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# Forest Management & Greenhouse Gas Mitigation Opportunities

Information Sheet #7

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Soil and Crop Sciences Section, School of Integrative Plant Science  
College of Agriculture and Life Sciences, Cornell University

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## Fast Facts

- **Impacts:** Forest management can store (sequester) carbon in growing trees and in long-lived wood products, and can provide biomass for bioenergy to replace fossil fuels, all of which reduces carbon dioxide in the atmosphere.
- **An imperative to act:** Improved forest management can increase profit and reduce carbon dioxide emissions to the atmosphere, reducing impacts from climate change.
- **Opportunity for proactive change #1:** Improved forest management can increase bioenergy products to displace fossil fuels, and thus reduce greenhouse gas emissions.
- **Opportunity for proactive change #2:** Improve forest management can provide increased income from sales of timber for long-lasting wood products to replace high-carbon-emitting steel and concrete building materials.

## Introduction

In New York State (NY), 63% of land is forested (19 million acres), three quarters of forestland is owned privately by 788,000 landowners, and a third of landowners state that their forestland is part of their farm (Widmann et al. 2015). Taken together, forests are the largest ‘carbon sink’ – the growing trees are the largest pool of active carbon accumulation in the state. Landowners have many forest management goals, but at least two thirds rank protecting biological diversity, water resources, and wildlife habitat as very important or important (Widmann et al. 2015). Greenhouse gas (GHG) emissions are now receiving much attention as an important environmental issue. At the same time, growing interest in bioenergy will likely increase the use of wood as bioenergy feedstocks to displace fossil fuels. Forests store carbon in trees and in soil and also in long-lived wood products such as plywood and lumber after harvest while also displacing energy-intensive steel and high CO<sub>2</sub> emitting concrete (Bergman et al. 2014). Forests can provide renewable biomass for bioenergy and building materials that reduces fossil fuel use and GHG emissions. Forests are great systems for capturing carbon and landowners can actively manage their forest to improve the climate change mitigation potential in addition to their existing suite of forest management goals and opportunities. This Information Sheet will demonstrate some of the management strategies to maximize carbon sequestration and minimize GHG emissions.



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## Environmental Concerns

Forests play an important part role in the global carbon cycle. Protecting forests and improving their management will ensure that the New York's largest CO<sub>2</sub> sink does not become a source of emissions (Raciti et al. 2012). Improved forest management, afforestation, and sustainable biomass harvest for bioenergy and wood products could provide large and cost-effective GHG mitigation opportunities (Raciti et al. 2012, Wightman & Woodbury 2015a, Bergman et al. 2014).

## Summary of Regulation of GHGs

Emissions of GHGs from forests are not regulated. However, there are opportunities for forest management activities to qualify for GHG mitigation credits (also called carbon credits or carbon offsets) from various carbon markets. New York State is a member of the Regional Greenhouse Gas Initiative (RGGI, a multi-state agreement to regulate emissions of GHGs from the electricity sector) that allows certain forest practices to earn carbon credits. The Federal Clean Power Plan is also expected to provide opportunities for mitigating GHG emissions by means of bioenergy production from woody biomass. While such programs may provide opportunities for payments for forest carbon sequestration, the requirements may be very stringent and the costs of compliance high (Fahey et al. 2010, Tonitto et al. 2016).

## Goal

This information sheet is intended to help individual landowners and those who work with them better understand the role forests and their products play in the carbon cycle so they may navigate methods for reducing GHG emissions by improved forest management along with other goals for their land.

## Summary of Potential GHG Mitigation Practices on Land

Description of Strategy	Opportunities	Considerations
Increase forest growth rate to increase carbon sequestration per area.	Improve forest management to increase wood growth and harvest for both high-value wood products and low-value residues for bioenergy.	Developing and implementing a forest management plan costs time and money and may not provide financial return for many decades.
Plant trees on available non-forest land (afforestation) to increase carbon sequestration per area.	Unproductive land can be planted with short-rotation woody crops, forest plantations, or native forest species to provide many benefits in addition to wood products and bioenergy feedstocks.	Land may not be available, and if land already has a productive use such as pasture, this pasture may deforest another location (i.e. leakage – no net gain). Planting trees can be costly and will not provide a financial return for decades.
Prevent deforestation to prevent loss of carbon stored in forests.	Maintaining land in forest provides many benefits including wildlife habitat but also carbon sequestration, wood products, and bioenergy feedstocks that can all reduce GHG emissions.	Maintaining forest land may limit opportunities for economic development that could provide a higher financial return than from forests.

