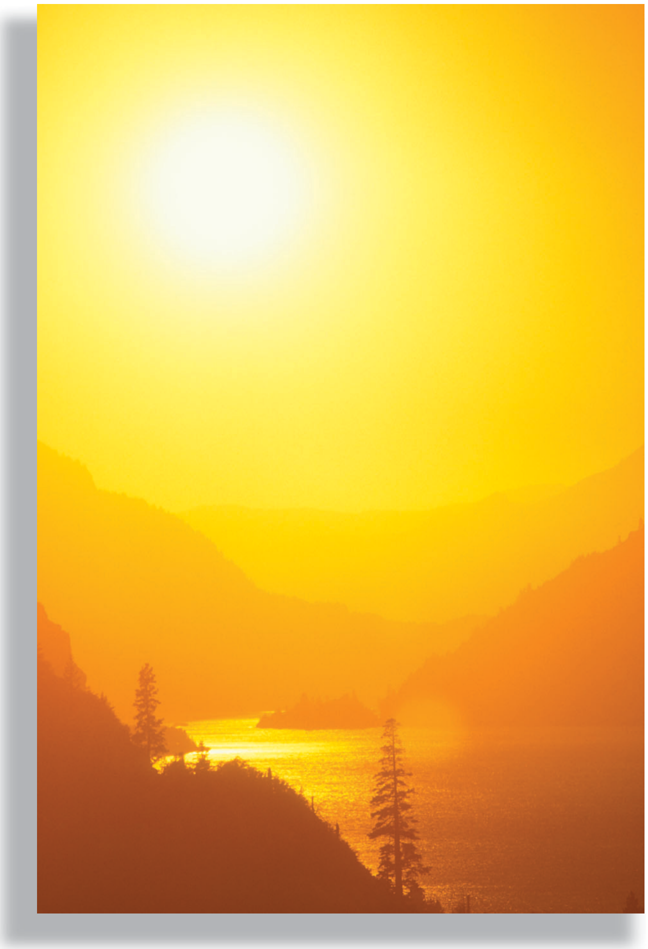
Forests, Carbon and Climate Change

A Synthesis of Science Findings



executive summary

Forests, Carbon and Climate Change

A Synthesis of Science Findings

A project of

The Oregon Forest Resources Institute
Oregon State University College of Forestry
Oregon Department of Forestry

TABLE OF CONTENTS

Preface

The Oregon Forest Resources Institute (OFRI) commissioned the book, *Forests, Carbon and Climate Change: a Synthesis of Science Findings,* on the relationships between forests, atmospheric carbon and climate change. This executive summary contains the introductory chapter by Dean Hal Salwasser and brief summaries of the other chapters from the synthesis.

While there is not scientific consensus about all the causes and implications of global climate change and the role of human activities, there is agreement that the relationships between forests and carbon, carbon and climate, and climate and forests are important and need to be better understood. It is also clear that Oregon is a forest-rich state, poised with opportunities for forests, forestry and forest product enterprises to contribute toward maintaining a livable climate.

As we might remember from school, carbon is **the** essential element of life. Plants convert atmospheric carbon from CO2 into sugars through photosynthesis. Animals eat plants and give off CO2 to the atmosphere through respiration. And all organisms give off carbon when they respire, die and decay.

We now know that there is a relationship between temperature and the amount of carbon in the atmosphere. Of the five greenhouse gases (those in the atmosphere that warm the earth because they let in light but do not let out heat), CO2 is the most prevalent. Recent research has enabled scientists to determine historic CO2 atmospheric levels as well as rates of increase and decrease, and these data have helped put the situation today in historical perspective.

We know that forests contribute to clean air and water and to wildlife habitat while providing wood products and recreation. We know that forests are dynamic and have changed both in location and species composition through cooling and warming periods over the last several million years. We know that climate sets the stage for livability on earth. And, we know that forests play an important role in maintaining a livable climate.

Beginning around 8,000 to 10,000 years ago, humans initiated massive losses of forest due to agriculture and, subsequently, urban and industrial development. While forest conversion has largely been reversed in North America and Europe, we still face big challenges to keeping the world's remaining 9.6 billion forest acres in forest use.

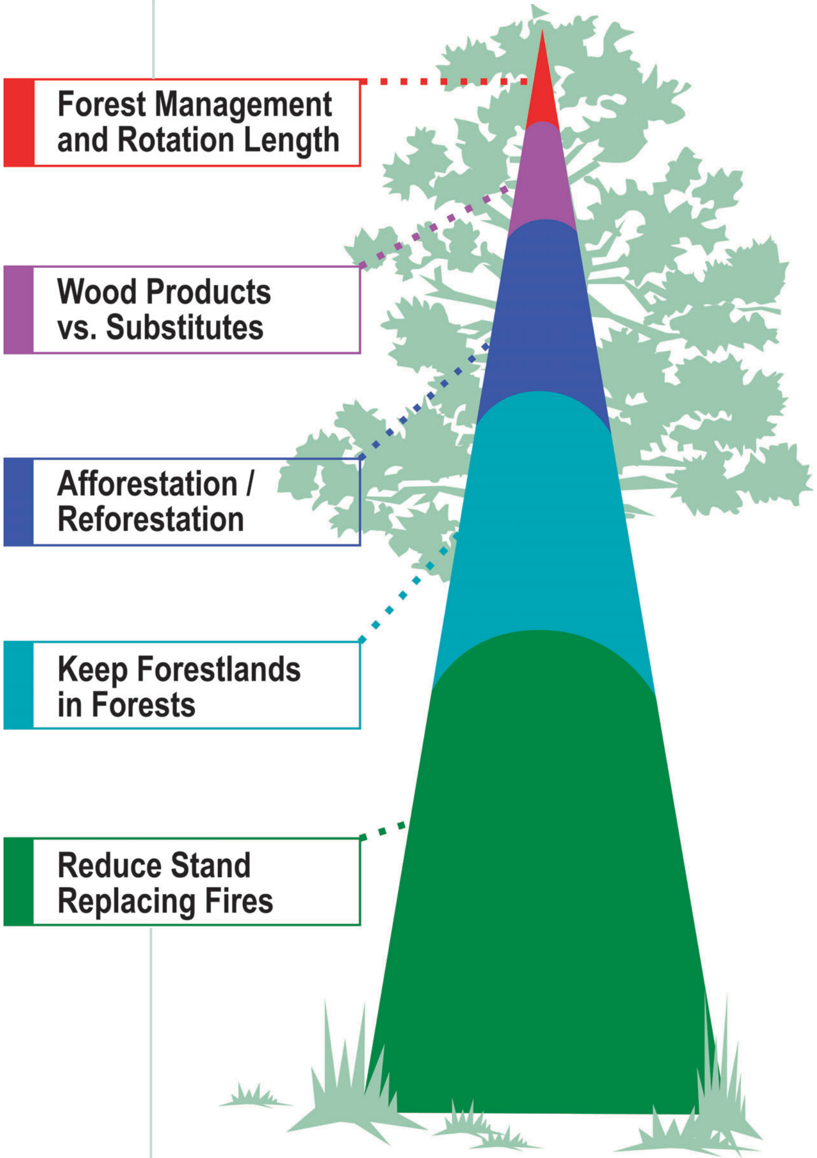
During the past 300 years of the industrial age, humans have accelerated the transfer of carbon from long-term stores in fossil fuels and forests into the atmospheric pool. The current level and rate of increase in both temperature and atmospheric carbon may exceed conditions over the past 650,000 years, with forests responding in complex ways.

Since forests play an important role in storing carbon, having more forest cover is a positive force in lowering atmospheric carbon levels. Conversion of lands currently in other uses to forests (afforestation), reforesting quickly and aggressively after harvest or natural disturbance, keeping forestland in forest use and managing forests for fire resilience all have obvious positive effects. Beyond that, recent research by forest scientists has confirmed that wood products continue to store carbon.

For Oregon and the other Northwest states that are rich in forest resources, the role forestry can play in reducing atmospheric carbon has been of key interest. This is evidenced even on the policy front, where California, Oregon and Washington have stepped ahead of the federal government in addressing the issue. Forests contain about 75 percent of the earth's biomass, so in a state like Oregon, with its highly productive forests, the per-acre potential for carbon storage is among the highest in the world.

Forest scientists have been studying the interactions of forests and climate for some time, and while there is, as might be expected, some complexity and contradiction, there are forest management strategies that can help in sequestering carbon or reducing its emission into the atmosphere. These techniques include:

- reducing forest densities to keep trees healthy and minimize the risk of stand-replacing fires and insect problems (for example, the 2002 Biscuit Fire in southwestern Oregon released about a fourth as much carbon into the atmosphere that year as was emitted statewide by the burning of fossil fuels);
- keeping forestland in forest use (this means ensuring that private forestlands can be managed profitably as forests);
- afforesting former forestlands that have been converted to non-forest uses and reforesting quickly and aggressively after harvest or natural disturbance;
- using wood products and energy generated from wood in lieu of using fossil fuel-intensive products such as steel and concrete and energy generated from fossil fuels; and
- changing forest management strategies to sequester carbon through thinning, increasing rotation lengths and other techniques can provide forest landowners an opportunity to profit from the sale of carbon offsets.



This “carbon sequestration tree” demonstrates my personal understanding of the relative importance of these strategies in affecting climate change. Moving up the tree from the bottom to the top, we have a series of management strategies that can help reduce the carbon in our atmosphere.

OFRI’s board of directors and staff appreciate the thorough and professional work done by the authors and reviewers of the various chapters. We especially appreciate the leadership of Hal Salwasser, dean of the OSU College of Forestry, in conceiving this idea and helping bring it to fruition. Finally we are grateful for the fine work of our editor, Donna Matrazzo of the Writing Works, who worked tirelessly with our authors and reviewers to pull this project together and translate scientific jargon into language the rest of us can understand.

We hope you enjoy this summary and are stimulated by these ideas. Copies of the book containing the entire synthesis are available from the Oregon Forest Resources Institute.

Mike Cloughesy
Director of Forestry
Oregon Forest Resources Institute

INTRODUCTION:
FORESTS, CARBON AND CLIMATE — CONTINUAL CHANGE AND MANY POSSIBILITIES

Hal Salwasser

WHY SHOULD WE CARE ABOUT FORESTS, CARBON AND CLIMATE?

This is a book about forests, carbon, and climate and how they interact. Forests are vital to our quality of life and well being. They protect our watersheds, harbor native plant and animal species, provide wood and fiber-based products used daily by nearly everyone, and are settings for varied recreational and cultural activities. Forest management and conservation and forest products enterprises also support many communities and drive a major part of Oregon's economy.

Climate, of course, sets the context for livability. It affects the means by which all organisms pursue their existence. It also affects the kinds of forests that occur in different places and at different times across the land surface of our planet. And, as we are increasingly aware, not only does climate affect forests, but forests affect climate. Carbon is one of the prime linkages between forests and climate, along with water and oxygen.

Carbon is a key component of all life's fundamental building blocks, including fats, carbohydrates, and proteins. In fact, about half of the dry mass of all living things is composed of carbon. Plants take carbon from the atmosphere in the form of carbon dioxide gas (CO_2) and use water and the sun's energy to make a new compound, glucose ($C_6H_{12}O_6$), composed of carbon, hydrogen, and oxygen. Some of the glucose is converted by the plant to cellulose and ends up as one of the main structural compounds in wood in the case of trees. Through this process, called photosynthesis, carbon is removed from the atmospheric pool. About half the carbon absorbed through photosynthesis is later released by plants as they use their own energy to grow. The rest is either stored in the plant, transferred to the soil where it may persist for a very long time in the form of organic matter, or transported through the food chain to support other forms of terrestrial life.

When plants die and decompose, or when we burn biomass or its ancient remains in the form of fossil fuels, the original captured and stored carbon is released back to the atmosphere as CO_2 and other carbon-based gases. In addition, when forests or other terrestrial ecosystems are disturbed through harvesting, conversion, or natural events such as fires, some of the carbon stored in the soils and organic matter, such as stumps, snags, and slash, is oxidized and released back to the atmospheric pool as CO_2. The amount released varies, depending on subsequent land use and probably rarely is more than 50% of the original soil store.

At the global scale, if more carbon is released through decomposition or burning than is captured and stored through photosynthesis or oceanic processes, the concentration of carbon dioxide (CO_2) builds in the atmospheric pool. Why is this important? Because CO_2 is a greenhouse gas, as are methane (CH_4) and nitrous oxide (NO_2). Like a car windshield on a sunny day, these gases let short wavelength sunlight energy pass through the atmosphere to the earth's surface, but do not let an equivalent amount of longer wavelength heat energy pass back out to the universe. Oceans also absorb and store—or sequester—large amounts of carbon through the accumulation of unoxidized products of photosynthesis, as well as through other chemical processes (IPCC 2001).

