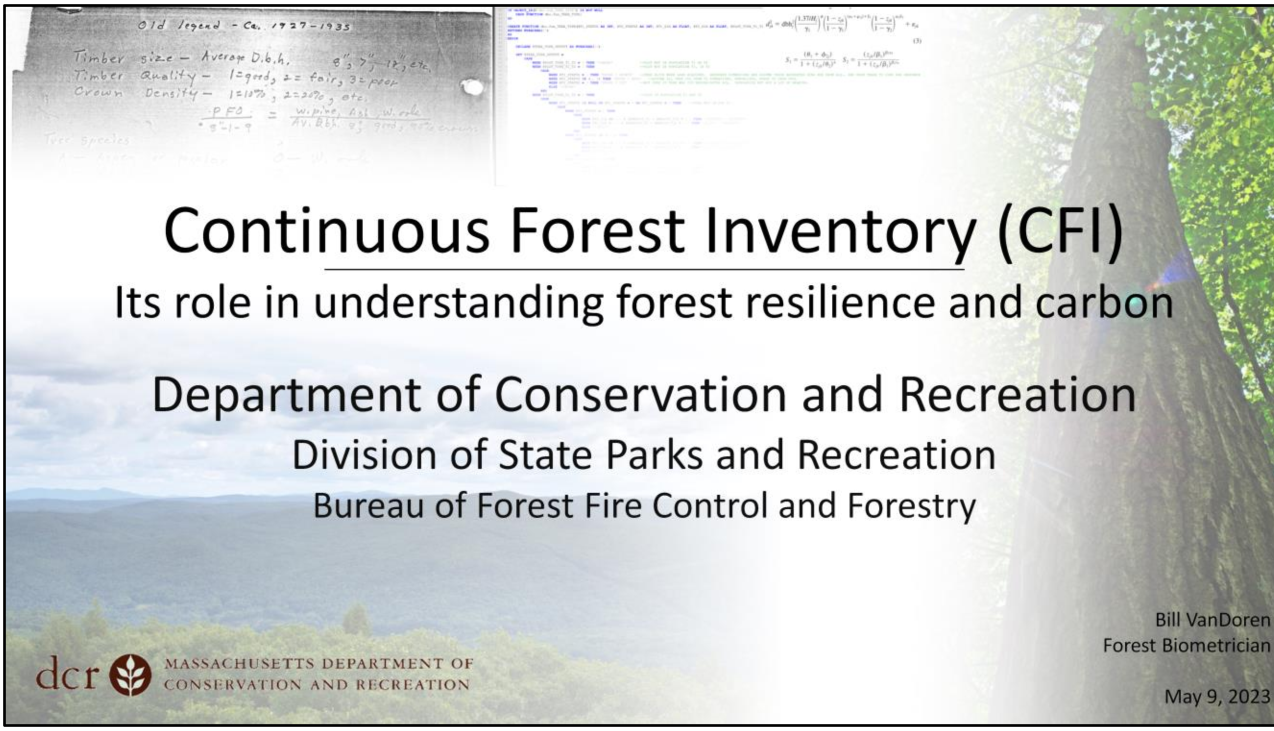


My name is Bill VanDoren; I work in the Bureau of Forest Fire Control and Forestry as a forest biometrician. This means I work with measurements, data, models, and predictions around forests and their management and ecology. I am grateful for the opportunity to speak with you today.

Continuous Forest Inventory (CFI)

- Program overview, history, and structure
- Examples of uses
- Carbon estimation examples
- Applications for climate resiliency

During my brief time today I'd like to accomplish several things.

First, I'll provide a short overview of the Continuous Forest Inventory, or CFI program, operated by the Bureau. Simply put, CFI is one of the most important tools to help us know what we know, and learn what we can, about the forests the Bureau stewards, at a strategic level.

I'll provide some examples of very general questions it has helped to answer in the past.

I'll work through an example of estimating carbon stocks, and components of change, as an example of how the CFI program addresses questions on forest ecosystem carbon dynamics.

And finally, I'll describe how our CFI data can help explore the relationship between resiliency and climate change adaptation, and forest carbon.

CFI Program Overview

- Provides strategic information on forest status and trends
- Complements operational, site-level, pre- and post-project data collection
- Used in reporting, modeling, planning, and analytics
- Basic phases include sample layout, field work, and processing
- Currently >2000 plots with >100,000 trees; now measuring 6th time over >60 years

The CFI program is one of the best tools the Division of State Parks and Recreation has to help understand both the potential of the forests it manages to mitigate atmospheric carbon; as well as their adaptive capacity and response; with respect to climate change. Our CFI program is very similar to the United States Forest Service's nationwide Forest Inventory and Analysis program, in that it inventories and samples the lands and vegetation managed by the Division.

Our CFI program operates at a strategic level, meaning it gives us high-level information on the status and trends of forests stewarded by DCR. It complements operational inventories we conduct before and after forest management projects.

Measurements and data collected through the CFI program help generate reports on the current character and condition of forests, and how they are changing; are used in modeling individual tree characteristics or stand dynamics; and are used to model forest growth and yield in to the future to help evaluate tradeoffs between different management approaches.

At the beginning of each calendar year we identify locations that are scheduled to be remeasured, and identify new acquisitions and determine if new sample plots need to be established. Our team then visits the sample locations and plots to see if they're on-property, and if so, measure trees, vegetation, and other forest attributes. We then review and compile the collected data.