These practices above are further enhanced if forest products 1) displace high-GHG-emitting building materials such as concrete and steel, 2) displace fossil fuels with woody biomass; 3) are recycled at the end-of-life for extended carbon-sequestration or for bioenergy.



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# Forest Management & Greenhouse Gas Mitigation Opportunities

Information Sheet #7 – IN DEPTH

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## Target Audience

**Target Audience:** Educators and technicians helping landowners manage forests

**Target Greenhouse Gases (GHG):** Carbon Dioxide (CO<sub>2</sub>)

## Background Questions by Educator to help in Landowner Planning

How much forest land do you have?

What are your short and long-term goals for managing your forest land?

Do you harvest your forest land?

If yes, do you harvest firewood, timber, or other materials?

If yes, do you use these products or sell them?

Do you have a forest management plan?

If yes, when was it last updated?

If no, are you interested in creating one?

Do you plan to sell your forest land? Or give it to a relative?

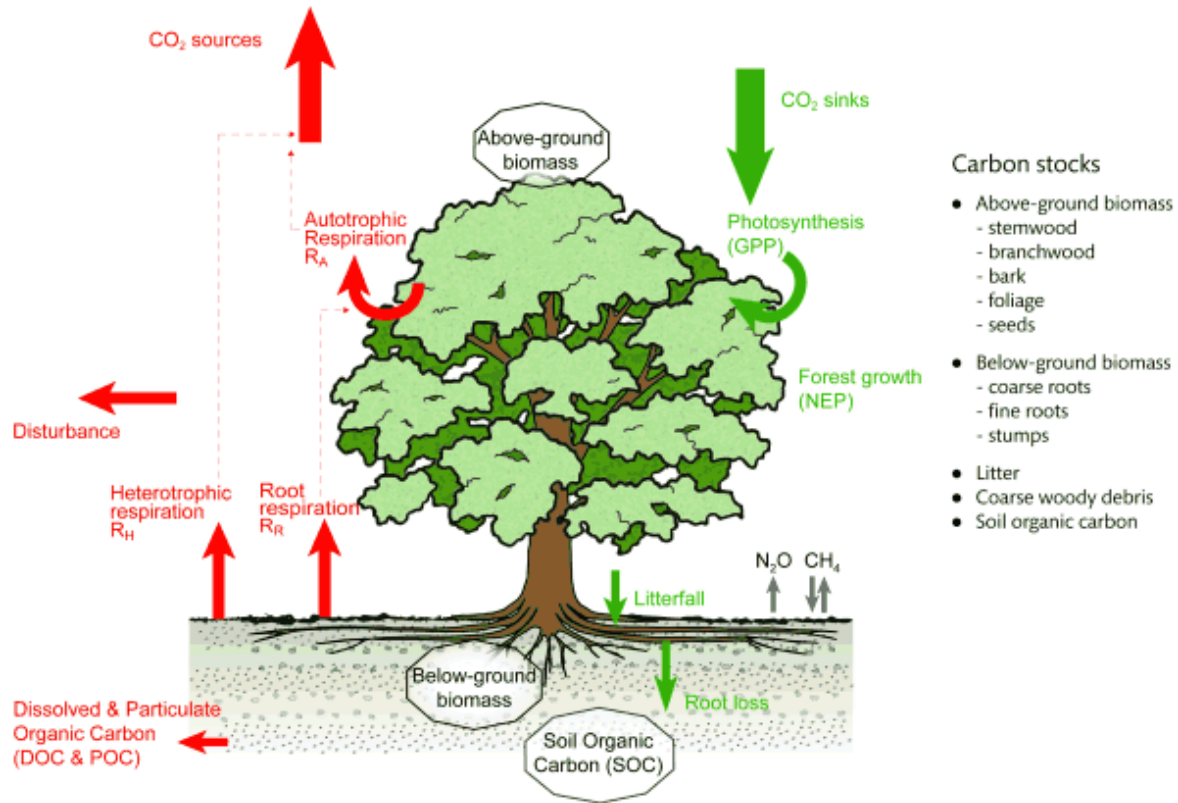
Do you have non-forest land that you might like convert to a forest?