Carbon dioxide levels in the atmosphere correlate with the earth's mean annual surface temperature, and global surface temperatures affect processes such as glaciation. From the geologic record, it appears that glacial periods coincide with atmospheric levels of around 200 parts per million (0.02%) CO_2. Interglacials (the periods of time between glacial epochs) have generally coincided with levels approaching, but not exceeding 300 parts per million (0.03%)—that is, until the past 100 years (Siegenthaler et al. 2005). Earth's atmosphere currently includes around 380 parts per million (0.038%) of CO_2, the highest detected or inferred level over the past 650,000 years. The current concentration of atmospheric CO_2 is about 30% higher than at the start of the industrial era, with a rate of change unprecedented since the last glacial maximum.

It is important to note that global temperature and CO_2 relationships are correlations. They may not necessarily result from a direct cause and effect relationship. Scientists are still not certain about the degree to which increasing carbon dioxide in the atmosphere causes warming or the degree to which warming causes increasing atmospheric carbon dioxide levels. Mean global surface temperatures during the most recent glacial period are estimated to have been around 10° F colder than present (IPCC 2001). Scientific evidence is clear that both temperature and CO_2 levels have increased over the past 100 years, reversing a prior cooling trend in the climate (IPCC 2001, NRC 2006), and human activity is strongly implicated.

The Intergovernmental Panel on Climate Change (IPCC) estimated about 0.25° F sensitivity in mean annual global temperature with each change of 10 parts per million in the level of atmospheric CO_2. This would amount to a global climate about 2.5° F warmer than 100 years ago, if CO_2 alone explained all climate change. But the climate warmed by only about 1.0° F over the past century, mostly during two periods: 1910-1945 and 1976-2000 (IPCC 2001). The difficulty in elucidating cause and effect between atmospheric carbon dioxide and climate results from lags in process responses and complex feedbacks among climate factors that are not completely understood at this time (Boisvenue and Running 2006). Major aspects of climate change are also driven by mechanisms unrelated to greenhouse gases, such as the shape of the earth's orbit, tilt of the polar axis, and solar and volcanic activity. Nevertheless, recent scientific evidence points to human-caused additions of greenhouse gases to the atmosphere as *very likely* (90%-99% probability) factors in recent warming trends over the past century (IPCC 2001, NRC 2006).

Forests play important roles in climate through other mechanisms in addition to carbon exchange. These mechanisms may be as or more important than that of carbon exchange. The massive amounts of water transpired by forests ultimately change the global distribution of energy in the atmosphere, affecting rainfall patterns, cloudiness, and storms. Even the optical or reflective properties of forests differ from those of most other objects; forests absorb 85%-95% of incoming shortwave solar energy. Evergreen conifers in the boreal region thus warm the atmosphere by holding solar energy, while boreal deciduous forests with snow on the ground in the winter reflect more incoming radiation away from the earth, as do deserts.

There is currently much public concern and scientific dialogue about the impacts of human-caused additions of CO_2 and other greenhouse gases to the atmosphere. Cycles of warming and cooling periods in our geologic history have greatly affected where certain organisms could thrive, including lately, humans. Thus the ability of plants and animals to move and adapt in response to climate change has been vital to the persistence of those lineages that have not gone extinct (Williams 2006). Some tree species, for example, have shifted in elevation as much as 3,000 feet or in latitudes as much as 1,000 miles in response to climate changes since the last glacial retreat around 10,000 years ago. In the past, species had the time and physical ability to make such adjustments.

Some studies suggest that the rate of climate change today is unparalleled in the geologic past, certainly in the past 1,000 years (NRC 2006). Other evidence indicates that climate changes may have been even more rapid and abrupt during previous glacial periods, associated with large releases of methane from the ocean floor, and that the interglacial period of the past 10,000 years may actually be a more stable climate than characterized much of the previous 2.5 million years, except perhaps for the past 100 years when the rate of change has been very steep (IPCC 2001, NRC 2006).

Irrespective of the rate of climate change currently underway, the landscape in many parts of the world is now filled with artifacts of human occupancy that present barriers to the free movement of many species, such as fenced highways, valley bottoms full of houses and farms, and dams on major river systems. Today's diverse assemblage of species has neither the luxury of time nor the freedom to move unimpeded by physical barriers or fragmented landscapes.

If human-caused additions of carbon dioxide and other greenhouse gases to the atmospheric pool are driving the rapid rate of climate change, then we have major reason for concern. Forests are affected. Hydrologic cycles are affected. Agriculture is affected. And ultimately our quality of life is affected. But we need not sit back and just let it all unfold. Some even say we have a moral imperative to act quickly and boldly to change human impacts on climate (Gore 2006). Options are many but lag effects of greenhouse gases already in the atmosphere appear to commit the planet to continued warming for many decades (Pacala and Socolow 2004). If we want diverse, productive and resilient future forests, we need to prepare them for a warmer future. And we need to look for ways forest resources can mitigate or ameliorate undesired climate change.

We can take actions to reduce the effects of human activities on climate, but not immediately reverse impacts already made. The most significant action to reduce human-caused atmospheric carbon is to use less fossil fuel energy to support our life needs. To reverse trends will require finding energy substitutes for fossil fuels at the global scale. These points cannot be overemphasized because without taking these actions soon the planet is going to get a lot warmer than it has been for at least several million years.

Annual per capita CO_2 emissions vary widely among nations: estimated at 22 US tons emitted per person per annum in the U.S., about 11 tons per person in European Union countries, about 3.3 tons in China and slightly over 1 ton for India (United Nations 2005). With the economies of India and China growing rapidly based on fossil fuel energy, principally coal-fired power plants, their per capita consumption rates are bound to increase; combined those nations already have nearly eight times the human population as does the U.S. Combined per capita carbon emissions in India and China need only rise to around 2.8 tons per person to equal the total CO_2 emissions of the U.S. at our current population and consumption. They may well reach this level of total emissions in the early 21st century. Unlike some local or regional environmental impacts, adding pollutants from anywhere to the atmosphere eventually effects the entire planet.

We can partially influence how much human-caused carbon dioxide is added to or sequestered from the atmosphere through how we manage and conserve forests and forest products. Major options include reducing deforestation which reduces carbon release, storing more carbon in existing forest ecosystems, accelerating afforestation which sequesters more carbon as the trees grow, and encouraging greater use of wood-based materials that store more carbon and use less energy in manufacture in place of more energy-demanding products such as steel, concrete, and plastics. These actions could also have significant co-benefits beyond their impacts on climate.

We can also influence future forest ecosystems so they are better able to accommodate the warmer climates they are likely to encounter. Westerling *et al.,* (2006) suggest that climate warming is a significant factor in the intensity of forest fire seasons in recent decades and that restoring resilience to fire in some forest types may reduce future impacts of even warmer temperatures on forest fires. Given that climate is warming, even if we do not understand all the driving factors, preparing forests to handle a future much different than the past makes sense. As the saying goes, "One cannot navigate the future by only looking in the rear-view mirror."

Forests, forestry, and forest products cannot collectively solve the entire "climate problem," but they are essential pieces to a comprehensive climate strategy (Pacala and Socolow 2004). The chapters in this book show that how we use, manage, and conserve forests and forest products can make a difference for future climates if we begin to bring carbon and climate into forest policies and decision-making.

How have Forests Changed over Time and Space?

So, what can we learn from the past that will help us navigate into the future regarding forests and climate? Satellite imagery has been used to show the kinds of vegetation or lack thereof currently covering the earth's land surface. If such imagery could have been obtained for prior times we would see much change in land cover. Over the past 2.5 million years we would see around 40 cycles of glacial and interglacial periods, sea levels rising and falling by 300-400 feet, and forests moving and changing not only in location but also in species composition. Over hundreds of millions of years we would see entire continents moving across the surface of the earth, isolating or reassembling their biotas in the process. ***Lesson 1:*** whatever we might consider as forest today, even without human actions it has never been stable or in the same place for all time.

Regardless of age, structure, or species composition, all forests are created and maintained by interactions among their constituent species and between those species and their physical environments, including the prevailing climate for the region. Forests are also affected by disturbance events such as fires, storms, droughts, landslides, volcanoes, floods, and human actions. While a given forest may look stable or seem in equilibrium to a casual observer on an annual or even decadal time scale, all forests are highly dynamic on multiple temporal and spatial scales with both species composition and structure changing over time and space. Some animal species move in and out of particular forest areas on a daily or seasonal basis. Hourly measures of carbon exchange between forests and the atmosphere show that large changes occur over the course of a day. ***Lesson 2:*** any perspective on forests must be taken with multi-scale dynamics in mind, especially change we can affect over decadal and centuries time scales at stand, landscape and regional geographic scales.

Prior to around a million years ago, the land surface cover we would see over most of the world if we had the satellite imagery would consist of whatever nature delivered in the absence of human beings. But with the emergence of early humans (*Homo erectus*) and their eventual diaspora out of Africa into Europe and Asia around 0.5 to 1 million years ago, nature without humans ceased being the only driver of change (Williams 2003, Wade 2005). Human influence on forests through use of fire, hunting, and gathering would most likely have been slight and localized at first, then spreading and more pervasive as behaviorally modern humans (*Homo sapiens*) subsequently evolved in Africa then dispersed across Eurasia an estimated 80,000 to 50,000 years ago. In some places they replaced earlier hominids, *Homo erectus*, and in others, such as Australia and the Americas, they were the first humans to show up. People arrived in the Americas perhaps as early as 15,000 to 20,000 years ago (Shreeve 2006), though the most credible earliest reliable dates so far recorded are closer to 12,000 years ago (see review by Roosevelt *et al.,* 2002). At the height of the Last Glacial Maximum approximately 18,000 years ago, sea levels were an estimated 300-400 feet lower than current (Lambeck and Chappell 2001), continental ice sheets covered vast areas of North America's middle to higher latitudes, and glaciers occurred even at low elevations, ca. 3,000 feet, in the Southern Sierra Nevada in California. By 12,000 years ago, continental and montane glacial ice was in retreat but sea levels were still nearly 200 feet lower than current. It is plausible that some of the first Americans lived in places now under coastal oceans and used watercraft and coastline resources (Erlandson 2002) in their rapid dispersal to South America, reaching present day Chile an estimated 12,500 years ago (Dillehay 2000).

The key point here is that whenever and wherever humans arrived, they did not encounter forests or any other ecosystem types in the same places or of the same species composition that we do today. When humans first arrived in what is now Oregon, as hunters and gatherers who also used fire, it marked the beginning of a new force of ecosystem change in our state—human action. ***Lesson 3:*** one must envision forests in periods prior to human occupancy—not just prior to Euro-American settlement—to get a sense of what a pristine forest unaffected by human activity might have been and that forest will never occur in exactly that form or place again.

Human influences on forests increased dramatically in scope and magnitude following the most recent glacial period. Sometime around 20,000 years ago in Southeast Asia, Hoa Binh people appear to have learned how to cultivate food plants to augment their hunter-gatherer existence. Around 8,000 to 10,000 years ago, perhaps earlier, humans began practicing agriculture in the near East (Mesopotamia), Indus River Valley, and Far East (China) and Mesoamerica. Farming enabled people to augment then replace small-band nomadic and hunter-gatherer lifestyles with more stable, larger communities based on sedentary rather than shifting agriculture and a larger, more consistent food supply. The early post-glacial domestication and selective breeding of cereal grains, maize, fruits, and vegetables entailed purposeful transformation of native plant communities, including areas of forest, to farm plots or the interplanting of food crops into native plant communities. With new, more stable food supplies, the total human population was able to grow from around 5-10 million prior to agriculture to perhaps on the order of 100 million as cultivating cultures spread and multiplied. It also enabled the evolution of social hierarchies, complex cultures, and the trappings of what we would eventually call civilizations, including highly organized warfare.