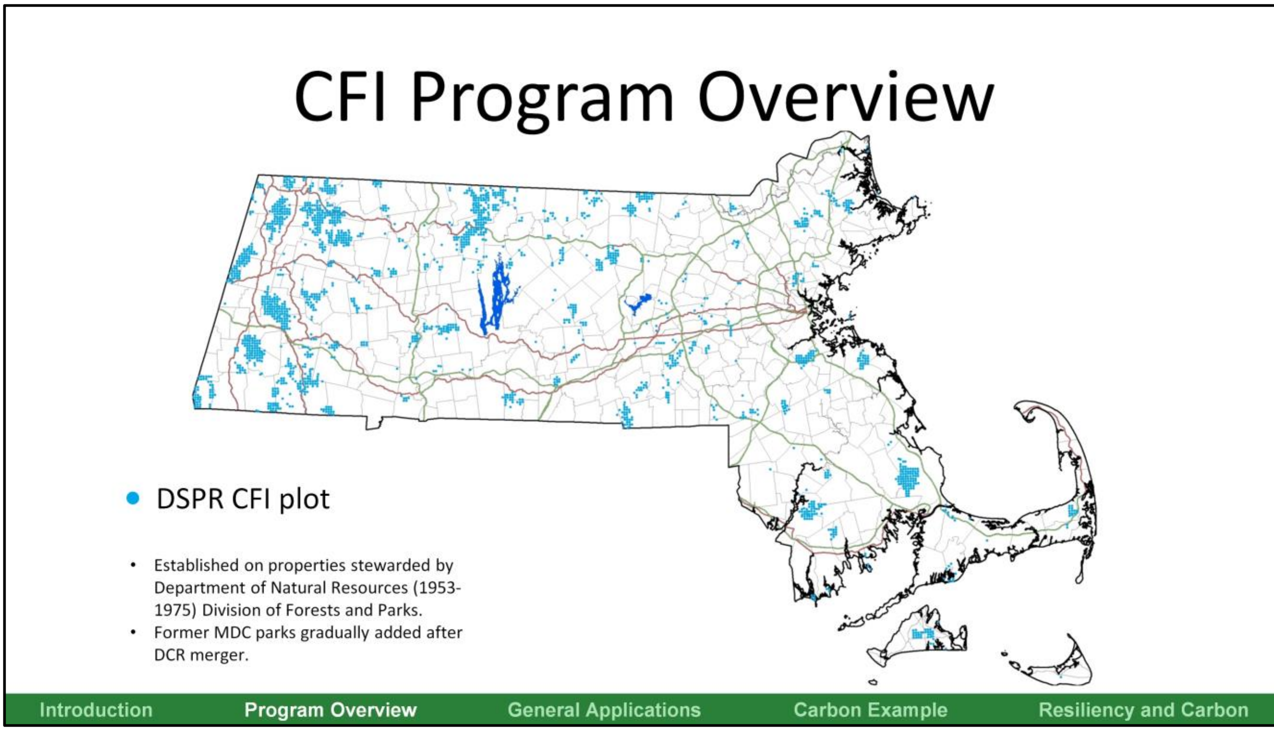
The management forestry program and its predecessors have conducted strategic inventories of the lands its managed since the 1920s and 30s. While it has evolved over time, the CFI program as it currently exists was established in the late 1950s. Approximately 1100 plots were established then. Six decades later, we're now measuring those original plots a sixth time. As the land base has grown, so has the number of plots, to the point where there are now over 2,000 plots, with measurements on over 100,000 trees.

CFI Program Overview

- Staffing:
  - Last measurement cycle: Combination of seasonal & year-round staff
  - Strategic Readiness Initiative converted one seasonal to year-round position

Of course, none of this would be possible without the dedication and expertise of my colleagues in the Management Forestry program – licensed foresters and other professionals – in the field collecting these measurements. This, and the Division of Water Supply Protection's, CFI programs are some of the longest continually-operating permanent sample plot inventories in the country – so our current program owes a huge debt of gratitude to our predecessors for their forethought.

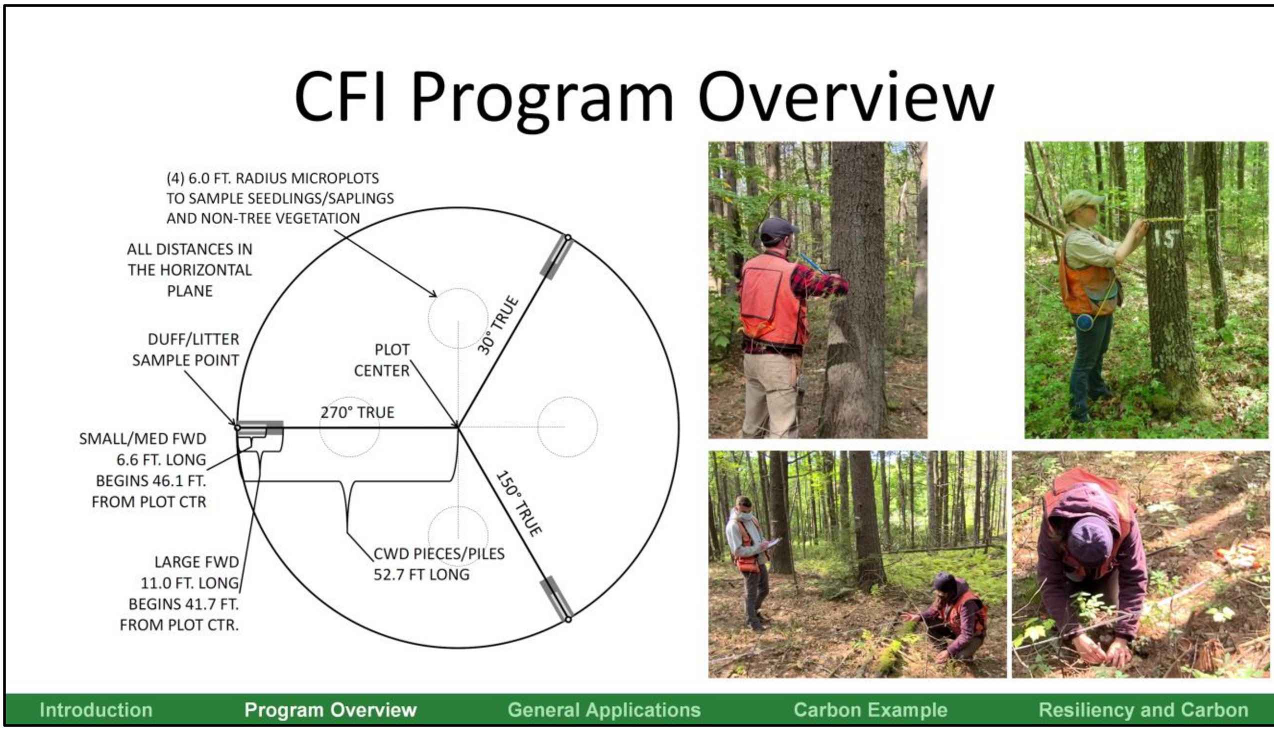
Over the last measurement cycle, we relied on a team of 9 licensed professional foresters that are year-round employees, and 5 seasonal employees devoting variable amounts of time to CFI; and there had been three seasonal employees dedicated to CFI over the past seven or eight or so years. Late last year, through DCR's Strategic Readiness Initiative, one of those three seasonal positions was converted to a year-round position, helping to gain some stability and efficiency in the CFI program.



This map shows the distribution of CFI plots on the properties the Division stewards across Massachusetts.

As we look at this map, I want to point out first, that the CFI system I'm discussing today was established by the Department of Natural Resources; after successor agencies merged to form the Division of State Parks and Recreation within DCR, we have been gradually including properties like Blue Hills, Middlesex Fells, and Breakheart Reservations, that were managed by the MDC.

Second, the Division of Water Supply Protection operates its own similar, but independent, CFI program, tailored to its mission. It also has a long, rich history, with the first 360 plots being established around the same time – 1960 – at the Quabbin, with 8 remeasurements between then and now; and close to 600 total plots across all four watersheds. This presentation focuses on the Division of State Parks and Recreation's CFI system, and its methods, data, and analysis.