## Background: GHG emissions from forest management

When trees and other plants grow, they use sunlight energy to convert carbon dioxide from the atmosphere into living plant tissues (also called biomass) through the process of photosynthesis. Forests therefore remove carbon dioxide from the atmosphere and store it in living biomass and dead material. Dead plant material is eaten by soil organisms, releasing most of the carbon back to the atmosphere as CO<sub>2</sub>, but some is stored for a long time in the soil and forest floor. Any perennial vegetation will store carbon in roots and soil (see [Information Sheet #6](#)) including forests. However, forests also store a great deal of carbon in living and dead wood aboveground. Carbon storage in a mature forest stand can exceed 100 tons per acre, with most of this carbon in living trees (Figure 1). This carbon storage, or sequestration, reduces carbon dioxide, (a greenhouse gas (GHG) in the atmosphere) and helps mitigate climate change.



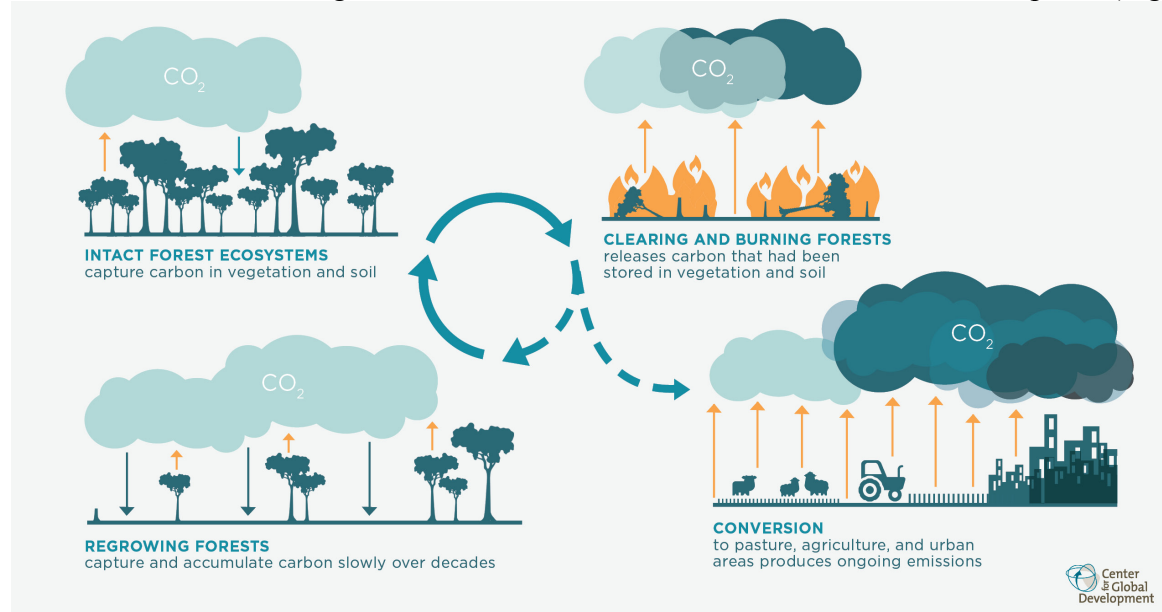
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**Figure 1. Cycle of carbon in Tree System**

From Forest Research, <http://www.forestry.gov.uk/website/forestresearch.nsf/ByUnique/INFD-62NBUH>

In addition to decay processes releasing this carbon to the atmosphere, disturbances such as forest fires, forest clearing, and land conversion can release carbon to the atmosphere (Figure 2).



**Figure 2: Disturbances of forest that results in net CO<sub>2</sub> release** (Note, it takes decades to sequester the carbon in the tree and just weeks to harvest, combust, and emit that carbon.) <http://www.cgdev.org/publication/ft/why-forests-why-now-preview-science-economics-politics-tropical-forests-climate-change>

While Figure 2 illustrates ways in which certain management strategies can result in a lot of GHG emissions, there are many opportunities to increase GHG mitigation by forest management. For example, forest management that uses wood products in place of materials such as concrete and steel that emit a lot of GHG to the atmosphere during their production. That is, forest products belong to a closed loop of carbon while fossil based industries do not. Eight opportunities (on the forest land and after harvest) are listed and discussed below.