It is likely that early farmers grew their first crops in forest or woodland openings, on floodplains or on terraces near water but above flood zones. Grassland sods would likely have been difficult to cultivate with primitive tools but their large-scale conversion to farms would eventually come beginning 3,000 to 5,000 years ago with metal tools, draft animals and, in the last 100 years, motorized machines. As the global human population grew, reaching an estimated 500 million prior to the start of the industrial era, its need for forest soils for crops, water for irrigation, and wood for fuel, farm implements, building materials, metallurgy, and conducting trade and war impacted forests farther and farther from the early communities (Perlin 1991). As Perlin (1991) compellingly documented, most Euro-Asian civilizations were enabled by wood and other forest resources. Many of those civilizations, in turn, dramatically transformed forests and forest soils, often to the long-term degradation of the land and the cultures they at one time supported (Marsh 1874, Perlin 1991, Williams 2003). The reader should note that what I am describing here is not forestry as we know it today; it was unsustainable resource exploitation, land degradation and land-use conversion. Forestry emerged as a "solution" to these unsustainable human land and resource use practices.

Sedentary agriculture and associated high densities of people arrived or emerged at different times in various places around the world. But whenever and wherever it did, it inevitably entailed human-caused land use change. These changes, in the most recent 2,000 years, include massive conversion of forests to agriculture and, prior to widespread use of fossil fuels, massive amounts of wood used for cooking, heating, shelter, tools and ships (Perlin 1991, Williams 2003). Forest trees provided the fuels that allowed prehistoric stone-age humans to begin smelting bronze beginning about 5,500 years before present and later iron beginning around 3,200 years before present. Both of these metals require very energy-demanding processes, i.e., lots of wood or charcoal to fuel the furnaces. New metal tools then enabled even more productive agriculture and more land conversion to farms and towns. While IPCC (2001) suggests relatively little human impact on climate prior to the industrial era, other evidence suggests potentially significant pre-industrial impacts (Perlin 1991, Ruddiman 2003, Williams 2003). ***Lesson 4:*** while it is commonly believed that most global forest loss and its associated climate impact occurred during and after the industrial era began in the mid to late-1700s, it is quite plausible that very early uses of forest resources and forest transformations actually began the era of human-aided climate change thousands, not just hundreds of years ago.

Ruddiman (2003) points to a divergence in the actual level of atmospheric carbon from that predicted by current global climate models—without human additions, atmospheric carbon dioxide levels based on Earth's physical processes should have declined, while actual levels estimated from proxy indicators increased. CO_2 release from widespread deforestation, burning of wood and forests, rise of paddy rice cultivation, and growing herds of domestic livestock are cited by Ruddiman as reasons why the climate at northern latitudes is now an estimated 3.6° F warmer than it otherwise might have been without human-caused additions of atmospheric carbon dioxide that started well prior to the industrial era. He posits that had it not been for pre-industrial age additions of carbon dioxide and methane to the atmosphere, Earth would have begun returning to the early stages of the next glacial period nearly 6,000 to 4,000 years ago.

Broecker (2006) rebuts Ruddiman's explanation and claims that the past 8,000-year record of atmospheric CO_2 can be explained by non-human factors. If Broecker is right, pre-industrial era impacts of human action on climate may not be of significant concern, though the recent and current roles certainly are. However, if Ruddiman is right, the roles of human action and forest loss in climate change over thousands of years would be even more substantial than we might currently think and would compel consideration in better understanding current impacts. At this point science is still debating and collecting data and running models. But it certainly is intriguing as we ponder the effects of climate warming to think about Ruddiman's hypotheses and whether or not the human enterprise has unintendedly postponed the next period of glacial advance.

Deforestation and fire create the second largest source of human-caused CO_2 emissions to the atmosphere, following fossil fuel burning. Future forest losses if deforestation is not halted could lead to something on the order of 25% of total future CO_2 emissions still coming from forest conversion. This is why the human-caused climate impacts of the last 150 years, the current rapid rate of human-influenced climate change, and further changes projected for the next 100 years are of prime concern now and for the foreseeable future and why forests and forest resources must be part of any comprehensive strategy to ameliorate undesired changes. ***Lesson 5:*** the rates of climate change since 1850 and projected for the next 100 years are extreme compared to most of the past and they will have profound consequences for our quality of life that will be compounded if we do not start taking actions to ameliorate them.

Working with Half the Forest

Why is this historical perspective on forests, carbon, and climate included in the introductory chapter? Because understanding the past is useful in knowing how to journey into the future. Human population growth, expansion, and land transformation have likely resulted in the more-or-less permanent loss of about 50% of the forest cover that existed 8,000 years ago, and much though certainly not all of this loss has occurred within the past 300 years (Figure 9.1, Williams 2003). (I say more or less permanent because if or when the earth's biodiversity no longer includes humans, forests may eventually return to those places where climate and soils support their species.) Some forests long ago converted to farms returned to forest when people abandoned areas of occupancy or decided to plant trees rather than food crops, while deforestation continues in other places to this day. Not all of the originally converted forests would have been old-growth full of stored carbon, since nature and human activities create and maintain mosaics of successional stages. But some or much of the original forest must have been old-growth or late-successional forest that stored maximal amounts of carbon for the forest type and geographic location.

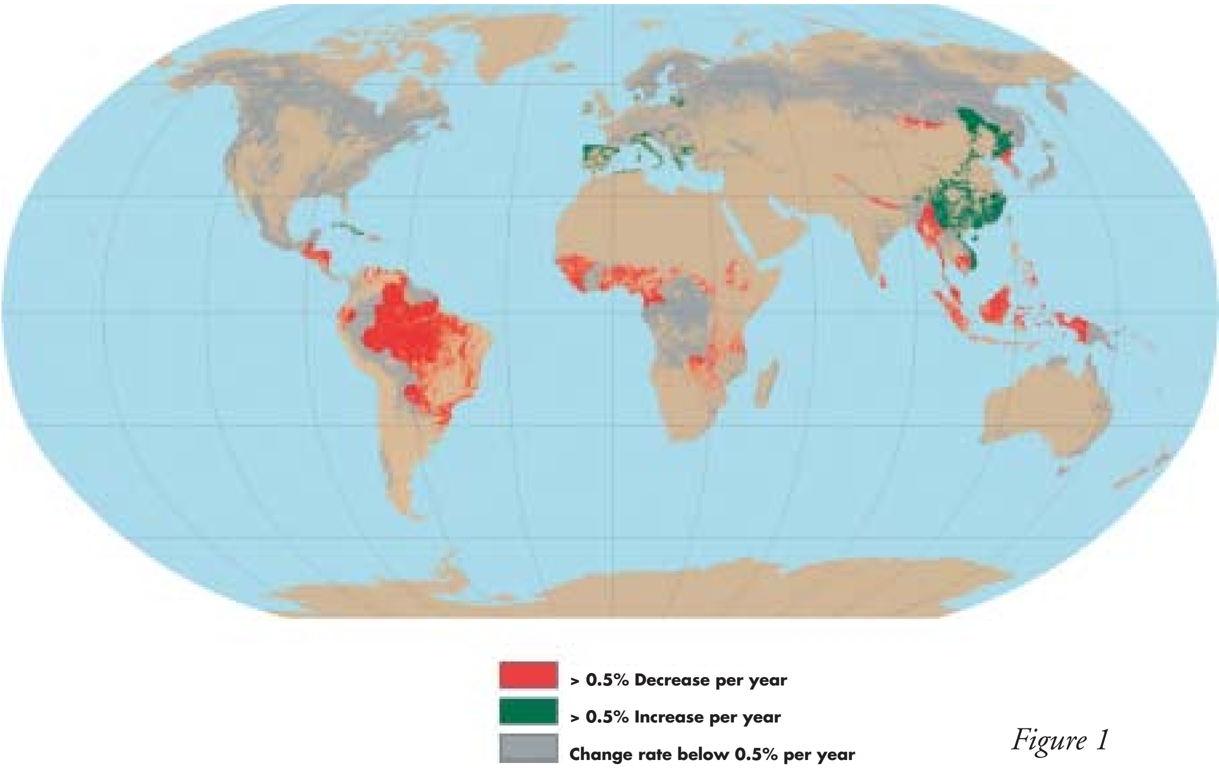


Figure 1

Source: Williams, Michael. 2003. *Deforesting the Earth: From Prehistory to Global Crisis*. ©University of Chicago Press.

The main point here is that whatever the developmental stage of the world's forests prior to the advent of agriculture or prior to the industrial era post 1750, approximately half of it is not forest of any kind anymore. It has been converted to agricultural use, or more permanently changed by multiple forms of human development. It has long ago given up its above-ground stored carbon to the atmospheric or oceanic pools or to temporary storage in durable wood products and some—probably less than 50%—of its below-ground carbon as well. How much total carbon? We can only estimate the answer. A plausible amount might be that something on the order of between 25% and 37% of the carbon once stored in forests has been released since about half the carbon stored in global forests is in the soils and between 50% to 100% of an equivalent to the original soil carbon pool may still be intact or subsequently replenished. By now, oceans have probably absorbed most of the CO_2 released from forests centuries to millennia ago and they may be turning more acidic as a result with undesired consequences to marine life (Kleypas *et al.* 2006).

Beyond knowing we are now working with about half the forest that might have been possible had the human enterprise not evolved as it has, we must also consider that much of the remaining half has been impacted by harvests and reforestation, afforestation after agricultural abandonment, or alterations in species composition resulting from "agroforestry" or introduction of non-native species. Hence, their ecological condition and carbon storage capacity are much different from that of pristine forests prior to human intervention. And humanity is not a mere 500 million souls anymore, but nearly 6.5 billion, heading for perhaps 8 to 10 billion by mid-century. This is on the order of 1,000 times more people than are thought to have existed at the advent of agriculture.

Global forests currently store just over half of the carbon residing in terrestrial ecosystems (FAO 2001). The total biosphere carbon pool is estimated at 2,190 Pg (a petagram is 1.1 billion U.S. tons) of carbon. Of this, approximately 1,000 Pg is in forests. How significant is that? It is roughly 50% more carbon than now resides in the atmospheric pool and about 20%-25% of the carbon pool stored in remaining, accessible fossil fuels, estimated at 4,000-5,000 Pg. This means the original forest prior to human impacts may have stored up to 40% as much carbon as the current pool in fossil fuels, or that deforestation may have already released an amount of carbon equal to up to 15% of the carbon currently stored in the fossil fuel pool. Far greater carbon pools are in deep oceans (38,000 Pg) and carbonaceous rocks (65,000,000 Pg), but contrary to forests, these pools do not turn over quickly.

Cumulative carbon losses due to changes in land use from 1850 to 2000 are an estimated 156 Pg of terrestrial carbon (Houghton 2003), 90% of which may be from deforestation alone (IPCC 2001). Emissions from burning fossil fuels and making cement during this same period are estimated at 275 Pg of carbon (Houghton 2003). Thus, carbon emissions from historical land use change could be equal to 56% of historical fossil fuel emissions making land use change, most especially deforestation and afforestation, a significant factor in atmospheric carbon accumulation and in any comprehensive climate strategy.

Throughout the industrial era, most though not all forest clearing occurred in temperate regions. Now most deforestation is occurring in tropical regions and global temperate forested area is relatively stable (or increasing though afforestation). However, much new temperate forest is quite different in composition and carbon storage capacity than the original forest it replaced and it is also quite different than primary tropical forest (FAO 2005). Temperate forest area stability, while true for many regions, is not true for certain U.S. regions, such as Washington, California, New England, the South, and Midwest, where forests are still being converted to residential uses.

Deforestation remains the primary source of carbon emissions from terrestrial ecosystems globally, amounting to net of about 2 Pg per year (FAO 2001). Releases from burning fossil fuels add more than 6 Pg per year. FAO (2001) estimates that reducing deforestation by 50%, combined with agroforestry and afforestation/reforestation over and above what is currently occurring could maximally offset about 1.5 Pg of the fossil fuel additions to the atmospheric pool. This is significant and should be considered in any comprehensive climate policy. But even if all global forests were managed for maximum carbon sequestration, they alone cannot completely offset CO_2 emissions from current rates of burning fossil fuels.

Humans are not through transforming land, particularly forests. And we're not through burning fossil fuels. Starting with only half the forestland that might have been possible absent humans, we face large challenges to retain even the remaining 9.6 billion acres of global forest *as* forest. Only by keeping or increasing forestland in forest uses, storing more carbon in those forests, using forest products in place of energy-demanding substitutes, or by lengthening the life of forest products can forests contribute to the amelioration of current climate trends. Doing all these things would maximize forest opportunities to contribute to desired climate outcomes.

How have Carbon and Climate Changed over Time and Space?

