Summary – Criterion 4

Forests play a vital role in conserving and enhancing soil and water quality and quantity. While nearly all of Delaware's watersheds are under 50% forested and most of Delaware is located in the Coastal Plain with little topography, our forests nonetheless provide excellent buffers and protect groundwater recharge areas. Forests also help protect water quality for Delaware's two large cities that utilize surface water for drinking water supplies. Approximately one-third of Delaware is located within the Chesapeake Bay watershed and protecting and expanding forested areas and buffers in this area as well as throughout all of Delaware is important. There could also be opportunities to restore the hydrology of bottomland forests by working with Delaware's tax ditch system. Regardless, maintaining and expanding forest buffers and forested areas critical to water quality protection is directly related to one of the S&PF national priorities—*Enhance public benefits from trees and forests.*

Criterion 5: Maintenance of Forest Contribution to Global Carbon Cycles

Forests are renewable and one of the largest terrestrial reservoirs of biomass and soil carbon. They have an important role in global carbon cycles as sinks and sources of carbon. Carbon stocks in forests include aboveground biomass, belowground biomass, dead and decaying organic matter and soil carbon. Carbon is also stored in wood products.

The biosphere has a significant influence on the chemical composition of the atmosphere. Vegetation draws CO2 from the atmosphere through photosynthesis and returns it through respiration and the decay of organic matter. The interchange between the biosphere and atmosphere is large—approximately one-seventh of total atmospheric CO2 passes into vegetation each year.

Global climate change could have significant impacts on the structure, distribution, productivity, and health of temperate forests as well as impacts on forest carbon stocks and fluxes.

Forest management practices also affect the carbon cycle and fluxes. Deforestation has a negative impact, but management activities that maintain and enhance the carbon stored in forests and forest products over the medium to long term can help mitigate atmospheric CO2 levels. In addition, biomass from forests can substitute for fossil fuels thereby reducing greenhouse gas emissions.

INDICATOR 11

Forest ecosystem biomass and forest carbon pools

Trees store carbon (referred to as a carbon sink) in their xylem (wood) and other tissues. Carbon storage is important because carbon (in the form of carbon dioxide) plays a role in the greenhouse effect and the warming of the Earth. Carbon dioxide concentrations in the atmosphere have risen every year since the industrial revolution. Forests "lock up" some of the carbon emissions produced each year and reduce the rate of increase of atmospheric carbon dioxide. Forest inventory data can be used to quantify carbon storage in Delaware's forests.

Forest ecosystem biomass

Forest biomass is closely related to forest carbon stocks—conditions that increase rates of tree growth will also increase rates of carbon storage within forests. The conditions that influence growth can include environmental conditions such as patterns of temperature and rainfall, atmospheric CO2, and nitrogen deposition. Forest management practices, such as invasive plant control and forest thinning, also influence tree growth. FIA data for Delaware from 2017 shows that live aboveground forest biomass was an estimated 25.7 million tons, an increase of 9% since 2011 (Table 11).

Table 11. Delaware forest characteristics, 2011 and 2017.

Characterisic	*2011*	*2017*
Area (thousands of acres)	340	356
Aboveground biomass of live trees (dry weight, thousand tons)	23,570	25,711
Net volume of live trees (million cubic feet)	861	947

Source: U.S. Forest Service Forest Inventory and Analysis

Forest carbon pools

In forest ecosystems, carbon is stored in different pools or stocks: aboveground live biomass, belowground live biomass, dead wood, litter, and forest understory (Table 12). Carbon fluxes are the amount of carbon moving from one stock to another over a specified period of time. Carbon is also stored in harvested wood, such as durable wood products (e.g., lumber for housing) that can last for a century or longer. Data from the 2017 growing season estimate the aboveground live tree carbon storage in Delaware's forests at 12.86 million U.S. tons (up from 12.60 in 1999). Dead, understory, litter, and belowground components account for an additional 6.59 million U.S. tons for a total forest carbon pool of 19.45 million tons in 2017.

Carbon may be a consideration in forest management activities even if it is not the primary objective. Carbon management often focuses on the amount of carbon stored in biomass and soil, as well as the rate new carbon is absorbed (sequestered) from the atmosphere to support tree growth.

Table 12. Total forest component carbon pool, 2017.