Our field measurement protocol has varied slightly over the years. Here's a diagram of our current plot design. The inventory was initially commodity-focused, but has since grown to include measurements and observations of the greater forested ecosystem in a holistic fashion. We currently sample over 200 attributes including:

- Site and stand characteristics;
- The dimensions, characteristics, vigor, and fate of live, standing dead, and down dead trees.
- Characteristics of other vegetation including vines, shrubs, herbs, forbs, ferns, grasses, and invasive plant species;
- Down woody material of all size classes; and
- Forest floor characteristics including the litter and duff.

General Applications of CFI

- These data allow us to answer questions:
  - Point-in-time estimates like:
    - 156,585,327 live trees where DIA ≥ 1.0
    - 0.6% of forest < 20 years old; 66% 70-120 years; 9% older than 120 yr
    - 15.5% of land is affected by invasives to the extent they threaten successful regeneration; 5.8% by two or more different species
    - 107,529 $MTCO_2e$ in live trees where DIA ≥ 5.0 at Hopkinton State Park
    - 0.71 $MTCO_2e$/ac in CWD at Manuel Correllus SF
    - White ash sawtimber in the 18 and 20 inch diameter classes has increased by 1.923 million board-feet between 1980 and 2020 at Middlefield SF
    - 60% of regeneration in northwestern part of the state is beech, red maple, and striped maple
    - 55% of beech biomass is infected by beech bark disease and associated decay
    - 15.61 tons C/ac in the duff layer in oak-hickory forests on the Worcester Plateau; 33.46 tons C/acre in the upper 8 in. of mineral soil

So, what can we do with all the data we collect?

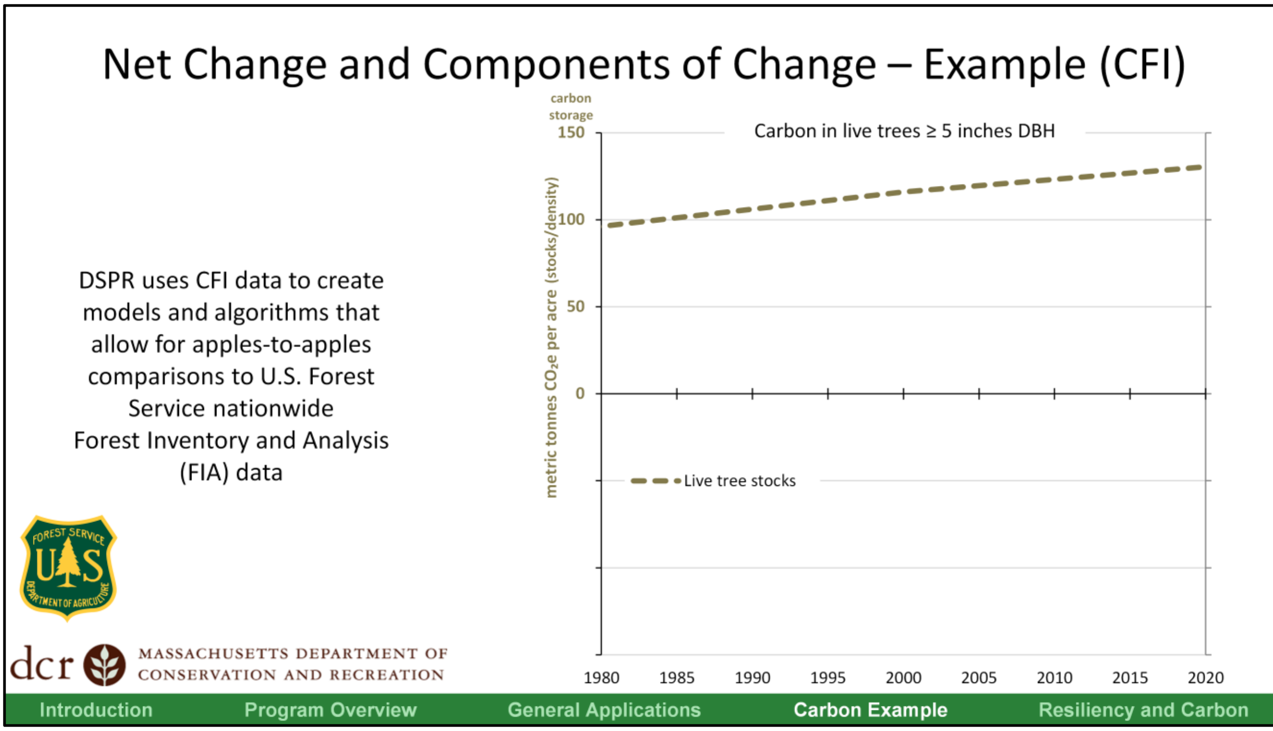
We get asked questions – a lot of questions – about the land we steward, both from our staff and the public. The CFI data can help us answer questions about conditions at a particular point in time. Here are some examples of estimates I've been asked to provide relying on our CFI data, and I'll highlight just a few of them. For example, we can estimate that, at present,

-There's about 156 million live trees greater than 1 inch diameter at breast height on the Division's forests;
-Most of our forest has an age structure in a relatively narrow range; between 70-120 years old; with relatively little very young and old forest; and
-Almost 16% of our land is affected by invasive species to the extent they threaten the successful regeneration of native tree species without intervention.