Absent the presence and impacts of humans, climate and atmospheric carbon continually change in cyclical patterns due to physical factors associated with the shape and position of Earth's orbit relative to the sun, tilt of the polar axis, solar activity, volcanoes, and ocean currents. There are also complex feedbacks between the reflectance of various land covers and climate trends. Ice sheets reflect more of the sun's energy than forests so when a glacial period starts it accelerates as the ice advances and vice versa. These climate processes have been at work for almost as long as Earth has existed and they will continue to cause climate change in the future. Thus the issues at hand are: what are the effects of human activities in modifying climate change and what can we do about those we do not wish to experience? These are the main points of contention among climate scientists.

Most climate scientists do not argue about climate change, they argue about how current change relates to past change, the magnitude of human impacts on climate, and how those impacts might be interacting with non-human factors that drive climate change (IPCC 2001, Ruddiman 2003, Broecker 2006, NRC 2006). The principal human activities that add carbon to the atmosphere are burning fossil fuels, manufacturing cement which consumes energy to heat limestone, converting ecosystems with high carbon stores (such as forests) to ecosystems with lower carbon stores (such as agricultural lands or residential areas), certain agricultural practices such as paddy rice cultivation which emits methane, and maintaining large populations of domestic livestock that also produce methane. Much of the estimated 50% loss of forests to other land uses over the past 8,000 years has occurred during the most recent 300 years of the industrial age, augmenting the additions of carbon to the atmosphere from other human activities.

The past 300 years are also significant in several other ways. The massive conversion of forests during this period coincided with burning wood harvested from those forests, and then burning fossil fuels. Used for smelting metals, making bricks and cement, and eventually fueling motorized transportation, fossils fuels helped enable dramatic increases in economic activity in certain nations, along with accelerated global trade. The industrial age has thus witnessed the transfer of large amounts of carbon from two of its long-term stores into the atmospheric and oceanic pools—from forests converted to other land uses and from wood and fossil fuels burned to drive economic development. The atmospheric carbon in excess of what nature's processes would otherwise deliver will eventually be taken back up by oceans, but not as quickly as we are delivering carbon to the atmosphere, and not all of it until human actions release only as much carbon as terrestrial and aquatic ecosystems are capable of sequestering.

Scientists are still working to understand more precisely how industrial-era carbon releases have impacted global climate. Relationships between carbon and climate are not simple. Nor are they linear, direct cause and effect. During this 400-year period of adding carbon dioxide to the atmosphere, Earth also experienced what is referred to as the Little Ice Age, a cooling period that ended during the latter half of the nineteenth century. Remnant glaciers have been receding since the late 1800s, dramatically so in recent decades. Did the addition of carbon dioxide from industrial era forest conversion coupled with burning fossil fuels bring the Little

Ice Age to a premature end? Ruddiman (2003) thinks it plausible. Or did long-term cyclical factors that drive climate override whatever impacts human activities might have had? Probably not (IPCC 2001, NRC 2006).

What does the Future Look Like From Here?

To a degree, what we know from the past tells us what we might expect in the future. Climate oscillates, it cycles at multiple scales, it often changes abruptly, and forests respond to climate change in complex ways. We should not expect any of these principles to be different in the future.

The transition time to any potential future climate equilibration—estimated to be at least a century from now, perhaps longer and then only if we boldly change course on emissions and sequestration soon—means that we and our grandchildren will live through warmer climates for many decades. Will the current levels of CO_2 in the atmosphere, and projected additions from future human activities, be enough to alter any non-human climate cooling forces? Or will they exacerbate non-human warming factors? We don't know for sure yet. We have only models to give us ranges of possible futures and the main scenarios examined point to a warmer, not cooler, future (IPCC 2001). These scenarios suggest future mean annual global temperature increases that range from a low of about 2 times the amount of increase over the past 100 years to a high of about 11 times the rate of increase during the twentieth century (IPCC 2001). Thus, the heightened concern about carbon and climate and what we can do about them.

What might these estimated future global mean temperatures mean for us? IPCC (2001) estimates the following as *very likely:* higher maximum temperatures and more hot days over nearly all land areas, higher minimum temperatures, fewer cold days and more frost-free days over nearly all land areas, and more intense precipitation events. They rate as *likely,* increased summer continental drying and associated risk of drought for most mid-latitude continental interiors. The U.S. south of the Canadian border is a mid-latitude region.

Using the best state-of-the-art models and databases, scientists describe what we might expect for climate and forests in Oregon—not a single future but a range of possible futures based on current trends and assumptions about their continuation. Most future climate scenarios for the Pacific Northwest show increases in mean annual temperature of from about 3.5 to 7.0° F by the end of the twenty-first century. Recall that global mean annual temperature rose by only about 1.0° F during the twentieth century. Regional precipitation may change little, perhaps become slightly wetter or slightly drier. But with a warmer climate more precipitation will come as rain than snow and growing seasons may be extended, leading to higher biomass accumulations and lower summer stream flows.

Woody vegetation is likely to increase in the dry ecosystems east of the Cascade crest and in southwestern Oregon, while alpine vegetation may be reduced as the upper treeline moves up in elevation — right off the top of the mountain in some cases. Projected warmer winter temperatures could open some Oregon forests to species that do not tolerate hard winter frost, changing the assemblage of species in our forests. It could also change the nature of insect and disease outbreaks, as cold winters are one of nature's checks and balances on their populations. In the past, plant and animal species were able to move freely across the landscape in response to climate change if it was tolerable and slow enough. But the current faster pace of change, along with extensive human infrastructure such as roads and developments throughout many landscapes, will hamper the natural ability of some species to adapt by changing location.

Perhaps the most significant implications of future climate scenarios for the Pacific Northwest are the potential impacts on fish and fire. Warmer temperatures, longer growing seasons, earlier snow melt, and more droughts mean earlier peak stream and river flows and lower summer flows. These are bound to impact native fish populations, including wild salmon runs. Forests in the future will be even more vulnerable to insect epidemics and uncharacteristically intense, large fires. Westerling et al. (2006) document data and model results suggesting that climate warming has made fire seasons since the 1980s more severe, regardless of fuel conditions or past forest management. Running (2006) suggests future fire seasons will even be more severe.

These changes in fire seasons will require either more resources dedicated to fire suppression, which will only make the eventual fires more severe, or a policy change to allow fires to burn where they do not endanger other's property or homes. With a declining federal discretionary budget, the latter may end up being the default option. Another option would be to purposefully ignite fires when forest and weather conditions are likely to lead to acceptable and more controllable fire intensity and area of burn. This may require rethinking how air, water, and endangered species laws are implemented, accepting some short-term risk to air and water quality and at-risk species to reduce long-term cumulative risk (Mealey *et al.,* 2005).

Whether future forest fires will add more CO_2 to the atmospheric pool than is removed by forests accumulating more biomass in a warming climate with longer growing seasons is not universally clear. It depends on the geographic scale and the severity of fires, as well as the forest type. It also depends on what happens after the fire in terms of burned trees and reforestation. In some cases the most positive effect on climate may entail harvesting fire-killed trees, turning them into durable products, and then actively reforesting the burned area as proposed by Sessions et al. (2004). But this also depends on how much fossil fuel would be consumed through harvest, transport, milling, and reforestation. In others the most positive effect may entail letting nature alone decompose the fire-killed trees and revegetate the landscape (Law *et al.* 2004). The issue of how best to respond following major forest disturbance events is currently receiving much attention in scientific and policy areas.

What can We do to Influence Future Climate through Forest Resource Management?

Scientists, among others, have suggested worst case scenarios for future climate and forests. But we are not doomed to worst-case scenarios on either climate or forests unless we do nothing to change course. There are significant actions that can be employed to mitigate the worst case, and help reduce net human-caused additions of carbon to the atmosphere, what Princeton scientists Steven Pacala and Robert Socolow (2004) call the Wedge Strategy to close the gap between worst case and possibly tolerable case. West Coast governors have agreed to work together to reduce CO_2 emissions. California has established a state-backed and third-party verified carbon registry that includes forest conservation and management for storing additional carbon beyond "business as usual." There are many actions the field of forestry can employ.

The U.S. Environmental Protection Agency (2005) estimated that forest and agricultural land in the U.S. is currently an annual "sink" of about .225 Pg of carbon equivalent. (Carbon equivalent represents all greenhouse gas effects expressed as the net effect of that amount of carbon dioxide. A sink is a carbon pool that is gaining carbon, such as a forest that is growing). Annual removal of CO_2 through carbon sequestration, i.e., the rate of carbon removals, in terrestrial ecosystems is greater than CO_2 emissions from forest harvests, land-use conversions, or fire—and 90% of this sink activity occurs on forest lands. U.S. forests currently offset about 12% of annual U.S. greenhouse gas emissions from all sectors. If fossil fuel use increases, the offset percentage may go down. If fossil fuel use stabilizes or declines and if forests and forest products are better used as sequestration mechanisms, it could go up. But the U.S. continues to lose forests to development at the rate of about 1 million acres per year in the 1990s declining slightly since then but with projected net losses of up to 23 million acres by 2050 (Stein *et al.* 2005, Alig *et al.,* 2003). This trend needs to be reversed if forests are to play positive roles in carbon storage and climate.

Forests could play more positive roles in atmospheric carbon and future climate if we manage and conserve them with their roles in carbon cycles in mind—as both long-term storage pools and active sinks—and use durable wood-based materials instead of higher energy consuming substitutes such as steel and concrete.

Land Use Strategies

The Food and Agriculture Organization of the United Nations (FAO 2005) estimates global net forest loss at about 45 million acres per year: about 79 million acres of forest lost in the tropics, offset by about 35 million acres of forest gained in temperate areas each year. But these are not one-for-one offsets. An acre of native forest in the tropics doesn't equal an acre of new forest in temperate zones for carbon or biodiversity for that matter. The two most positive impacts on global climate the forest sector can make are land-use strategies that reduce forest conversion to other uses—i.e., keep forestland in forest uses—and the creation of additional forests on soils capable of supporting forest trees but were not in forest use. Managing for and perpetuating high-carbon-storage older forests are also part of landscape-scale solutions. But this will require new thinking about what old forest conservation means in the face of a continually warming climate with more droughts, insects, and fire; it may not mean passive preservation with no human intervention.

Starting points are significant in determining a given forest's contribution to global atmospheric carbon. Afforestation of abandoned agricultural land that is suitable for tree growing will have a net positive effect, removing more carbon than is being released. Reforestation of recently cut old or mature forests would have negative net effects until such time as the new trees capture and store more in-forest carbon than was released through harvest and processing, as well as that released from on-site decomposition. Also, determining the net effect of forestry on carbon sequestration is not a stand-scale problem; it requires landscape-scale and inter-regional assessments over periods of time. Storing more carbon in domestic old growth or secondary forests will do little to increase the global rate of carbon sequestration if primary forests in other regions of the world are harvested to produce the wood products we consume but do not produce (Shifley 2006). This is a real and timely concern as the U.S. now imports nearly 40% of softwood timber products used annually (Howard 2006), much of it from boreal primary forests in Canada at present. Between 1965 and 2005 softwood lumber consumption in the U.S. – our largest use of wood products — rose by 93% while the portion of consumption supplied by imports rose by 400%. Domestic strategies for using forests to sequester and store carbon must be considered in the global context of how much wood the U.S. is using and where it is coming from.

Forest Management Strategies

Beyond avoiding deforestation and creating new forests on suitable lands, there are multi-pronged management strategies that can be employed for existing forests. For example, more carbon can be stored per acre of land by accelerating reforestation and tree growth after disturbance, whatever the cause. On forests managed for timber production, extending the length of time trees grow prior to harvest along with protection against fires and insects, would increase in-forest carbon storage and reduce vulnerability to carbon loss at the landscape scale. In fire-prone forests this might mean favoring a diversity of tree species rather than a single species, and keeping stocking levels lower than full-site occupancy for maximum productivity, i.e., reducing vulnerability to drought stress, insects, and fire. Lower stocking and diverse species tend to reduce fire severity resulting in more trees surviving the fire and hence more carbon stored than if a fire kills most or all standing trees.

Perpetuating old growth forests in a warming climate subject to more fire may require landscape-scale strategies to reduce fire hazards within reserves and buffer surrounding areas from high severity burns. In interior lower elevation forests, it may mean active management to restore stand and landscape conditions that support low severity sub-lethal fires as opposed to stand replacing fires. In wood production forests, growing trees on shorter rotations and turning the young trees into durable products then returning a fast-growing forest composed of species or provenances suited to the changing climate (St. Clair and Howe submitted) may also be part of a comprehensive solution if combined with use of wood products offsetting use of more energy demanding materials (Perez-Garcia *et al.,* 2005). Paying sharper attention to the carbon impacts of forest management activities that consume fossil fuels, such as reducing the use of fuel inefficient machines, petroleum-based chemicals, and long-distance transport of logs and biomass to processing facilities, could also have some positive impacts.