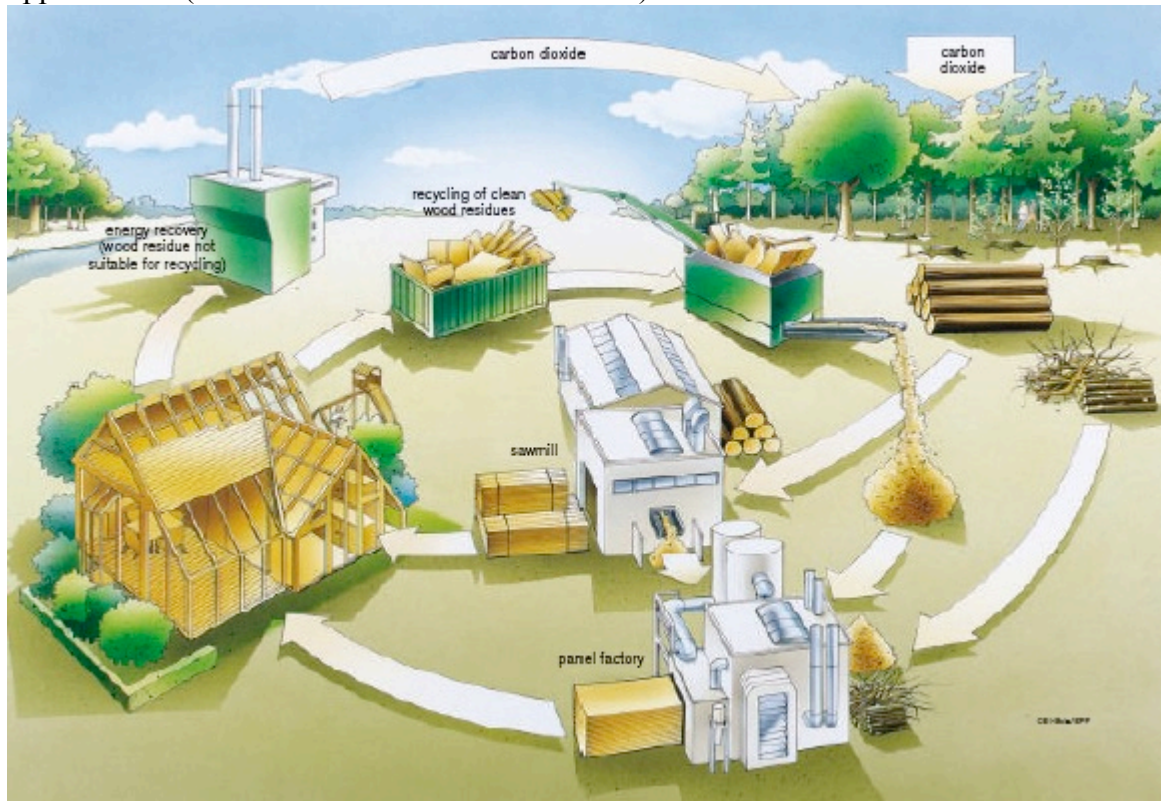


Figure 3. Carbon Cycle of Forest Wood Products. From CEI-Bios, European Panel Federation

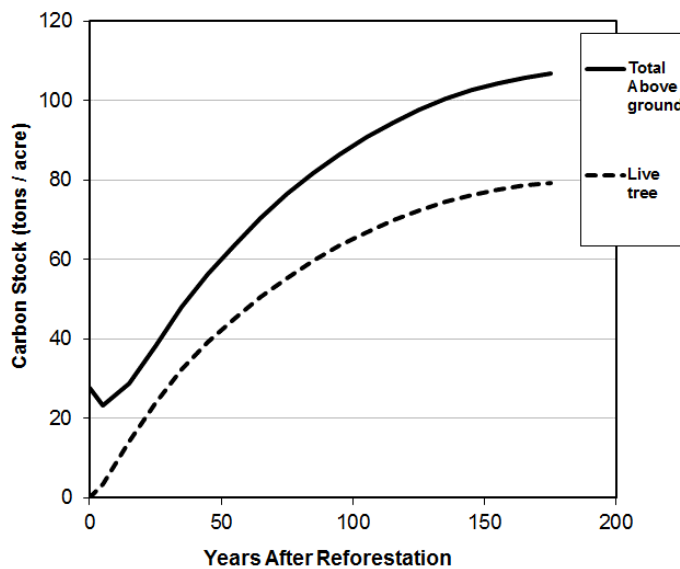
### Key concepts for mitigation opportunities