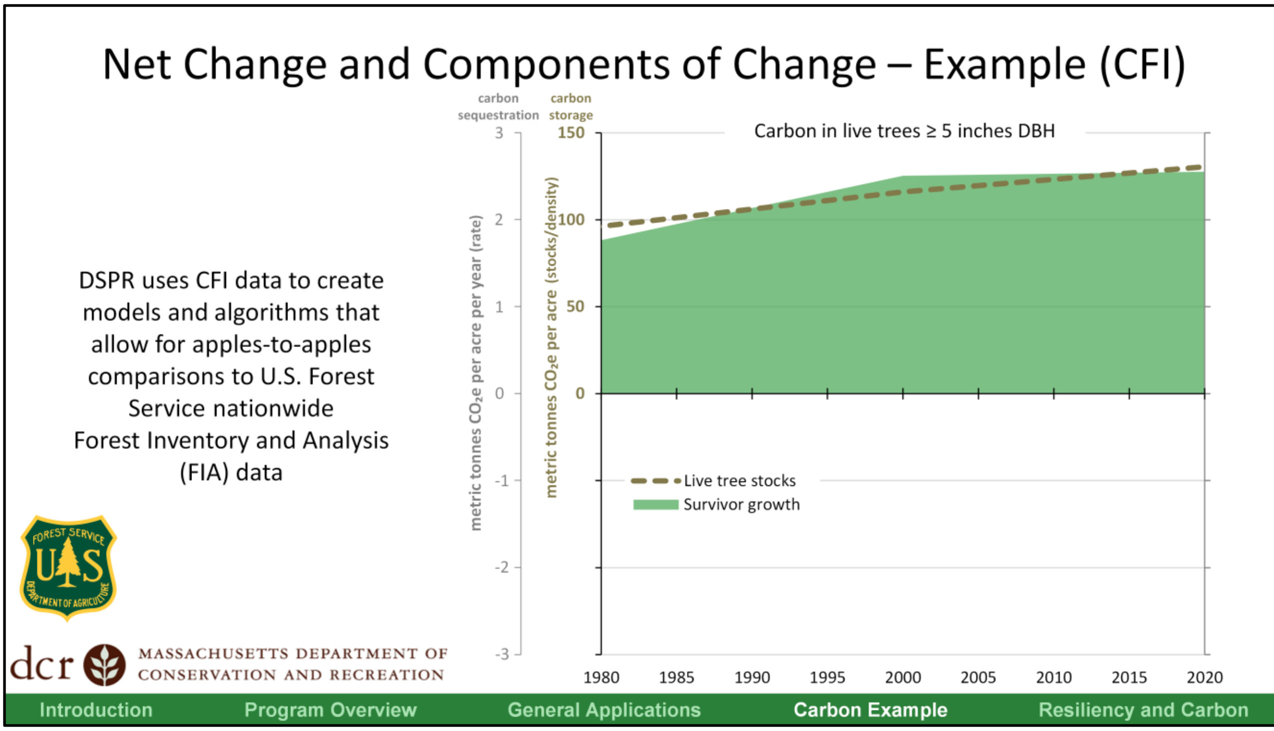
CFI: Forest Carbon Stocks and Change

- Worked example of forest carbon estimation

Now we'll take a closer look at how CFI data can be used to explore forest carbon dynamics, showing how they can help estimate forest ecosystem carbon stocks at different points in time, as well as how and why they're changing over time.



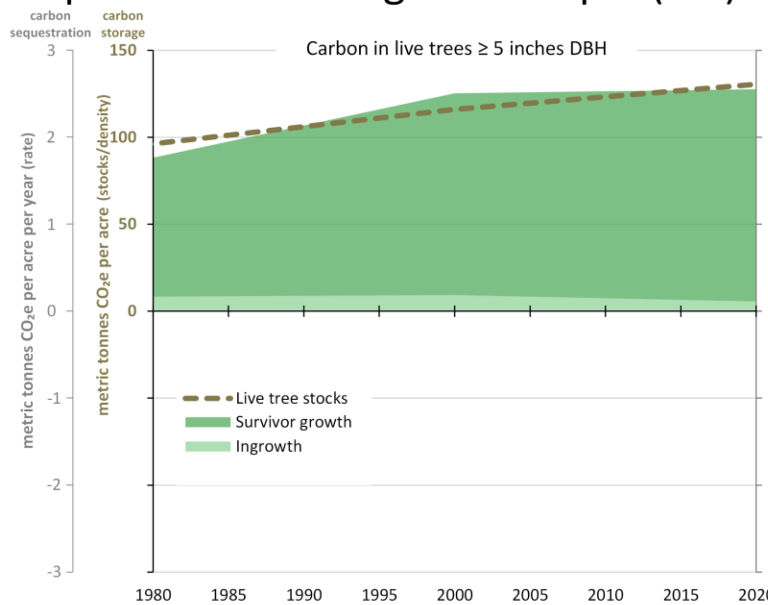
We'll work through this example, over the next few minutes, using this graph. First we'll look at stored carbon. Our CFI program measures trees in such a way that we can apply different models of estimating the carbon in them, and so for this example I've used the models and methods used by the U.S. Forest Service's Forest Inventory and Analysis program, or FIA – so we can have an apples-to-apples comparison with estimates of forest carbon available from FIA over Massachusetts and the northeastern US. Here we can see that stored carbon is increasing in the forests the Division manages. The dashed brown line represents carbon stored in the above- and below-ground parts of live trees over 5 inches diameter over all DSPR's forest land. The units are metric tonnes of CO2 equivalent per acre, the unit commonly used in the US to measure forests' contributions to emissions mitigation. And the timeframe is since 1980. As you can see, with each passing year these live trees on forest land the Division manages store more carbon than the year before.



Visualizing the net result of a process, as that first line showed, is useful, but equally as important is understanding how and why it is changing, which we will begin to do as we add data to the graph. These components of change that we'll be adding contribute to what we call flux, or carbon sequestration. We'll start by adding a new y-axis for these new data showing the change in carbon stocks per acre, *per year*, and again this will apply to all the new data we'll add. This is one area where the real power of CFI shines – repeated measurements at the same systematically selected points on the land, and trees, over time – yield valuable insights. And here, represented by the height of this bright green area, we're looking at the growth on existing live trees, called "survivor" growth – the growth on trees that remained alive between any two visits to a plot. This is the most substantial component of our growth at present. It is positive – adding to our stored carbon each year and so is above the x-axis in positive territory – and as we can see, the increase in survivor growth is not as rapid as it once was.

Net Change and Components of Change – Example (CFI)

DSPR uses CFI data to create models and algorithms that allow for apples-to-apples comparisons to U.S. Forest Service nationwide Forest Inventory and Analysis (FIA) data



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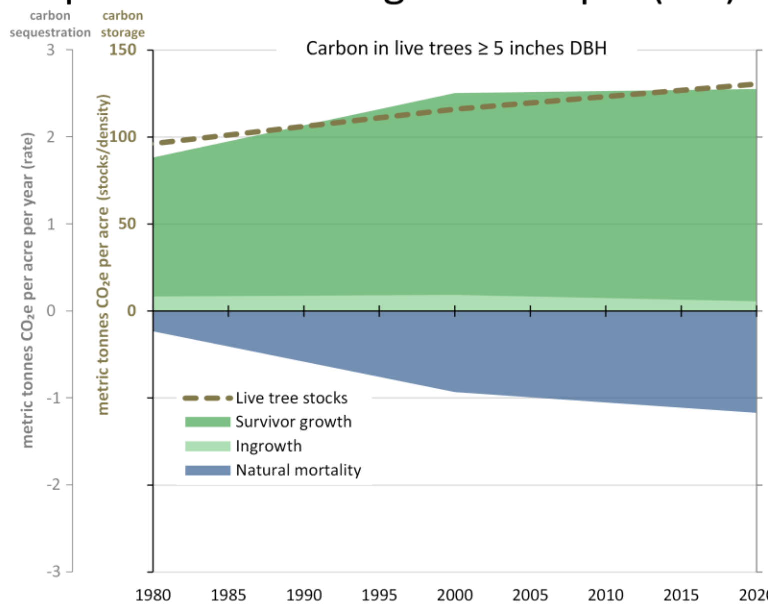
Now, we've added “ingrowth” as this light green area, the height of which represents new trees or young growth in the forest; and are trees that grew in to our sample plots between two visits. This is again, an addition to stored carbon, and so is shown above the x-axis. These are smaller trees and so while it's still adding to overall growth, we wouldn't expect it to be as much as survivor growth. However, it has been declining over the past 20 years and is 50% of what it was during the middle part of the 20th century. As stands and forests develop, and disturbance patterns change, there has been less establishment, regeneration, and growth of young and small trees. We call the sum of survivor growth and ingrowth, gross growth.