Some of these options have co-benefits beyond carbon storage. Longer rotations, for example, generally provide habitats for a wider diversity of wildlife species and have the potential to generate higher value wood products. Restoring forest resilience to extreme disturbance events through thinning to reduce stocking levels can generate wood-based products or biomass energy as byproducts of forest treatments while decreasing the likelihood that large-scale future disturbances would create both immediate and long-term carbon releases through fire or decomposition. Rapid regeneration of forests after large disturbance events, especially if it entails transfer of significant portions of the carbon in damaged trees into durable wood-based products, may accelerate the return of a net carbon sink for the landscape so affected. But full accounting must consider carbon consumed in harvest, transport, manufacturing and reforestation relative to carbon transferred from the forest pool to the product pool.

Forest Product Management Strategies

Once trees with their stored carbon leave the forest, what happens next as wood products can provide additional opportunities for carbon sequestration. Forest products carbon is a transfer of carbon from one pool to another, not a new pool or stock of carbon. In the mill, carbon capture in manufactured wood products is typically about 50 percent of the carbon in the log as it entered the mill, and perhaps one third of what was in the forest carbon pool. In modern mills the capture may be higher. Also in the mill, biomass not suited for wood-based products is increasingly being used to generate energy, offsetting the burning of fossil fuels for that amount of energy. The role of wood-based products in global carbon could be significant if those products are durable and store carbon for very long periods. Even wood products in landfills continue to store carbon. Technological advances in the manufacturing sector have resulted in significant improvements in biomass capture into products since the 1950s. More may be possible. Durable wood-based products are additionally valuable for carbon storage when they are used in place of substitute materials such as steel, concrete, and plastics that have higher fossil fuel needs in their manufacture.

Forest Profitability from Carbon Markets

The Kyoto Protocol arose from an international treaty on climate change negotiated in 1997 and came into force in 2005. The protocol does not embrace all potential roles for forests and forest products in carbon sequestration, however, due to resistance from some environmental groups. They were and perhaps still are concerned that fully crediting carbon sequestered and stored in forests and forest products would be used to justify continued fossil fuels emissions. The U.S., Australia, India, and China have chosen to not participate in Kyoto. Rather, they are working with Japan, South Korea, and other members of an Asian-Pacific partnership on a non-binding plan to cooperate on development and transfer of technologies that would enable greenhouse gas reductions, including better use of forests and forest products. Collectively, these non-Kyoto nations account for around 50 percent of global greenhouse gas emissions, energy consumption, gross domestic product and population. But they are still talking about what to do, without taking significant action yet.

In the meantime, California is developing carbon offset markets to generate revenue streams for forestland owners who go beyond "business as usual" to store additional carbon in their forests. On September 27, 2006, Governor Arnold Schwarzenegger signed into law Assembly Bill 32, making California the first state in the nation to direct its Air Resources Board to establish a state greenhouse gas emissions cap by 2012. Oregon-based The Climate Trust is working on the state's Carbon Dioxide Standard and creating a voluntary carbon offset market. Under the offset concept, forestland owners receive payments for the amount of carbon they store that (1) cancels out other emissions, (2) are recorded in a registry, and (3) work as if the emission had not occurred. Offsets, in essence, are compensations based on the promise that the additional carbon storage would have the same atmospheric effect as if the emissions being offset had never occurred in the first place. The potential emitters pay the entity making the promise to store a particular amount of carbon for a certain period of time.

The U.S. has rudimentary carbon markets, mainly starting to develop at state or regional levels. While there is much attention to and interest in carbon markets and how they might add streams of revenues to forestland owners, there is also much uncertainty in how those markets would function and how the carbon benefits would be measured and accounted for. Some states and entities are creating regulations that set emission reduction standards.

A recent study cited in this book shows the potential for carbon markets to augment revenue streams over and above those from traditional forest management. The potential to deliver internal rates of return competitive with short rotation, industrial forestry are possible through extended rotation lengths that store additional carbon, if accompanied by a small premium for higher value logs, sale of carbon sequestration offsets, sale of conservation easements, and New Market Tax Credits. There remain significant uncertainties in this possibility, but these are all possibilities for those who choose to participate in emerging markets. The power in this concept comes from finding ways to value and price the public benefits of private forests, in turn creating streams of revenues for forest ecosystem services beyond those that currently have markets, such as wood, recreation, and some aspects of biodiversity conservation. Stavins and Richards (2005) document that forests can play a significant and economically valuable role in future climate policy.

To date, carbon markets look at rewarding landowners for storing additional carbon beyond "business as usual." This is the reference point used in the Kyoto Protocol. But an alternative reference point could be "beyond alternative land uses." Where pressures to convert forest to other land uses or where regulatory costs of forestry are high, landowners may see business as usual as sell the land for development or high value agriculture such as wine grapes or specialty orchards (Alig et al. 2003). Treating existing forestry practices under state forest protection laws as the reference for additionality fails to reward landowners for keeping their land in forest uses in the first place. This coupled with the potential impacts on timber supply of compensating landowners for storing more carbon in their trees rather than sending them to mills (Im *et al.* in process) could be among the contentious issues as state or federal forest-carbon policy takes shape.

The Future for Oregon

Can any of this happen in Oregon? Yes, it can and likely will. Oregon is poised to be a player in carbon markets. Our forests have relatively high productive capacity, i.e., high potential for carbon storage, and a wide diversity of values that are compatible with and may even be enhanced by "stacking" streams of revenues from all forest ecosystem services, including sustainable wood production. This potential warrants serious policy consideration as the state explores its forest futures.

So, where do we sit on the policy front? California has a carbon registry and a new law to set emissions caps. Oregon's governor has a Global Warming Initiative. Oregon is also teaming with California and Washington to develop regional and state strategies for reducing contributions of greenhouse gases. The forestland parts of the strategies include reducing wildfire risk by creating markets for woody biomass, considering greenhouse gas effects in farm and forest land use decisions, and increasing afforestation on under-producing lands. These are good first steps and all journeys start with first steps. But they just get us started on the possibilities. What is significant about Oregon's first steps is they have an Executive level mandate.

Final Comments

This introduction has attempted to set a global and temporal context for the material covered in this book. I have brought in some information that is not covered by other chapters to help describe long-term relationships between forests, carbon, climate and people and what is possible for forest roles in carbon and climate. The chapters you are about to read tell part of the story of forests, carbon, and climate—a story that is also only partially revealed to date. We still have a lot of learning to do. But we already know enough to get started.

What we know so far is that our climate is rapidly getting warmer due to human activities. This will affect our quality of life for many decades, perhaps longer. Forests can play vital roles in ameliorating some of future climate change because they are significant carbon sinks and carbon pools. They could be managed to be even more significant in the future. Forests are also very responsive to climate change. They will exist in a warmer climate with more severe disturbance events than at any time since the last glacial maximum, perhaps even longer. This needs to be considered in revising conservation and management plans that were not developed with climate change in mind. We know that how we conserve and manage forests and how we produce and use wood products have potential to ameliorate some of the carbon being added to the atmospheric pool through other human activities. We know that managing forests for carbon storage, as well as for wood and other ecosystem services, has co-benefits that generally improve our quality of life. We know that carbon markets have the potential to add streams of revenue to forestland owners, perhaps significant enough to help conserve forests from conversion to other uses less beneficial to the climate. Finally, we know that forests managed and conserved to sustain a multitude of values, uses, products, and services also help maintain economic and community vitality in our state.

These are some of the major reasons we should all care about forests, carbon, and climate. Because Oregon is such a forest-rich state, the future is indeed bright with many possibilities for Oregon forests, forestry, and forest products enterprises to play positive roles in maintaining a livable climate.

Literature Cited

Alig, R. J., A. J. Plantinga, S.E. Ahn, and J. D. Kline. 2003. Land use changes involving forestry in the United States: 1952-1997 with projections to 2050. USDA Forest Service Gen. Tech. Rep. PNW GTR-587. Portland, OR.

Boisvenue, C. and S. W. Running. 2006. Impacts of climate change on natural forest productivity – evidence since the middle of the 20th century. *Global Change Biology*, Vol. 12(5):862-882.

Broecker, Wallace S. 2006. The Holocene CO_2 rise: anthropogenic or natural? *Eos,* Vol. 87(3):27-29.

FAO. 2001. *State of the World's Forests*, Food and Agriculture Organization of the United Nations. Rome, Italy. FAO 2005. *Global Fores Resources Assessment 2005:*

ogress Toward Sustainable Forest Management. Food and Agriculture Organization of the United Nations. Rome, Italy. ftp://ftp.fao.org/docrep/fao/008/A0400E/A0400E00.pdf

Gore, A. 2006. *An Inconvenient Truth.* Rodale Press, NY

Houghton, R. A. 2003. Revised estimates of the annual net flux of carbon to the atmosphere from changes in land use and land management.1850-2000. Tellus 55B:378-390.

Howard, J. L. 2006. U.S. timber production, trade, consumption and price statistics, 1965-2002 (with 2005 statistical table update). USDA Forest Service, Research Paper, FPL-RP-615. Forest Products Laboratory, Madison, WI.

Im, E. H., D. M. Adams, and G. S. Latta. (in process). Potential impacts of carbon taxes on carbon flux in western Oregon private forests. Forest Ecology and Management.

IPCC. 2001. *Climate change 2001: the scientific basis.* Contribution of Working group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC).

Kleypas, J. R., R. A. Feely, V. J. Fabry, C. Langdon, C. L. Sabine, and L. L. Roberts. 2006. *Impacts of ocean acidification on coral reefs and other marine calcifiers: a guide for future research*, report of a workshop held 18-20 April 2005, St. Petersburg, FL, sponsored by NSF, NOAA, and the U. S. Geological Survey, 88 pp.

Law, B. E., D. Turner, J. Campbell, O. J. Sun, S. Van Tuyl, W. D, Ritts and W. B. Cohen. 2004. Disturbance and climate effects on carbon stocks and fluxes across Western Oregon USA. *Global Change Biology*, Vol. 10(9):1429-1444.

Mann, C. C. 2005. 1491: New revelations of the Americas before Columbus. Alfred A. Knopf, New York.

Marsh, G. P. 1874. The Earth as modified by human action. Scribner, Armstrong and Co., New York

Mealey, S. P., J. W. Thomas, H. J. Salwasser, R. E. Stewart, P. L. Balint, and P. W. Adams. 2005. Precaution in the American Endangered species Act as precursor to environmental decline: the case of the Northwest Forest Plan. in R. Cooney and B. Dickson, eds. Biodiversity and the precautionary principle: risk and uncertainty in conservation and sustainable use. Earthscan Press, Sterling, VA.

NRC (National Research Council). 2006. Surface temperature reconstructions for the last 2,000 years. The National Academies Press, Washington DC.

Pacala, S. and R. Socolow. 2004. Stabilization wedges: solving the climate problem for the next 50 years with current technologies. *Science*, Vol. 305(5686):968-972.

Perez-Garcia, J., B. Lippke, J. Comnick, and C. Manriquez. 2005. An assessment of carbon pools, storage, and wood products market substitution using life-cycle analysis. Wood Fiber Science, Vol. 37:140-148.

Perlin, J. 1991. A forest journey: the role of wood in the development of civilization. Harvard University Press, Cambridge, MA

Ruddiman, William. F. 2003. The anthropogenic greenhouse era began thousands of years ago. *Climatic Change*, Vol. 61:261-293.

Running, Steven W. 2006. Is global warming causing more, larger fires? *Sciencexpress.* 6 July 2006. July 6 2006; 10.1126/science.1130370 http://www.sciencemag.org/cgi/rapidpdf/1130370v1.pdf

Sabine, Christopher L., Richard A. Feely, Nicolas Gruber, Robert M. Key, Kitack Lee, John L. Bullister, Rik Wanninkhof, C, S, Wong, Douglas W. R. Wallace, Bronte Tilbrook, Frank J. Millero, Tsung-Hung Peng, Alexander Kozyr, Tsueno Ono, and Aida F. Rios. 2004. The oceanic sink for anthropogenic CO2. *Science*, Vol. 305:367-371.

Sessions, John, Pete Bettinger, Robert Buckman, Mike Newton and Jeff Hamann. 2004. Hastening the return of complex forests following fire: the consequences of delay. *Journal of Forestry*, Vol. 102(3):38-45.