1. As forests grow, they remove CO<sub>2</sub> from the atmosphere and store it as carbon in the forest.
2. Planting trees on available non-forest land (afforestation) removes carbon from the atmosphere and stores it in the new forest.
3. Preventing deforestation prevents loss of forest carbon to the atmosphere.
4. After timber harvest, wood products like lumber and plywood can EXTEND this carbon sequestration by storing carbon in buildings for a long time.
5. Using wood products in place of steel and concrete greatly reduces total CO<sub>2</sub> emissions by displacing the GHG emissions from the production of steel and concrete.
6. Improved forest management to increase yields can increase profits and decrease CO<sub>2</sub> emissions.
7. Using woody biomass for bioenergy instead of fossil fuels for energy reduces CO<sub>2</sub> emissions.
8. Recycling demolition wood for use in new products or for bioenergy reduces CO<sub>2</sub> emissions.



## MITIGATION OPPORTUNITY 1: Improve Forest Growth to Increase Carbon Sequestration

**As forests grow, they remove CO<sub>2</sub> from the atmosphere and store it as carbon in the forest.** New York State contributes nearly 1% of total global greenhouse gas (GHG) emissions, emitting more than countries like Chile and Norway. However, NY is 65% forested and forests accumulate carbon in trees as they grow. This “carbon sequestration” removes carbon dioxide (CO<sub>2</sub>) from the atmosphere. Maintaining land in forests is called avoided deforestation and it is important because in the USA, forests remove about 10% of the GHGs that are emitted each year, with much of this removal in the Northeast (Woodbury et al. 2007a, 2007b). Forest stands can be left to grow unharvested and will continue to sequester carbon, but the growth and carbon sequestration rate diminish greatly after many decades (Figure 4). For example, an average maple-beech-birch stand (the most common forest type in New York) will remove 2 tons of carbon each year at age 35, but only 0.2 tons of carbon per year at age 175 because their growth rate slows which slows the rate of accumulating carbon (Figure 4).



**Figure 4. Carbon sequestration over time in an average Maple-Beech-Birch forest stand** (derived from Smith et al. 2006)

Of course, New York State has many kinds of forests with many kinds of trees suitable for different kinds of products. For example, of the nearly 19 million acres of NY forests, less than 1 million are forest plantations (NYDEC 2011). The rest is naturally regenerated with a predominance of Maple/Beech/Birch (56%) and Oak/Hickory (16%) forest-type groups. Together these two forest-type groups account for 72% of the State forests (NYDEC 2011). These different forest-types will sequester carbon in trees and in soil at different rates. For example, Table 1 below shows the standards used by the EPA for carbon sequestered in growing stock and soil in a range of Northeast (NE) forests. Notably, throughout the NE region the Maple/Beech/Birch is the dominant forest-type.

**Table 1.** Average Carbon Density (Mg C/ha) by Carbon Pool and Forest Area (1000 ha) According to Forest-Type (EPA 2013).

Region (States) Forest Types	Above-ground Biomass	Below-ground			Soil Organic Carbon	Forest Area (1,000 ha)
		Biomass	Dead Wood	Litter		
Carbon Density (Mg C/ha)						
<b>Northeast</b> (CT,DE,MA,MD,ME,NH,NJ,NY,OH,PA,RI,VT,WV)						
White/Red/Jack Pine	78.1	16.1	6.8	13.8	78.1	1,645
Spruce/Fir	39.1	8.2	7.4	30.7	98.0	3,046
Oak/Pine	70.8	14.0	5.6	27.9	66.9	1,203
Oak/Hickory	77.9	14.7	6.3	8.2	53.1	13,053
Elm/Ash/Cottonwood	55.3	10.4	5.4	7.1	111.7	1,467
Maple/Beech/Birch	70.9	13.6	6.7	27.3	69.6	13,710
Aspen/Birch	41.5	8.1	5.8	8.6	87.4	1,591
Minor Types and Nonstocked	45.4	8.9	5.7	11.0	73.8	1,854
All	67.9	13.1	6.4	18.0	69.0	37,569

Forests can be managed to increase wood harvest for both high-value wood products and low-value residues for bioenergy at the same time. Developing and implementing a forest management plan costs time and money and may not provide financial return for many decades. However, it is a great investment for the future, and can be considered like a bank account or investment that will provide a good return over a long time period.