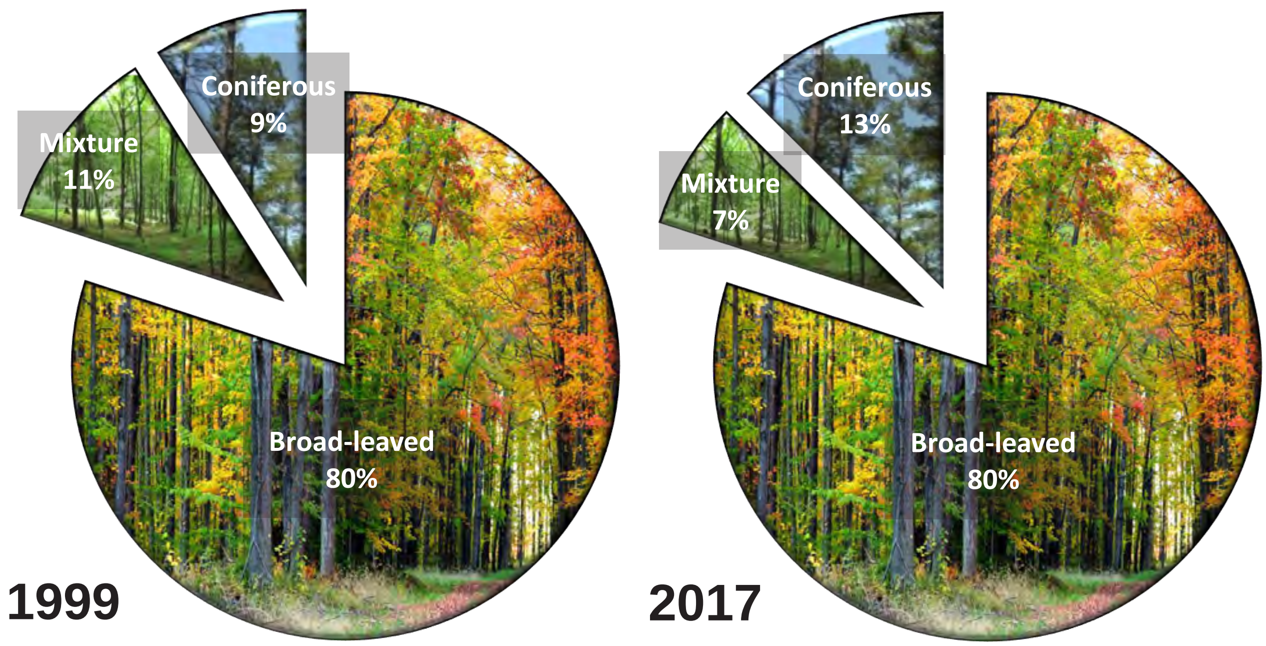
Component	*U.S. Tons (millions)*
Aboveground live tree	12.86
Standing dead	0.61
Understory	0.32
Down dead wood	1.35
Litter	1.76
Belowground live roots	2.55
Total	***19.45***

Source: U.S. Forest Service Forest Inventory and Analysis

Forest carbon by forest type

Four-fifths of the aboveground carbon is found in broad-leaved stands (Figure 33). These are forests dominated by deciduous trees such as red and white oaks (*Quercus* spp.), maples (*Acer* spp.), sweetgum (*Liquidambar styraciflua*), and yellow-poplar (*Liriodendron tulipifera*).This percentage is the same as it was in 1999, however there is a noticeable shift in aboveground carbon (4%) away from mixed to coniferous forests. Most of this increase is attributable to the increases in loblolly pine acreage and volume. Both forest types sequester and store carbon at various rates depending on age, condition of trees, and other factors.

Figure 33. Aboveground live tree carbon by forest type in 1999 and 2017.



Source: U.S. Forest Service Forest Inventory and Analysis and DNREC Division of Climate, Coastal & Energy

Urban and community forests

Urban and community forests play an important role in carbon sequestration and storage. Trees in urban and community environments may have higher rates of carbon sequestration as a result of lower tree densities, greater foliar biomass, irrigation, and fertilization (from stormwater runoff and/or landscape management). Proper siting and maintenance are important for maximizing the carbon benefit of urban forests. Trees that are well-adapted to their site have higher growth rates and lower mortality rates, thus providing more long-term carbon storage.

Trees in both forest and urban and community settings absorb atmospheric carbon through photosynthesis. This ongoing process of carbon sequestration adds to the amount of carbon storage as trees accumulate more biomass. The annual rates of carbon sequestration by urban and community forests continue to grow as tree canopy cover in urbanized areas expands.

The U.S. Forest Service has conducted research on urban and community forest carbon sequestration and storage (Nowak, et al. 2008, Nowak and Greenfield 2012, 2018). Carbon sequestration and storage estimates were updated in 2018 using urban land estimates from the 2010 U.S. Census, with tree cover estimates and carbon values based on earlier published methods. Some of the estimated benefits for Delaware are:

- Carbon storage: 3.1 million U.S. tons
- Carbon sequestration:136,300 U.S. tons annually
- Air pollution removal: 2.7 U.S. tons annually
- Number of trees per capita: 25.3 trees

Trees in urban and community settings provide other environmental benefits. Trees remove air pollutants by filtering particulate matter on plant surfaces and absorb some pollutants through respiration— these values vary under local conditions based on the amount of tree canopy cover, pollution concentrations, and other factors. The estimates shown above are a first-order approximation of a statewide total. It should be noted, however, that local-scale design of trees and forests can affect local-scale pollutant concentrations.

Urban trees and forests also shade buildings and act as wind buffers, thus reducing energy demand for cooling and heating. Reducing building energy use results in avoided emissions of greenhouse gases and other pollutants that would have been generated through fossil-fuel combustion from heating and electricity production.