Shifley, S. R. 2006. Sustainable forestry in the balance. *Journal of Forestry*, Vol. 104(4):187-195.

Shreeve, James. 2006. The greatest journey. *National Geographic.* March, 2006. 62-69

Siegenthaler, U., T. F. Stocker, E. Monnin, D. Luthi, J. Schwander, B. Stauffer, D. Raynaud, J. Barnola, H. Fischer, V. Masson-Delmotte, and J. Jouzel. 2005. Stable carbon cycle-climate relationship during the Late Pleistocene. *Science*, Vol. 310(5752):1313-1317.

Stavins, R. N. and K. R. Richards. 2005. The cost of U.S. forest-based carbon sequestration. Pew Center on Global Climate Change. Arlington, VA.

St. Clair, J. B. and G. T. Howe. (in process). Genetic maladaptation of coastal Douglas-fir to future climates. submitted to Global Change Biology.

Stein, S. M., R. E. McRoberts, R. J. Alig, M. D. Nelson, D, M. Theobald, M. Eley, M. Dechter, and M. Carr. 2005. Forests on the edge: housing development on America's private forests. USDA Forest Service. PNW-GTR-636. Pacific Northwest Research Station, Portland, OR.

United Nations. 2005. *Millennium development indicators.* http://millenniumindicators.un.org/unsd/mi/mi_series_resultsd.asp?rowID=751&fID=r15&cgID=&action=print

U.S. Environmental Protection Agency. 2005. *Greenhouse gas mitigation potential in U.S. forestry and agriculture.* U.S. Environmental Protection Agency, EPA-430-R-05-006.

Wade, Nicholas. 2005. *Before the Dawn: Recovering the lost history of our ancestors.* The Penguin Press, NY.

Westerling, A. L., H. G. Hidalgo, D. R. Cayan, and T. W. Swetnam. 2006. Warming and earlier spring increases western U.S. forest wildfire activity. *Sciencexpress*. 6 July 2006.

Williams, J. W. 2006 (in press). Quaternary vegetation distributions. In *Encyclopedia of paleoclimatology and ancient environments.* Earth Science Series, Kluwer Academic Publishers, New York.

Williams, Michael. 2003. *Deforesting the Earth: From Prehistory to Global Crisis*. University of Chicago Press, Chicago.

ATMOSPHERIC CARBON DIOXIDE

Mark E. Harmon

Introduction

As part of several greenhouse gases, carbon plays a critical role in regulating the surface temperature on earth. With the release of carbon dioxide through human activities, increasing concentrations are sufficient to warm the earth's surface temperature above that expected in natural cycles. Current concentrations and recent rates of increase exceed that observed in the last 420,000 years.

Carbon Dioxide as a Greenhouse Gas

Carbon dioxide is one of five main greenhouse gases, which retain heat by allowing short-wave radiation (light) to pass through, but act as a barrier to long-wave radiation (heat). Next to water vapor, carbon dioxide is the most prevalent of the greenhouse gases and it is often used to indicate the overall greenhouse effects on climate, which are expressed in carbon dioxide units. Arrhenius in 1896 hypothesized that the release of carbon dioxide from the burning of fossil fuels could increase the earth's surface temperature. Charles Keeling's measurements since 1958 showed the trend in increasing concentrations.

The Global Carbon Cycle

Carbon Cycle and Time Scales. The geologic cycle is examined over millions of years, while the biological carbon cycle is typically examined from less than a year to hundreds of years. Both cycles occur simultaneously, but the biological cycle is the one most relevant to managing atmospheric carbon dioxide in the next 100 to 200 years.

Human Effects on the Carbon Cycle. Human activities, principally burning fossil fuels, manufacturing cement and converting land cover types, currently release approximately 8.5 Pg (a petagram is 1.1 billion U.S. tons) of carbon per year. Approximately 50% of this is stored in ocean and terrestrial "sinks;" the other half has accumulated in the atmosphere. The natural processes that remove carbon dioxide from the atmosphere are currently not removing all the carbon added by humans.

Measurements of Atmospheric Carbon Dioxide

A ground-based global network of over 40 stations measures concentrations of carbon dioxide and other greenhouse gases, as well as gases that help determine atmospheric circulation patterns. Gases trapped in snow and ice in glacial deposits have yielded very precise and accurate measurements of past carbon dioxide concentrations and provide certain evidence that while concentrations have fluctuated in the past, current levels are higher than any time in the last 420,000 years, and increasing at an unprecedented rate.

Historical Changes in Atmospheric Concentrations of Carbon Dioxide

Concentrations have fluctuated greatly in the past due to variations in volcanic release of carbon dioxide and glacial activity. Human release of carbon since 1850 has caused an upward increase, higher than the cycle peaks in the recent geologic past and increasing at greater than 90 times the rate observed in past cycles.

In addition to long-term trends, recent observations show seasonal cycles, and short-term climatic cycles such as El Niño. Some years there is a slower rate of increase, which seems to result from increased volcanic activity. Overall, human-related inputs of carbon dioxide are so high at this point that natural processes cannot change the resulting overall increase in atmospheric concentrations.

Future Trends

The oceans' capacity to store carbon is expected to remain about the same. For terrestrial uptake, the amount of enhanced photosynthesis and net uptake of carbon due to a carbon dioxide fertilization effect is likely although uncertain. Regardless of any increase in plant uptake, if climate warms, plant and soil respiration will increase, offsetting many gains of plant uptake.

Humans have the potential to influence fossil fuel release and change land use to enhance carbon sequestration. Management actions on forest land are limited, but not to be ignored. An intermediate scenario of carbon dioxide emissions (16.5 billion metric tons/year until 2050, decreasing to 14 billion metric tons in 2100) leads to a predicted carbon dioxide concentration of 660 ppm by 2100 — over twice that before the industrial revolution.

While the future range of atmospheric carbon dioxide is high, and the pattern of increase is strongly dependent on how quickly alternative energy sources are used, the overall outlook is one of increased carbon dioxide concentrations for the foreseeable future.

CLIMATE CHANGE AT MULTIPLE SCALES

Constance Millar, Ron Neilson, Dominique Bachelet, Ray Drapek and Jim Lenihan

Introduction

Climate change is a key driver of historic vegetation change. Understanding natural climate patterns and mechanisms is important to comprehending current and future changes, and making decisions to steward forests.

The Natural Climate System — Overview

New high precision tools, theories based on high-speed computing capacity, and a critical mass of research have revealed more about past climate.

Climate Oscillates. Climate naturally cycles, showing that distant periods in the past may be more similar to the present than the recent past.

Climate Cycles at Multiple Scales. Climate has varied at different time cycles, with major long-term warm and cold periods, and cycles of progressively shorter scales, operating together.

Climate Often Changes Abruptly. Climate changes can be gradual or abrupt (a few years to a few decades), and can be triggered by random effects.

Vegetation Responds Complexly to Climate Change. At each scale, ecological and physical systems respond to climate change, with often-dramatic shifts in wildlife and vegetation.

The Natural Climate System — A Primer on Past Climates

Studying ice-, sediment-, and tree- core samples is the most widely applied new method for understanding past climates, yielding detailed, high resolution information at many scales.

Multi-Millennial Climate Cycles. Records now document the repeating nature of over 40 warm and cold cycles during the Quaternary Period, i.e., the past 2.5 million years.

Century- to Millennial-Scale Climate Cycles. Within longer cycles are oscillation patterns called “Bond cycles,” which average 1300-1500 years of warm/cold phases.

Interannual- to Decadal Climate Change. El Niño and others patterns are high-frequency changes causing varying conditions that last a few years to several decades.

Climate as a Force of Ecological Change. Abundant evidence worldwide indicates that life on earth has responded to climate change on each of these scales.

Implications of Natural Climate Change for Vegetation Ecology

Sustainability. Past records show that ecological conditions are in an ongoing state of change, and species shift naturally even in the absence of human influence.

Population Size, Population Abundance, and Native Species Range. Changes may result from natural species adaptation; even small shifts in climate can bring large changes in population condition. With the current rapid change in climate, species ranges and demographics are expected to be highly unstable.

Reference Conditions and Restoration Targets. Pre-contact period, 1840-1860, was the coldest part of the Little Ice Age and likely to be a poor model for forest management.

The Human-Dominated Climate System

The global Northern Hemisphere average temperature in the last part of the 20th century was higher than over the past 1,000 years. Models show that trends since 1975 can only be explained by non-natural forces; without human influence, natural climate systems would be cooling. Future scenarios depict an average global temperature increase of approximately 2.7 to 10.4 °F by 2100 and an increase in carbon dioxide concentrations of 575-1000 parts per million. Cascading effects from a continually warming world are projected to accelerate. Even with CO_2 decreased to early 20th century levels, the atmosphere would not stabilize for 100 to 300 years.

Potential Impacts of Climate Change on Oregon Ecosystems

The VINCERA Project. Three climate centers (in Canada, Australia and the United Kingdom) developed models simulating changes in global climate. These future climate scenarios were then used by a USFS general vegetation model that simulates vegetation distribution, carbon balance and disturbances from drought and fire.

Temperature and Precipitation. Most temperature scenarios show increases in Oregon from the present time to the end of the 21st century from about 7 to 8 °F, which can lengthen the growing season by at least four to six weeks. Precipitation scenarios generally show 10% decrease to 24% increase in winter, and 10 to 40% decreases in summer.

a) **Impacts of Climate on Future Distribution of Vegetation.** Temperature increases would bring significant reductions in alpine vegetation and with increased precipitation significant increases in woody vegetation in interior dry ecosystems. Changes could bring range expansions of some species and frost-sensitive species from the Southwest potentially displacing many eastern Oregon species

b) **Impacts of Fire on Biomes.** Fire becomes increasingly important in the wet, maritime forests. With a "suppressed fire" scenario, maritime forest and savanna/woodlands mainly decreased, while continental forest increased, replacing all shrubland/grassland. With no fire suppression or exclusion, the shrubland/grassland was, instead, largely replaced by savanna/woodland and to a lesser extent by continental forest.

c) **Extended Growing Season.** Both spring and fall growing seasons would be longer, with vegetation demanding more water overall; woody expansion would increase with increased precipitation, improved water use efficiency and the effectiveness of fire suppression.

d) **Change in Vegetation Carbon.** With warmer temperatures, wet maritime forests tend to lose carbon, while interior dry ecosystems tend to gain carbon. Fire suppression or its absence significantly changes most scenarios.

Summary

Even with the newest modeling techniques, balances in the real world projections about actual future climates and impacts are difficult to forecast. However, colder ecosystems (Alpine) will be threatened while warmer ecosystems will increase. Fire is likely to increase, even in wet coastal ecosystems. Ecosystem carbon gains and losses will be mixed, but fire suppression or exclusion could have a profound positive influence on ecosystem carbon sequestration.

Management in the Face of Changing Climates

Mitigation, adaptation and conservation frame the discussion of changing climates and increasing atmospheric carbon.

Reduce Greenhouse Gases.

A priority must be to contribute actively to mitigation of human-induced climate and atmospheric effects by reducing greenhouse gas emissions. Forestry has a large potential for positive effects through deliberate forest management.

Sequester Greenhouse Gases.

Forest management practices have a diversity of options for removing and restoring carbon dioxide including afforestation, maintaining healthy stock, keeping sites fully occupied, and minimizing disturbances by fire, insects and disease. Its path through the utilization cycle also has tremendous opportunity.

Reduce Unnecessary Emissions.

Wildfires, insects and disease are the primary sources of unintended carbon emissions from forests. Management practices that lower vulnerabilities to these should be widely implemented.

Maintain House in Order.

Energy conservation and emission reduction from resource-based activities should be a priority for forestry.

Resist Effects of Climate Change.

Maintaining prior species and the status quo may require additional investments and intensive management.

Create Resilient Vegetation.

This will become more difficult as changes in climate accelerate. Intensive management at young ages may enable retention by commercially-desired species even if the site is no longer optimal.

Respond to Climate Change.

An adaptation option for management is to anticipate the projected effects of climate change and plan protective and opportunistic measures.

A sampling includes:

Follow Climate Change. Use models to anticipate future conditions and make projections.

Anticipate and Plan for Indirect Effects such as changes in fire regime.

Increase Redundancy; spread risk rather than concentrate it.

Expand Genetic Diversity Guidelines for reforestation.

Establish "Neo-Native Locations" using information from historic species ranges.

Experiment with Refugia and identify more-buffered environments.

Promote Porous Landscapes that have continuous forest habitat.

Conduct Triage through aggressive intervention and management alternatives.