Just like a garden or a crop field, a well-managed forest yields higher income. Many forest landowners value timber production. Family owners with 10 or more acres (34% of family forest land), two-thirds have cut trees for personal use, and about 40% have sold timber (53% of family forest land). A forest management plan that removes unhealthy or low-value trees and allows healthy trees to grow faster or a plantation of fast-growing trees can have higher growth rates and more valuable products than an un-managed or poorly managed forest stand. Poor forest management includes “high-grading” in which valuable trees are removed without enough consideration for leaving valuable trees to replace them (either a younger trees or as seed-producing trees to re-seed). Such “high-grading” produces short-term income, but does not produce long-term value in the forest. There are 3.5 million acres of timberland that are poorly stocked with growing-stock trees or non-stocked; this represents a loss of potential growth (Widmann et al. 2015) and carbon mitigation potential. More than 50% of family forest owners feel that management advice would be helpful, but 84% have not received any management advice and only 9% have a written plan (Widmann et al. 2015). Development of a management plan with a professional forester and periodic (e.g. every 10 years) review of the plan can greatly improve forest productivity and carbon sequestration.

The potential rate of forest carbon sequestration for different kinds of forests can be estimated using online tools (e.g. tables of the average growth rate of different kinds of stands as discussed in “Further Resources and Tools” below). Estimates for a specific forest stand using specific management practices can be developed by a professional forester based on site conditions and management plans.

## **MITIGATION OPPORTUNITY 2: Plant trees on available non-forest land (afforestation)**

**Unproductive land can be planted with short-rotation woody crops, plantations, or mixed native forest species to provide many benefits including wood products and bioenergy feedstocks.**





We estimated that there are approximately 1.2 million acres of underutilized land that is not currently forested and could be available for bioenergy feedstock production (Wightman et al., 2015b). This acreage could be planted with short rotation willow (a 21-year planting cycle) and used exclusively for bioenergy feedstocks. Alternatively, these lands could be managed as afforestation projects with a conservation easement, for example under the RGGI program. Land may not be available, and if land already has a productive use such as pasture, this use may shift to another location (i.e. leakage). Planting trees can be costly and will not provide a financial return for decades. However, many former agricultural lands are naturally reverting to forests, increasing the amount of forest in the state and sequestering substantial amounts of carbon (Widmann et al. 2015, Woodbury et al. 2007b). The potential rate of forest carbon sequestration can be estimated using online tools such or tables of the average growth rate of different kinds of stands as discussed in the section “Resources and Tools” below.

### **MITIGATION OPPORTUNITY 3: Prevent deforestation**

Maintaining land in forest provides many benefits including wildlife habitat but also carbon sequestration, wood products, and bioenergy feedstocks that can all reduce GHG emissions. Therefore, these values should be evaluated carefully when considering clearing land from forest for other uses. Forests are currently removing approximately 10% of all GHG emissions in the USA, which is a valuable service (Woodbury et al. 2007a, 2007b). Of course, in some cases, maintaining forest land may limit opportunities for economic development that could provide a higher financial return than from forests.

### **MITIGATION OPPORTUNITY after the Forest:**

#### **Use wood for bioenergy instead of fossil fuels for energy reduces CO<sub>2</sub> emissions.**

Carbon dioxide is the predominant greenhouse gas globally and is generated primarily from fossil fuel combustion. Enough new biomass could be produced throughout the State to equate to 7.4% of total energy consumption (Wightman & Woodbury 2015b). However, wood for fuel is not nearly as financially valuable a product to sell as is wood for high-value products such as floorboards or veneer. Therefore, it makes sense to use low-value wood for bioenergy, including non-commercial species, and tops and limbs from timber trees. However, some tops and limbs should be left in the forest to provide habitat and nutrients as part of an appropriate forest management plan. Another option is to plant short-rotation woody crops such as willow, but willow plantations can be expensive and may require specialized equipment. Using wood for bioenergy can displace fossil fuels and reduce total CO<sub>2</sub> emissions. For example, firewood or wood chips can be burned on the farm for heat or biomass can be sold as a heating fuel or for electricity production. Wherever such fuels are used, it is important to use high quality stoves and furnaces that meet current air pollution standards because serious air pollution can be caused by inefficient stoves or furnaces.