Change in forest carbon

The amount of carbon absorbed and stored within a forest ecosystem is affected by land-use change, management activities, disturbance, and climate. Disturbances—both natural and human-induced—influence the composition, structure, and function of forests. Natural disturbances include insect pests, disease, fire, and wind. Climate change will affect forests by altering the frequency and severity of disturbance.

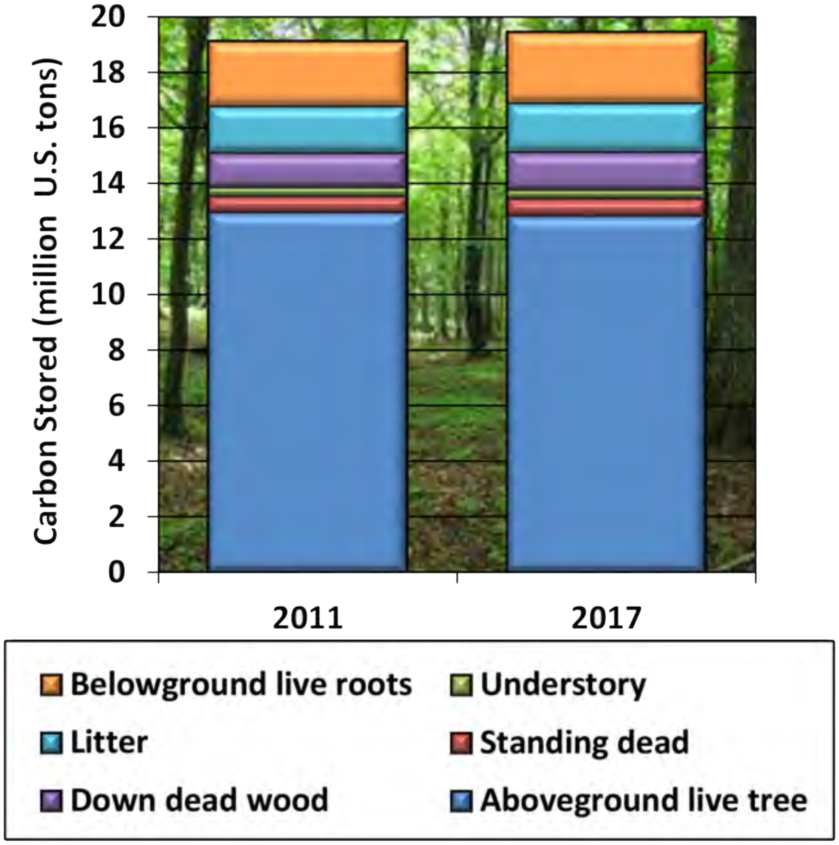
Avoiding forest losses resulting from deforestation and conversion to non-forest uses helps maintain both the carbon already stored in the forest system and the capacity of the forest to continue absorbing (sequestering) additional carbon.

In the past decade, forestland acreage in Delaware has not changed significantly. However, forest growth has increased the total amount of biomass in forest ecosystems. Annual net growth of forest trees has outpaced annual harvest removals and annual mortality.

Figure 34 shows the change in carbon storage in different pools from 2011 to 2017. Total carbon storage increased by 1.7% from 19.13 to 19.45 million tons. The increase since 1986 is 8.1%. These increases are expected because trees in Delaware's forests are growing larger (see Figure 11). While larger trees can store more carbon in living biomass and the trend of increasing carbon storage is desirable, it is important to remember that as forests continue aging, their ability to sequester additional carbon decreases. Therefore, maintaining a balanced mixture of young through mature forests is important not only for wildlife habitat, sustainable forest management, and other purposes, but also for carbon sequestration.

Avoiding forest losses from deforestation and conversion to non-forest uses helps maintain carbon already stored in the forest system and the capacity of the forest to continue absorbing additional carbon.

Figure 34. Carbon pools of Delaware forests in 2011 and 2017.



Source: U.S. Forest Service Forest Inventory and Analysis and
DNREC Division of Climate, Coastal & Energy

Conclusions

Delaware's forests are excellent carbon sinks. Furthermore, research has shown that forest management activities can increase the amount of carbon stored by forests. Preserving forests during periods of increased development is also important for carbon storage because affected forests are usually not replaced or, at best, only partially replaced so this carbon storage source is eliminated or greatly reduced. Voluntary carbon markets still exist within the United States and Delaware is a member of the Regional Greenhouse Gas Initiative (RGGI), which includes ten northeastern and mid-Atlantic states. All except New Hampshire have formally committed to advance the goals of the Paris Agreement and reduce their emissions 26–28% below 2005 levels by 2025. Currently, forestry practices approved by RGGI for carbon credit are afforestation (planting open land with trees), improved forest management (to increase carbon stocks), and avoided conversion (of privately-owned forestland). Conserving our existing forests, expanding forestland where possible (including urban forest areas and community open spaces), and including carbon storage in forest management plans will help maintain and increase the role of Delaware's forests in the global carbon cycle.

Preserving forests during periods of increased development is important for carbon storage because affected forests are usually not replaced or, at best, only partially replaced.