GLOBAL WARMING: A SKEPTIC'S VIEW

George Taylor

Is There Global Warming?

1. ***Is the world warming?*** *The answer depends largely on the starting and ending points analyzed. While the world has certainly warmed within the last 300 years, it may be warmer than the last 1,000 years and is probably not warmer than the last 5,000 years.*
2. ***Are we seeing unprecedented conditions?*** *In a millennial time scale, current conditions are comparable to and even cooler than temperatures in the past.*
3. ***Are humans influencing climate?*** *Clearly there is a human influence but I believe that natural variations have and continue to dominate the climate.*

Scientific Consensus

While several organizations, such as the American Meteorological Society (of which I am a member) have issued policy statements about human-induced global warming, this was created by a small working group without input from the broader membership. Other scientists state that "a significant number of climatologists are by no means convinced that the underlying issues have been adequately addressed."

Consensus may be wrong. Alfred Wegener (Continental Divide), Gilbert Walker (El Niño), and J. Harlan Bretz (Missoula Floods) were all ridiculed and rejected by the "consensus" scientists. Each was later proven to be correct.

Glaciers

Glaciers are often considered good indicators of climate change, and glacier dynamics are quite complex. Scientists studying Glacier National Park showed that while glaciers have shrunk since the 1850s, most of the reduction occurred prior to the modern greenhouse gas buildup and thus must be due primarily to natural effects.

Polar Regions

Global climate models suggest that polar regions should warm more quickly than temperate or tropical regions in a greenhouse-enhanced world.

Arctic. High-latitude northern hemisphere data show a slight increase in temperatures in the last several decades, with regional differences. Alaskan temperatures since 1976 have remained steady and Greenland temperatures have generally cooled.

Antarctic. While there is considerable year-to-year variation, the overall trend is positive — Antarctic ice is growing.

Climate of Oregon and the Pacific Northwest

The early records of Oregon's climate history are sparse and discontinuous.

Temperature. Since the mid-70s there has been a warming trend, but current temperatures remain below those observed 70 years ago.

Snowfall. While snowpack data for Oregon from 1950 to 2000 shows a decline, that may be a function of the period studied, since the early 1950s were an exceptionally snowy period.

Sea Level. The central and northern Oregon coasts show rising sea levels, while the southern coast has lowered sea levels. Both may be a geologic factor of land moving downward or upward relative to sea level.

Decadal-scale variability. El Niño and Pacific Decadal Oscillation effects, natural long-term effects that influence climate, may explain most of the warming and cooling in Oregon in the last century.

Summary

While the world is currently warming, it has been warmer in the past, during the Medieval Warm Period. Recent warming may be a natural cyclical climate change. The U.S., and Oregon, have experienced warming in the past 100 years, but the warmest decade was the 1930s. Since the thermometer was invented only 300 years ago, "proxy" methods like ice cores are used to estimate earlier conditions, and they may not be accurate. Modeling the earth's climate is not an exact science and General Circulation Models can vary and be arbitrary. There remain strong influences on climate that we as yet do not understand.

FOREST MANAGEMENT STRATEGIES FOR CARBON STORAGE

Olga N. Krankina and Mark E. Harmon

Introduction

Forests play a major role in the global carbon cycle by storing carbon in live plant biomass, dead plant material, and soils. The amount stored represents the balance between absorbing CO_2 from the atmosphere and releasing carbon through respiration, decomposition and burning. While projections of the role of forests in carbon exchange with the atmosphere are uncertain, there is a solid body of knowledge that demonstrates how forest harvest, regeneration and growth control the carbon balance on forest lands.

Assessment of the Role of Forests

Major recent scientific advances in understanding the role of forest management in global climate change are related to:

Evolving consensus of carbon emissions from deforestation in the tropics and carbon removals through forest regrowth in the temperate and parts of the boreal zone.

Technological advances through more numerous and sophisticated earth observation satellites, remote sensing methods and flux towers.

Consideration of overlooked fluxes, like carbon export through river systems.

Improved understanding of limitations and the need for integrated assessment methods for considering all important effects on climate.

The historic process of forest clearing for agriculture contributed to carbon accumulation in the atmosphere. Globally, carbon stocks in forest biomass continue to decrease—by 1.1 Pg (a petagram is 1.1 billion U.S. tons) annually in 1990's. The global potential for storing more carbon on land, mostly in forests, is estimated at 60 to 87 Pg over 50 years.

Forest Management and Carbon Storage: A Conceptual Overview

The intent is to reduce atmospheric carbon dioxide. Disturbances such as timber harvest or fire have a profound effect, shifting a forest from carbon sink to source of carbon. Disturbance events can transfer carbon out of the ecosystem, and restart the cycle for a new stand. At the landscape level, carbon store is controlled by the characteristics of the disturbance regime. The average store remains constant where a selected management option is repeated indefinitely. Increased intervals between disturbances or reduced disturbance severity increases the landscape store of carbon.

Options to mitigate carbon release include avoiding deforestation, increasing carbon density with accelerated forest regeneration or using longer rotations, and using forest-derived materials to substitute wood products or biomass energy for fossil fuels. These options last for many decades and their impact changes over time.

The net effects from management practices depend on initial conditions. For example, establishing a forest plantation on agricultural land will increase carbon stores, but converting a productive old-growth Douglas-fir forest into a plantation with management for timber production can decrease carbon stores by as much as 45%.

In the Pacific Northwest, with active forest disturbance regimes, **patterns of carbon sources and sinks are complex and shift rapidly.**

Carbon Storage and Other Management Objectives: Synergies, Trade-offs and Additional Considerations

Current management objectives that include recreation, biodiversity, improved fisheries, watershed management and other goals are generally synergistic with increasing on-site carbon stores. Measures to accelerate the growth of trees provide for faster uptake of carbon, but those gains may be offset by shorter harvest rotations, declines in wood density or decay-resistance. Salvage of trees killed by fire reduces carbon stores unless the salvage replaces a similar harvest of live trees. Recent design efforts to improve fire or disease prevention can result in maintaining carbon stores.

Protecting Carbon Gains against the Impacts of Future Climate Change

Higher carbon stores on land might mean the risk of higher future carbon emissions with more forest disturbance resulting from climate change, for example, lack of drought resistance or invasion of new pests. Several measures that can reduce the risk of economic losses and losses of carbon: Selection of species for potential growth and resilience in a warmer climate. Stand and landscape architecture can be designed to increase resistance and resilience. Plans for coping with large-scale disturbance events can ensure optimal results.

Forest Management and Carbon Storage: Pacific Northwest Forests

The potential for carbon storage in Pacific Northwest forests is among the highest in the world. Douglas-fir, the dominant tree species, is long-lived with high growth rates for a very long time. Protecting old growth, creating protected areas and using longer rotations may be more effective for on-site carbon storage than elsewhere. However, timber harvest in this region over the past 100 years has decreased carbon stores. Altering management practices offers considerable potential to increase carbon stores. Simulation models show that rotation length, amount of live mass harvested and amount of detritus left by burning slash are crucial factors in maximizing on-site carbon storage.

Forest management can contribute significantly to reducing and perhaps even ending the ongoing rise of carbon concentration in the atmosphere, providing a cumulative sequestration of 25 billion metric tons of carbon globally over 50 years.

KEEPING LAND IN FOREST

Jeffrey D. Kline

Forestland Development

Forestlands have been the largest source of land for development in the U.S. in recent years, one million acres annually from 1992-1997. Loss of forest cover releases sequestered carbon into the atmosphere. Policies, whether regulatory or incentive-based, can be used to influence the location and rate at which development occurs. Oregon forests comprise 49% of land area and population is expected to grow by 54% by 2040. Can the state's current policies sufficiently address these trends?

Socioeconomic Factors

Growing population and incomes, and desires for second homes in scenic forest settings increase demands for land in developed uses. Land prices rise, giving some forestland owners a financial incentive to sell.

Timber Revenue. Forestry revenues alone often are an insufficient incentive to forest owners to keep land in forests when development is an option.

Energy Prices. Energy prices can affect demand for particular forest commodities, including fuel wood.

Quality of Life. As places become more populated and affluent, and forestlands increasingly are lost to development, people tend to become more willing and able to protect remaining forestlands.

Affluence and Amenities. Oregon's population has increased 69% since 1970. One reason is in-migration of people seeking locations rich in environmental amenities.

Declines in Oregon Forests. Land use projections for Oregon and Washington combined suggest a projected 2.8 million acres of additional forestland lost by 2050.

Oregon's Land Use Law

A panacea to some, a bane to others, Oregon's 1973 Land Conservation and Development Act's goals include the protection of forestlands. The law doesn't prevent development, but restricts the rate, location and density.

Resulting Protection. Estimates suggest that from 1974-1994, Oregon's land use planning saved less than 1% of forestland from development. However, urban growth boundaries tended to include forestland most likely to be developed, which reduces the magnitude of protection from the program.

Measure 37 and the Future. The measure requires the state to compensate landowners for value lost from land use regulations, or waive them. Projections suggest that approximately 4% of forestland could be developed, but significant uncertainty currently exists about the future outcome of the measure.

Development Effects on Forests and Forestry

As development draws near, a multitude of factors are thought to create conflicts and change expectations about the future of forestry.

Parcelization. Forestland owners on smaller tracts are less likely to manage their land for commercial timber production.

Proximity of Residential Development. Forestland owners tend to manage lands differently with increasing development, which may reduce future harvests.

Changing Management Activities. Planting, replanting and harvesting have varying effects on carbon sequestration, and have to be considered relative to global activities.

Development Projections. The most productive forestlands tend to be steep and inaccessible, which may counter development pressures.

Policy Strategies for Maintaining Forestlands

Two issues have the strongest influence: addressing socioeconomic factors that motivate landowners to develop, and balancing the interests of private landowners with society's land conservation interests.

Land Use Regulations and Zoning. An advantage is the relatively low cost to government to administer, but perhaps less effective because of tension between conserving land and upholding private property rights.

Preferential Taxation and Other Programs. Reducing property tax burdens of forestland owners is one approach; others include purchasing development rights and easements, and transferable rights.

Private Land Preservation and Land Trusts. Sixteen land trusts operate in Oregon with 5,200 acres owned; a growing trend is cooperation between nonprofits and public entities.

Forest Legacy Program. A voluntary private land conservation program offers cost-sharing leveraged by federal financial assistance to purchase easements and land.

Ecosystem Services Compensation. Ideally, owners can be induced to retain forestland through compensation for ecosystem services like water filtration, preventing soil erosion.

Programs to Sequester Carbon — Cost Shares, Direct Payments, Carbon Markets. Various forms of assistance could be used to encourage owners to conduct particular forestry activities to enhance sequestration.

The Future

Forestland development is influenced by many factors. Socioeconomic forces exert strong pressures favoring development. Successful policy implementation to protect forests depends on circumstances that can change over time. Measure 37 has forced an opportunity to consider how landscapes are valued and how best to secure them for future generations. The future will depend on the willingness to investigate and evaluate potential outcomes of different policies to achieve the desired balance of forestland protection and development.

USING WOOD PRODUCTS TO REDUCE GLOBAL WARMING

James B. Wilson

Introduction

Greenhouse gases are at their highest level of concentration in the past 650,000 years, and have increased dramatically in the last 200 years with the onset of the Industrial Revolution. As a building material for home construction, wood products can reduce greenhouse gases through storing wood in products, substituting wood for fossil fuel-intensive products like steel and concrete, and by using wood as fuel instead of fossil fuels.

Measure of Wood Products' Performance

The formula GWPI (kg CO_2) = CO_2 kg + (CH_4 kg x 23) + (N_2O kg x 296) can be applied to the life cycle of wood products and comparison materials to calculate the control or elimination of the release of carbon dioxide, methane and nitrous dioxide in terms of CO_2 equivalents into the atmosphere, and thus the reduction of global warming potential. GWPI is the Global Warming Potential Index.

Three reduction approaches can be calculated: managing forest and wood product manufacture, use, and disposal; substituting a wood product for a fossil fuel-intensive product; and using wood biomass as fuel.

Environmental Performance of Wood Products

CORRIM (Consortium for Research on Renewable Industrial Materials) collected data to document all inputs and outputs to produce, use, dispose or recycle wood products, tracked through each stage. To study environmental impacts, a house was designed for a warm climate, and another for a cold climate, analyzing various building materials and making life cycle assessments.

The Dynamic Effects of Various Management Scenarios

One study examined three components of carbon storage: in the forest, in wood products, and substituting wood for some of the other materials such as concrete in house construction.