#### **Recycle wood products at the end-of-life for further use or for bioenergy**

Recycling demolition wood for use in new products or for bioenergy reduces CO<sub>2</sub> emissions. When wood products reach the end of their life, recycling those that are suitable can provide financial and CO<sub>2</sub> reduction benefits. For example, barn siding or dimensional lumber might be repurposed for construction or used as a fuel. Repurposing the wood continues the mitigation potential by carbon sequestration; combusting the wood for bioenergy displaces fossil fuel



emissions. However, cost and feasibility may limit the extent to which some materials may be recycled or used for bioenergy.

### **Use long-lived wood products**

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After timber harvest, wood products like lumber and plywood can extend this carbon sequestration by storing carbon in buildings for a long time. When forests are harvested for timber, the timber can be used for wood products like joists, studs, plywood, and floorboards that sequester carbon in buildings for many decades. With repeated harvest cycles, more wood can be stored in buildings than can be stored in an un-harvested forest (Bergman et al. 2014). This is because the growth rate is higher for young forest stands than for older forest stands, and appropriate harvesting can maintain a forest stand in a young rapidly-growing state (Figure 4). Some wood products can be produced by local sawmills and used locally, while others may be produced and used in more distant locations.

### **Use Wood Instead of Concrete and Steel**

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Using wood products in place of steel and concrete greatly reduces total CO<sub>2</sub> emissions by displacing the GHG emissions from the production of steel and concrete. Sustainably harvested wood is renewable in terms of the carbon cycle, meaning that CO<sub>2</sub> is removed from the atmosphere as forests grow and only emitted back to the atmosphere when the wood decomposes at end of life -- a two-way flow of carbon. However, fossil fuels have only a one-way flow from deep (geologic) storage to the atmosphere, where the CO<sub>2</sub> accumulates. Materials like steel, concrete, and aluminum require a lot of energy to produce, usually from fossil fuels that emit a lot of GHG including CO<sub>2</sub>. Using wood in place of these materials can greatly reduce total CO<sub>2</sub> emissions (Bergman et al. 2014). For example, wood can often be used in place of concrete for wall and floor construction, and in place of steel for building frame (such as joists and studs) construction. Modern techniques even allow very tall buildings to be constructed using wood frames. However, use of wood products for specific situations should be carefully evaluated, because concrete or steel may be more suitable than wood for some applications such as barn floors.

### **Resources and Tools**

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For many resources about managing forests, see the Cornell Department of Natural Resources web site with topics ranging from

Forestry: <http://blogs.cornell.edu/ccednrpublications/miscellaneous-forestry/>

Agroforestry: <http://blogs.cornell.edu/ccednrpublications/agroforestry-forest-farming/>

Other topics: <http://blogs.cornell.edu/ccednrpublications/agroforestry-forest-farming/>

For estimating the potential growth rate of forests under average management, online tools and lookup tables are available that use forest inventory (FIA) data to calculate forest carbon fluxes (Smith et al. 2006). For specific regions, the Carbon Online Estimator (COLE) tool can also be used (Proctor et al., 2005; Van Deusen and Heath, 2010). The COLE tool was developed to allow easy estimation of forest carbon stocks for a user-specified region of interest (Proctor et al., 2005). Users can select specific forest regions of interest and generate a report that estimates the carbon accumulated in each forest carbon pool over time (Van Deusen and Heath, 2010).



For further information about forest carbon sequestration in the Northeast and the USA see Fahey et al. (2010) and Woodbury et al. (2007a, 2007b). For challenges in quantifying GHG benefits for carbon markets and other purposes see Tonitto et al. (2016). For further information about the benefits of specific wood products see Bergman et al. (2014). For further information about various opportunities to mitigate GHG emissions, including forestry see Fahey et al. (2007) and Raciti et al. (2012).