Net Change and Components of Change – Example (CFI)

DSPR uses CFI data to create models and algorithms that allow for apples-to-apples comparisons to U.S. Forest Service nationwide Forest Inventory and Analysis (FIA) data



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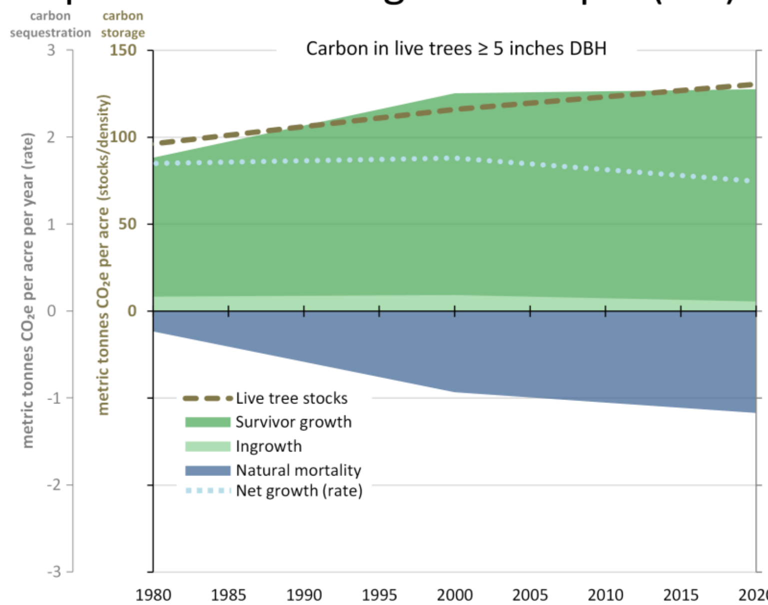
Next we'll add natural mortality. This includes – for this example – the carbon that was in trees in plots that died between two measurements. Since this removes carbon from the live tree pool it's below the x-axis. As you can see natural mortality has been increasing in our forests. Factors that can be causing this include stressors such as forest pests or droughts, or disturbances like severe weather; and also the legacy of landscape-scale patterns of agricultural abandonment, succession, and changes in age structure. The effects of these natural disturbances are compounded when trees' crowns are crowded as they have become over large portions of our land base, and trees don't have the room they need to remain vigorous and resilient. To be clear, these aren't immediate emissions back to the atmosphere – carbon in standing and down dead trees can persist for quite some time and is important for myriad reasons, and we remeasure standing and down dead trees, and measure forest floor attributes, in our CFI program. But right now, for the sake of this simplified example, we're focusing on additions to and removals from the live tree pool as we focus on the growth of living trees.

Presently, for each ton of carbon per year sequestered in live trees as survivor and ingrowth, about 44% is lost each year as natural mortality. It is very important to account for that mortality in the accounting of forest carbon dynamics – mortality can act, as it does here, as a heavy tax on growth. Simply remeasuring trees that stayed alive during a measurement interval paints an incomplete picture of growth and forest dynamics. In a more complex example, with more time, we could explore the dynamics of standing and down dead wood, the forest floor, soils, and other pools; but for now, we're focusing on changes to the live tree pool as the most dynamic, readily influenced by disturbance or humans, and having the largest immediate effects on other ecosystem services.

Net Change and Components of Change – Example (CFI)



DSPR uses CFI data to create models and algorithms that allow for apples-to-apples comparisons to U.S. Forest Service nationwide Forest Inventory and Analysis (FIA) data

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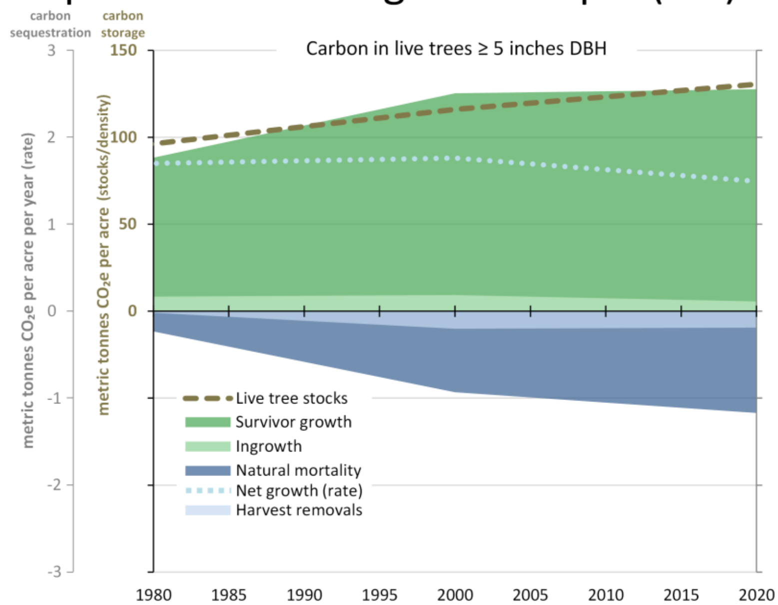
In the study of forest growth and yield, we call survivor growth, plus ingrowth, minus mortality, net growth.

This is interesting – we can see that while total stocks are increasing, net growth – the rate of carbon sequestration in this live tree pool due to tree growth and death – is declining. Again – carbon in our forests is increasing but at a decreasing rate – net growth has declined by 15% over the past 20 years, and by about 37% since the first remeasurement data from our CFI program.

Net Change and Components of Change – Example (CFI)

DSPR uses CFI data to create models and algorithms that allow for apples-to-apples comparisons to U.S. Forest Service nationwide Forest Inventory and Analysis (FIA) data



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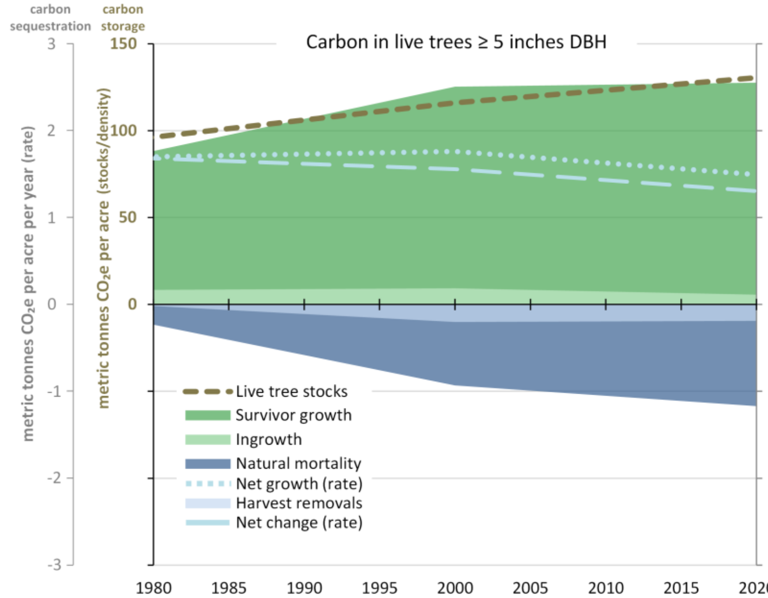
Now, we've just added to the graph the carbon in live trees removed by harvesting, the last major component of change. This is a removal of carbon from live tree stocks so it's below the x-axis. Harvest removals increased from 1980 to the turn of the century, then have declined a bit. We do use standard models to estimate how much carbon is stored in wood products created by trees harvested from our lands; but – for the purposes of this simplified example now, we're not showing it.