Carbon storage in forests. Comparing harvest cycles of 45, 80 and 120 years with "no action," the latter scenario was found to store the greatest amount of carbon.

Carbon storage considering forests, wood products, and concrete substitution. Alternately, a combination of a 45-year harvest cycle, producing wood products, and substituting wood for some concrete in a house sequesters more carbon than the "no action" forest management scenario.

Carbon storage in houses. A significant amount of wood products go into wood-framed house construction, but mass-wise, normally concrete is the largest component. Wood stores carbon for at least the 80-year average service life of a house, while concrete does not. The study used a Global Warming Potential Index to calculate the comparisons and found that the steel-framed design has a 26% greater global warming potential, and concrete-framed design 31% greater global warming potential, than the wood-framed house.

Carbon storage in U.S. housing stock. One method of calculation looks at new housing stock and uses the average carbon storage mass per house of 4,380 kg for the wood structure. In the U.S., the total translates into approximately 25 million metric tons of CO_2 that is prevented from being recycled or released to the atmosphere annually just from new home construction. Another method, looking at the total carbon pool for all existing U.S. housing stock, shows an equivalent of nearly 2,000 million metric tons of CO_2 of being prevented from going into the atmosphere.

Wood Fuel Use Reduces Global Warming

When wood is substituted for fossil fuels, less of harmful carbon dioxide is released into the atmosphere. For Pacific Northwest lumber, wood fuel generates about 65% of the on-site energy used in the production of wood building products. In the U.S., from cradle-to-gate (ie., seedling to product manufacturing), wood fuel represents from 35% to 71% of the total energy needed to produce a unit volume of product.

Ways to Foster Increased Use of Wood Products and Wood Fuel

New practices, policies, research and education can offer opportunities for increased efficiencies. Individuals, companies, architects, engineers, builders, government agencies and legislators could promote the wise use of wood. Tax incentives could be created, and standards and guidelines developed, for substituting wood products for fossil fuel-intensive ones and for using more wood fuels. Markets are developing for trading the wood industry's greenhouse gas assets know as carbon credits.

Summary

Wood should be a material of choice for those wanting to build green. The use of wood products can reduce the amount of CO_2, a major greenhouse gas, in the atmosphere. Wood presents opportunities for reducing global warming by growing more trees, producing wood products for long-term applications, using more wood to build houses instead of steel and concrete, and substituting wood fuel for fossil fuels. Policies and practices are needed to further promote the use of wood for these purposes.

EMERGING MARKETS FOR CARBON STORED BY NORTHWEST FORESTS

Bettina von Hagen and Michael S. Burnett

Introduction

The capacity to store carbon has increasing value in emerging international and regional markets for carbon credits. Relative to other emission strategies such as renewable energy, carbon sequestration in forests poses some unique challenges, but offers some unique benefits.

Do Forests Matter?

Deforestation since 1850 has been a major source of carbon dioxide buildup in the atmosphere — equivalent to approximately 20 years' worth of current global emissions. The current standing stock of carbon in forests vegetation is more than 60 times larger than worldwide annual fossil-fuel-related emissions. The potential to remove accumulated CO_2 from the atmosphere by managing lands to increase forest biomass is sizable — nationwide in the U.S., there is a potential to mitigate 384 million metric tons (or 27%) of CO_2 annually.

Market-based Approaches to Reducing Greenhouse Gas Emissions

Currently there are a number of both regulatory and incentive approaches for encouraging forest carbon sequestration. A favored regulatory approach is establishing greenhouse gas emission caps, resulting in cap-and-trade systems where an entity below its cap can sell its surplus to one in excess of the cap.

Current and Developing Mechanisms and Markets for Emission Reduction

When the international treaty agreement known as the Kyoto Protocol came into force in 2005, it created emission trading schemes. In their first year of operation, the global aggregated market for carbon was over US $10 billion, more than the entire $7.1 billion wheat crop. Because the U.S. is not a signator to the treaty, news coverage of carbon markets is limited in the U.S.

The Kyoto Protocol and its Market Mechanisms. The largest program is the multinational European Union trading scheme, with a 2005 market value of $8.2 billion.

Markets for Emission Reductions in the U.S. and Other Non-Kyoto Countries. In the U.S., regions, states, tribes and local governments are setting emission reduction targets.
Oregon was an early innovator, the first state to establish offsets for new power plants.

The Voluntary Carbon Market. An emergent voluntary market transacted 10 to 20 million metric tons of carbon in 2005; one of the most comprehensive is the Chicago Climate Exchange; members range from corporations like DuPont to Iowa farmers.

Understanding Carbon Offsets

A carbon offset project has three elements: (1) it cancels out emissions, (2) reductions are recorded in a greenhouse gas registry, and (3) the end effect is as though the cancelled emissions never occurred. Offsets can potentially help address climate change at the lowest overall cost, and have other economic and environmental benefits.

Forestry-Related Offsets: Land Management-Based. Offset types include afforestation, reforestation, avoiding deforestation and changing forest management practices.

Forestry-Related Offsets: Product Substitution-Based. Wood can be substituted for other products, and biomass can be used instead of fossil fuels to create energy.

Challenges to Carbon Markets in Forest Sequestration

Permanence. Concerns about credits in perpetuity and unplanned disturbances such as fire or impacts are leading to approaches such as temporary crediting.

Ownership and Legal Title. Landowner's consent, and clear title to the offsets must be verified.

Insurance and Vintaging. Self-insurance and vintaging (pacing timing of reduction credits to target dates) are approaches being developed to mitigate risks of permanence.

Co-Benefits and Ecosystem Services

Forest offset projects often generate environmental and social co-benefits, including job generation, habitat retention/enhancement, water quality improvements, recreational opportunities and potential co-production of timber and non-timber forest products. Many co-benefits are being quantified and monetized. Ecosystem services can be "bundled" with, for examples, species protection, to further capitalize on these new financial opportunities.

Summary: Options for Consideration for Oregon Forests

Pacific Northwest forests can store more carbon than most other forest ecosystems. Given that it is heavily forested, Oregon has an advantage in achieving low-cost reductions relative to other states. Some considerations include: collaboration between the forest industry and environmental groups, the establishment of a cap-and-trade system, pursuing a regional carbon market trading system, investing in infrastructure to support an active carbon market and developing the intellectual capital needed for market development, and develop trading patterns.

CARBON ACCOUNTING: DETERMINING CARBON OFFSETS FROM FOREST PROJECTS

Jim Cathcart and Matt Delaney

Introduction

Forest-based carbon projects offer the potential to provide landowners with income while helping reduce greenhouse gases. The challenge to landowners is knowing what is required of them for measuring and reporting the amount of CO2 emission reduction benefit that can be sold or credited. The science of carbon accounting is still in early stages of development and the concepts here are pioneering.

Principles of Carbon Accounting

The following key principles are quality assurances that have become almost universal for any carbon project to address.

Additionality. Credits must arise from an activity that would not have otherwise occurred "but for" the carbon investment in the activity.

Baseline. A "without project" estimate of emissions is compared with the project estimate to provide an initial amount of estimated carbon credit.

Leakage. Lost carbon benefits due to countervailing activities or actions.

Permanence. A time period that ensures that CO2 benefits are not prematurely reversed.

Measurement. The quantification of the CO2 benefit through direct means, indirect means such as look-up tables, modeling or some combination thereof. Forecasts are used to estimate the anticipated CO2 benefits for investment analysis purposes. For forecasts, the underlying quality assurances include:

Reliability. Long-term legal and contractual arrangements, project management and accounting over time.

Timing. Assurance that the time the carbon credit is realized occurs in the period the purchaser wishes to report the credit.

Risk. Whether the forecasted carbon credits are realized and maintained throughout the accounting period.

Measurement Standards

Currently in the U.S. there are four CO2 emission reduction initiatives, ie., private and government sector programs that facilitate the reporting, purchase or trade of carbon credits: the California Climate Action Registry, the Chicago Climate Exchange, the Climate Trust, and the U.S. Department of Energy's Voluntary Reporting of Greenhouse Gas Emissions. All use a stock change accounting approach wherein physical carbon stocks are measured, estimated and assigned values based on look-up tables.

As of 2002, new national reporting guidelines include a grading system for the quality of the measurement standard, with grades A though D determined by the form of direct measurement.

What to Measure

The U.S. Department of Energy's technical guidelines provide a thorough overview of measurement protocols and calculation methods for various forest types. Standards are moving in the direction of conducting periodic measurements to support a project's carbon benefit claims.

Live Trees and Understory Vegetation. Carbon stock is calculated from forest inventories of fixed or variable plots, with biomass converted to carbon.

Standing Dead and Down Logs. Density, line intersect and other methods are used to estimate volume.

Soils, Litter and Debris. Soil carbon accumulation can be added to the measurement pool using calculations from soil baseline stock.

Forest Products. The amount of continued carbon storage is calculated by type and longevity of use and type of disposal.

Roles and Responsibilities in Forest-Based Carbon Projects

Projects typically involve four parties:

Investor. Usually a private firm such as a utility or power company with an interest in offsetting a portion of CO2 emissions arising from business activities.

Forest Landowner. Person or entity with direct responsibility for the project or hosts the project on owned lands through a lease or other contractual relationship.

Professional Forester or Natural Resource Specialist. Necessary for making preliminary estimates, and can coordinate measurement and reporting.

Coordinating Organization. Third-party organization to assist the landowner with stability and longevity to ensure project's reliability.

Summary

Over the past 15 years, carbon accounting has evolved from indirect to direct measurement, and the principles and standards are still in the early stages of development. Specific measurement and accounting protocols will continue to be tested as markets develop for carbon credits. Standards will progress to develop and improve market confidence that the reported carbon credits represent actual reductions in atmospheric carbon dioxide.

GOVERNOR'S GLOBAL WARMING INITIATIVE

Gail L. Achterman

West Coast Governors' Global Warming Initiative

A regional commitment to reduce greenhouse gas emissions.

In 2003, Governor Kulongoski joined with the governors of Washington and California to create the West Coast Governors' Global Warming Initiative. The states agreed on a detailed list of recommendations. The one most relevant to forests is the development of a market-based carbon allowance program. Here's how it works: power plants and other businesses that emit greenhouse gases could "trade" those emissions for "credits" from businesses that reduce emissions, such as forest biomass renewable energy projects. The governors believe that the promise of new programs and technologies will both protect the environment and grow the region's economy.

Governor's Advisory Group on Global Warming

Developing directions for Oregon to achieve measurable and meaningful reductions in greenhouse gases

That same year, the governor appointed a group of citizens and public officials to draft a Global Warming Strategy for Oregon. One recommendation regarding forests is to increase the amount of carbon "captured" and fixed in forests and new forest growth. This could result in support for forest restoration and conservation reserves.

The group's draft report made 60 recommendations, which, combined, would stop the growth of Oregon's greenhouse gas emissions and begin to reduce them by 2010. Other significant strategies include establishing targets for energy efficiency and increasing renewable energy sources.

Biosequestration is the process of sequestering, or holding, carbon in plants, like trees. Three biosequestration strategies were proposed for forests: reducing wildfire risk by creating a market for the small diameter trees (also known as woody biomass) that fuel flames in wildfires; considering greenhouse gases in forest land use decisions; and increasing forestation on marginal agriculture and pasturelands.

Renewable Energy Action Plan

A process to achieve the greenhouse gas reduction goals

The governor directed state agencies and the Department of Energy to develop a Renewable Energy Action Plan. Relative to forests, it centers on biomass as an energy source. Biomass could be used to generate electric power, with low greenhouse gas emissions. It can also be used in biorefineries, which convert biomass into a gas to produce liquid fuels. The Plan also suggests that small, energy-efficient biomass heating and electrical systems could be created to provide power throughout Oregon.

A 33-member Working Group was appointed to implement the Plan. They will advocate for renewable energy, track developments and submit status reports. A Forest Biomass Working Group was also formed. They will explore ways to expand the market for biomass in Oregon.

A number of directives are aimed at the Oregon Department of Forestry: to study and seek funds for biomass energy generation, support aggressive fire suppression on public and private forestlands, and work with federal agencies to promote forest biomass energy opportunities.

Next Stage: Climate Change Integration Group

Continuing to carry out the Strategy

The governor is in the process of appointing a citizen-led group to track implementation of the Strategy, work as a clearinghouse for shared information, and continue to make additional recommendations.

Oregon Forest Resources Institute
317 SW Sixth Avenue, Suite 400
Portland, Oregon 97204
(971) 673-2944
1-800-719-9195

www.oregonforests.org