To learn more about opportunities to reduce GHG emissions, see other information sheets in this series:

**Tier II Worksheets** Identifying Farm & Forest GHG Opportunities

<b>Information Sheet</b>	<b>Topic</b>
<b>IS#1</b>	Intro to Farm & Forest GHG
<b>IS#2</b>	Dairy Manure Storage
<b>IS#3</b>	Planning for Quantitative Methane Capture and Destruction from Liquid Dairy Manure Storage
<b>IS#4</b>	Energy Efficiency
<b>IS#5</b>	Nitrogen Fertilizer Management
<b>IS#6</b>	Soil Carbon Management
<b>IS#7</b>	Forest Management
<b>AEM Technical Tools</b>	Water Quality BMPs <a href="http://www.nys-soilandwater.org/aem/techttools.html">http://www.nys-soilandwater.org/aem/techttools.html</a>

## Vocabulary

**Afforestation and reforestation:** Human-induced conversion of non-forest land through planting, seeding, or human promotion of natural seed sources. Afforestation differs from reforestation only in that the former applies to land that has not been forested for at least 50 years, whereas the latter applies to land that was not forested in 1990. (Afforestation is a subset of reforestation using these working definitions.) Both could qualify for carbon offset credits in compliance and voluntary carbon markets.

**Avoided deforestation:** An action that results in forest not being cleared, when the absence of that action would have led to clearing. Note that if a forest is clear cut (completely harvested) but immediately regenerates as forest this is not considered deforestation. Deforestation means that forest land becomes some type of non-forest land.

**Carbon offset:** A financial instrument, measured in units of CO<sub>2</sub> equivalents, that is used by an entity (individuals, companies, or governments) to meet required or voluntary greenhouse-gas (GHG) reductions through actions not directly linked with the actions of that entity. All offsets are expected to meet five criteria: real, additional, verifiable, permanent, and enforceable. Some forest management activities qualify as carbon offset projects under various emission control agreements.

**Carbon Online Estimator (COLE):** A computer-based tool, developed by the USDA Forest Service that uses FIA data to estimate forest carbon stocks for a user-specified location.

**Carbon Sequestration:** Storage of carbon in a biological or geological sink. Biological sinks are soil, trees, and oceans.

**Forest inventory and analysis (FIA) of USDA Forest Service:** Periodic census of all forest lands in the US (one plot represents 6000 acres), provides a broad-scale assessment of forest conditions. These census data cover several decades, varying among geographic regions.



**Greenhouse Gas (GHG):** Any gas that causes atmospheric warming by absorbing infrared radiation in the atmosphere (common greenhouse gases include water vapor, carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), halogenated fluorocarbons (HCFCs), ozone (O<sub>3</sub>), perfluorinated carbons (PFCs) and hydrofluorocarbons (HFCs).

**Leakage:** When an emissions reduction strategy in one location creates an increase of emissions in another location. Leakage can occur across country borders, or across industry products but results in no net greenhouse gas mitigation benefit. For example, leakage can occur for avoided deforestation carbon offset projects if there has been no concurrent reduction in demand for wood products (A lumber company may place 1,000 acres of forest into conservation without harvest to sequester carbon, but another lumber company increases production by unsustainably harvesting a different 1,000 acres to meet the market demand for lumber.).

**Mitigation:** In general terms mitigation refers to the elimination or reduction of the severity of exposure to risks, or minimization of the potential impact of a threat or risk. Mitigation in the context of Climate Change refers to efforts that reduce the amount of greenhouse gases (GHG) in the atmosphere by reducing emissions (e.g. Increased energy efficiency, See IS#4), minimizing GHG potency (e.g. flare methane to reduce its GWP, See IS#2), or sequestering GHG (e.g. photosynthetic capture and storage of atmospheric CO<sub>2</sub> in long-lived wood products, See IS#7).

**Regional Greenhouse Gas Initiative (RGGI):** An agreement made by 10 Northeastern States to cap emissions of GHG from electricity generation using a cap-and-trade program.

**Weather versus Climate:** Weather describes atmospheric conditions for a specific place and time (often short-term, like a day), while climate is the average of those weather conditions over long periods of time.

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