Natural mortality is currently 6.2 times greater than harvest removals. Again, natural mortality is responsible for greater losses of live tree carbon from our forests, than forest management. And at present, harvest removals are only about 12.6% of net growth.

Having harvest removals well below net growth, in and of itself, is not necessarily sustainable or good for forest health and resiliency. In fact, having too high a ratio of net growth to removals can lead to excessive stand density and reduced tree health, high rates of mortality, fuels buildup, and other negative outcomes. It is important to identify stands that are more resilient to higher levels of stocking because of certain factors, for example, diverse size species mixes that hedge bets against disturbances that might disproportionately affect a single species or size of trees; or, sites that are sheltered from the predominant local natural disturbance types.

Net Change and Components of Change – Example (CFI)

DSPR uses CFI data to create models and algorithms that allow for apples-to-apples comparisons to U.S. Forest Service nationwide Forest Inventory and Analysis (FIA) data



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Net growth minus harvest removals equals net change, and we can see that trends in our net change are, at present, influenced far more heavily by declines in survivor growth and increased natural mortality, than by ingrowth or harvest removals.

The end result of all these factors – the structure of our forest, inertia, stressors, and management patterns – is that over the coming years and decades, the forests the Division manages will likely continue to store an increasing amount of total live tree carbon, but if none of those factors changes substantially, the rate at which is sequestering carbon in live trees – that rate of increase of stocks in that pool – may continue to gradually decrease.

CFI – Forest Resiliency and Carbon

- Forest carbon – ecosystem and harvested wood product – are important
- We are able to measure, estimate, and model carbon, and arrive at single numerical values
- Forests are far more complex, and forest management solely for short-term carbon gains might have poor outcomes

Introduction | Program Overview | General Applications | Carbon Example | **Resiliency and Carbon**

We just worked through a quick and straightforward example of how the CFI data are used to estimate forest ecosystem carbon stocks and dynamics over time. I hope this shows how the net change in live tree carbon stocks only tells a small part of the story of forest carbon dynamics; understanding how and why they're changing is at least as important as that net result. The CFI program provides the measurements and data to help us strive to understand that.

It might have seemed easy to arrive at numbers representing carbon stocks and their components of change over time. While climate change and reducing atmospheric carbon concentrations are some of the most pressing issues of our time, those simple numbers representing carbon might make it easy – perhaps too easy – to start thinking about carbon first, when we think about forests. While we're able to measure, estimate, and model carbon; it's not easy to do all that and takes time and resources.

And relying on forests for a single attribute or ecosystem service above others – like wood, revenue, or in this case carbon – does forests a disservice. Forests are far more complex and forests provide a suite of services – habitat, clean water, wood, a sense of place – that a narrow focus on solely maximizing short-term ecosystem carbon gains, without regard to other ecosystem services, may have poor outcomes down the road.

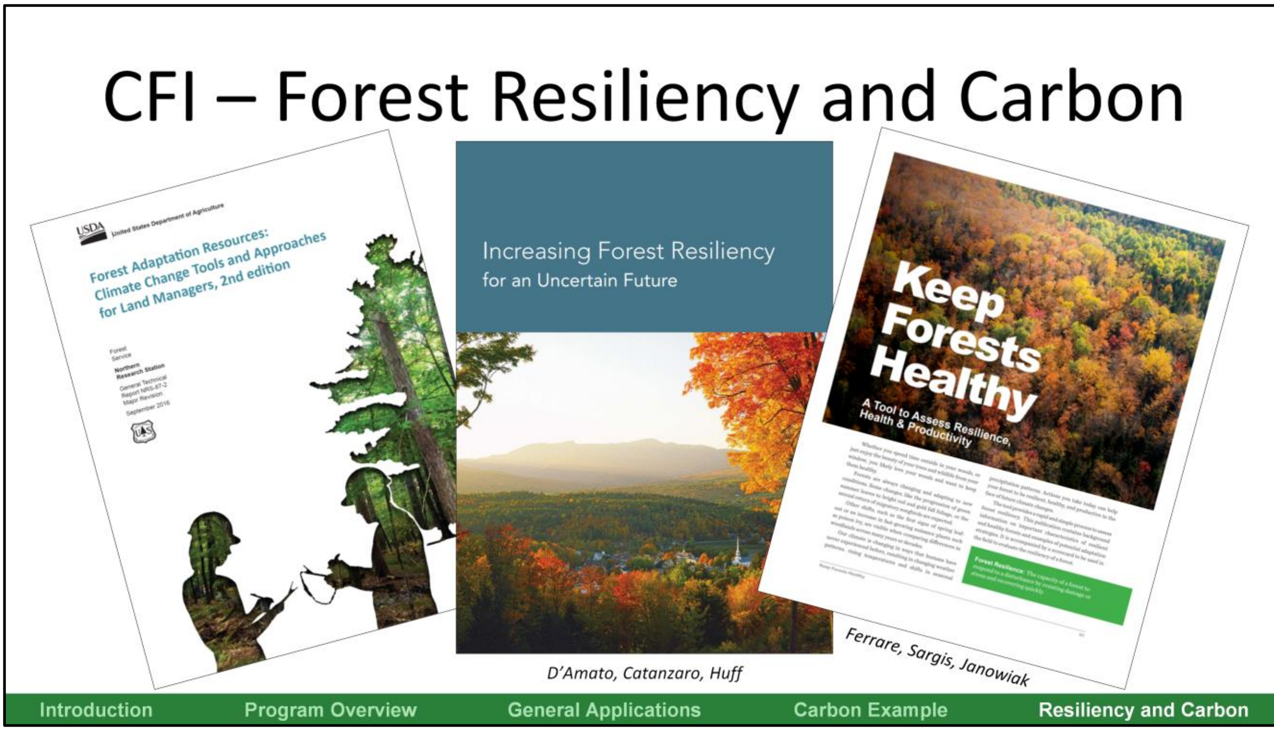
CFI – Forest Resiliency and Carbon

- Additional metrics of forest sustainability besides carbon?
- ***Forest resiliency***: the capacity of a forest to respond to disturbance by resisting damage and stress, and recovering quickly. Some degree of change can be accommodated with a return to near-prior functioning.
- What are components of forest resiliency at different scales? What happens to forest carbon when we manage for resiliency?

One of the key considerations about looking to forests to mitigate climate change we're learning about is stability – helping to ensure stability of high rates of sequestration, and stability of stocks in ecosystems and harvested wood products. This means forests need to be resilient in the face of climate change.

Forest resiliency is the capacity of a forest to respond to disturbance, by resisting damage and stress, and recovering quickly while accommodating some change if needed.

If it was so easy to arrive at a single number for carbon, though, why should we look any further? Is it even worth trying to think about metrics that we can measure and use as proxies for, or components of resilience? And what happens to forest carbon when we manage for resiliency?



Fortunately, there is an abundance of work in this emerging field, grappling with these questions and trying to use measurements and data to answer them and continually improve management approaches. The foresters in our program work with affiliates of the Northern Institute of Applied Climate Science, called NIACS, and stay up to date on research in to the field of how forests can adapt to climate change.

CFI – Forest Resiliency Metrics

- Species diversity
  - richness, distribution
- Species suitability
- Tree health
- Insects and diseases
- Standing/down dead wood
- Tree density/crown spacing
- Regeneration abundance/composition
- Structural diversity
  - Vertical canopy layers
- Structural diversity – range of tree ages and sizes at multiple scales

A number of proxies for resiliency have been suggested. They include things like species diversity, projected suitability under climate change projections, tree health, presence of stressors, tree density, and many others; at multiple scales.

It turns out that, foresters had been measuring and managing for some of these in our complex southern New England forests in an indirect way, long before "resiliency" was in our vocabulary.

We have many proxies to choose from and explore. Some of these Nicole touched on but might be a little more complex or harder to explain in a short amount of time – these could include things like stand density or stocking that have feedback loops with things like understory conditions that may promote moist or low-airflow conditions conducive to fungal growth as well as vigor of trees to be able to defend against pests and pathogens; or, things like trying to increase the diversity of tree species at different spatial scales that could help stands and landscapes be more resilient to outbreaks of pests or pathogens. So, I'll pick one that's straightforward to work through in the time we have. Let's take a close look at structural diversity and tree sizes.

CFI – Forest Resiliency Metrics

- Structural diversity – range of tree ages and sizes at multiple scales

Ferrare, Sargis, Janowiak

Address Vulnerabilities.
As the climate changes, conditions for current tree species will change, too. Hedge your bets and have a variety of native tree species present in your woods, so eventual "winners" will be ready to thrive. If your focus is on maintaining a single tree species, you run the risk of that species being unable to handle future conditions — and your whole forest loses out. A diverse forest structure is just as important as the individual species. A woodland with all the same size trees can also be at risk. Keeping a good population of young trees, middle-aged trees and old trees will not only provide diverse places for wildlife to live today, but it will also enable your woods to handle a variety of situations in the future.

FOREST STRUCTURE

When it comes to forest structure, more complexity is often better. Forest structure includes having a diversity of tree sizes and species, varying the number of trees per acre, and ensuring the presence of dead wood –both standing and down. These conditions make your woods more likely to attract wildlife and recover quickly from disturbance.

D'Amato, Catanzaro, Huff

VIGOROUS TREES OF VARIOUS SIZES AND AGES
Some stressors have a disproportionate influence on trees of particular sizes and ages. For example, windstorms have a bigger influence on large trees with dominant crowns. Certain insects target or are more lethal to trees of a particular size, such as white pine weevil and spruce budworm. Forests with a diversity of tree sizes and ages are more resilient to a given stressor, and there is a lower probability that any given stressor will affect a large proportion of the stand.

Trees in overcrowded forests compete with one another for limited sunlight, water, and nutrients. This severe competition can increase the stress of a tree and reduce its vigor, increasing its vulnerability to stressors. Reducing the number of trees in a forest can free up limited space and resources, increasing the overall vigor of the forest.

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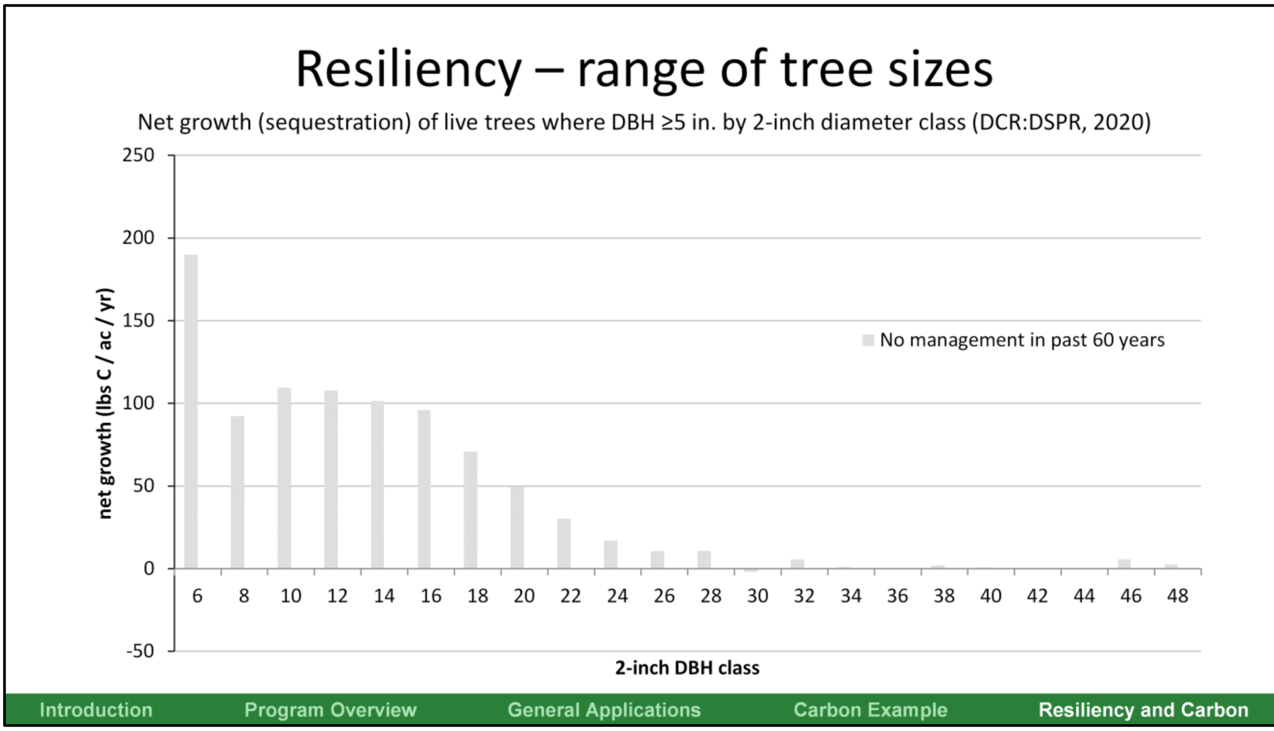
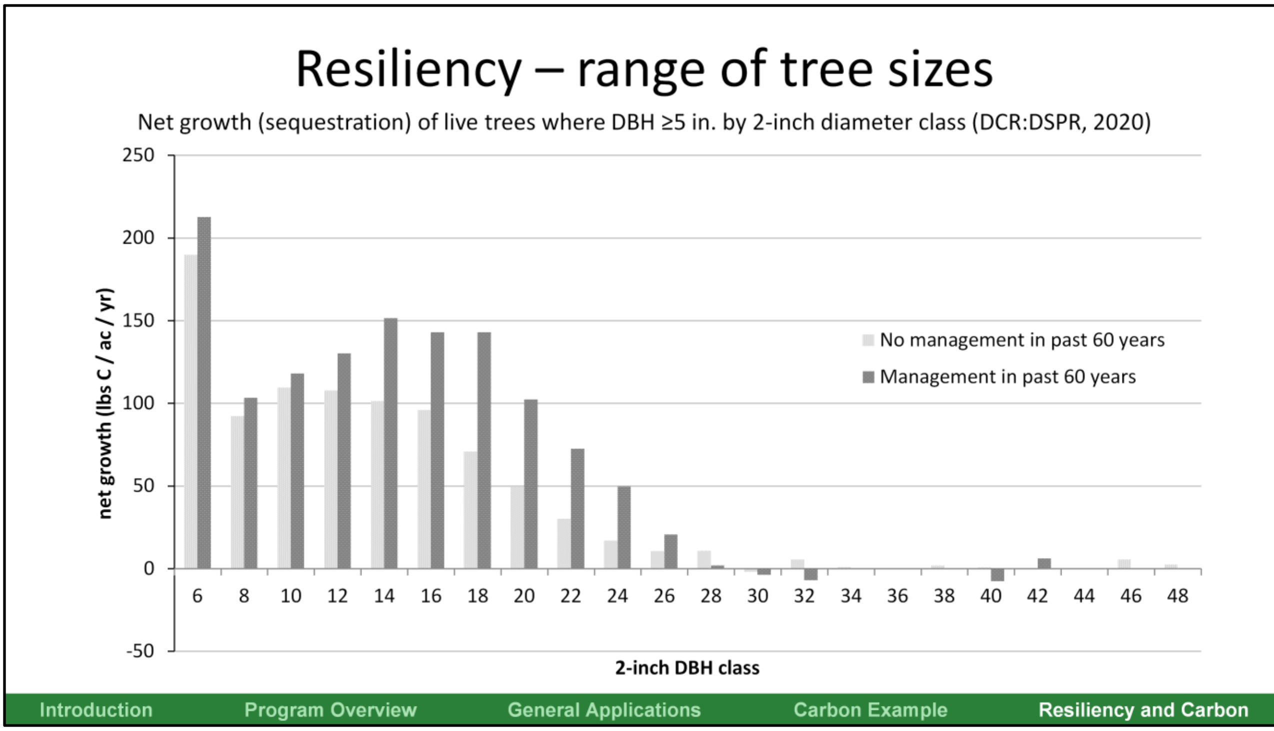
Tree size should be a fairly relatable metric – we can save the explanations of slightly more complex topics like canopy strata, stand structural stages or stage class, or density and resource availability, for another presentation.

We can turn to these publications to try to understand why a range of tree sizes that are vigorously growing might help forests rebound from stress and disturbance more quickly. Some of those disturbance agents could disproportionately affect a single size class or range of sizes. Having a range of sizes of trees, growing vigorously, can not only help stands and forests handle a wide variety of future situations – that climate change may exacerbate – but could also be beneficial for wildlife habitat and other ecosystem services.

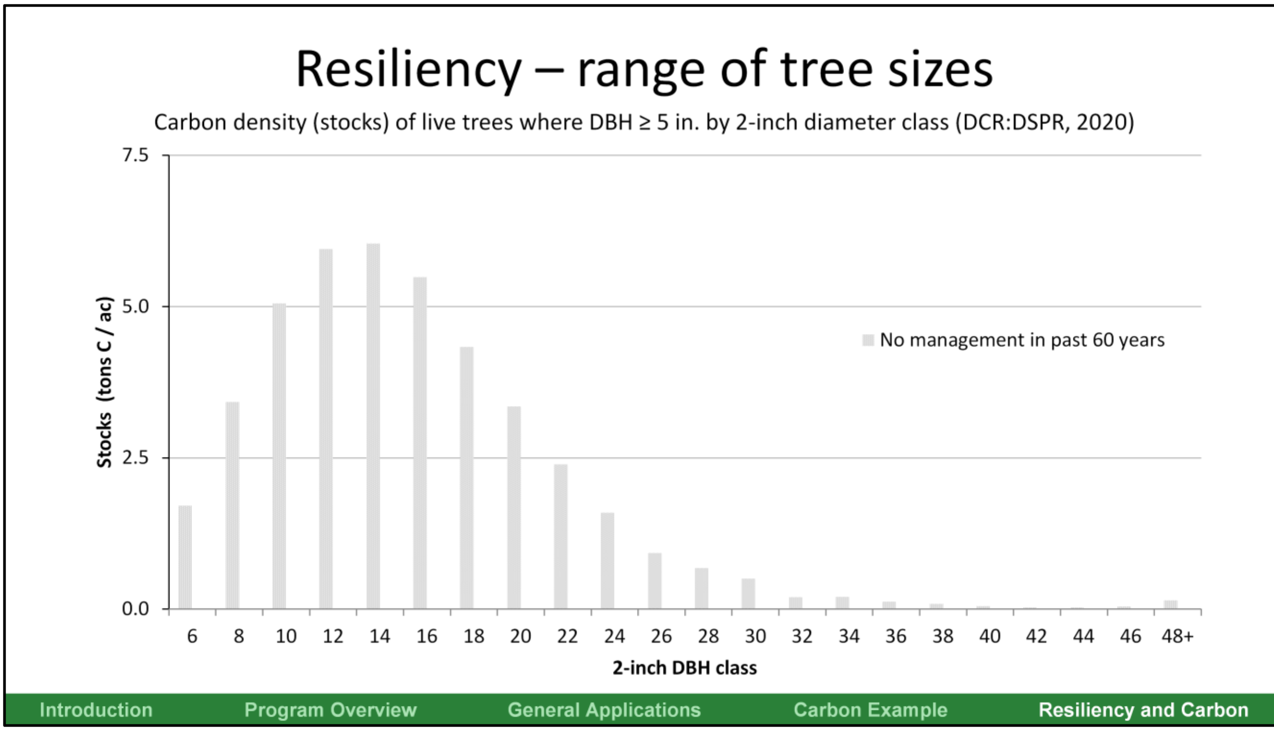


Let's explore what the data from our CFI program show.

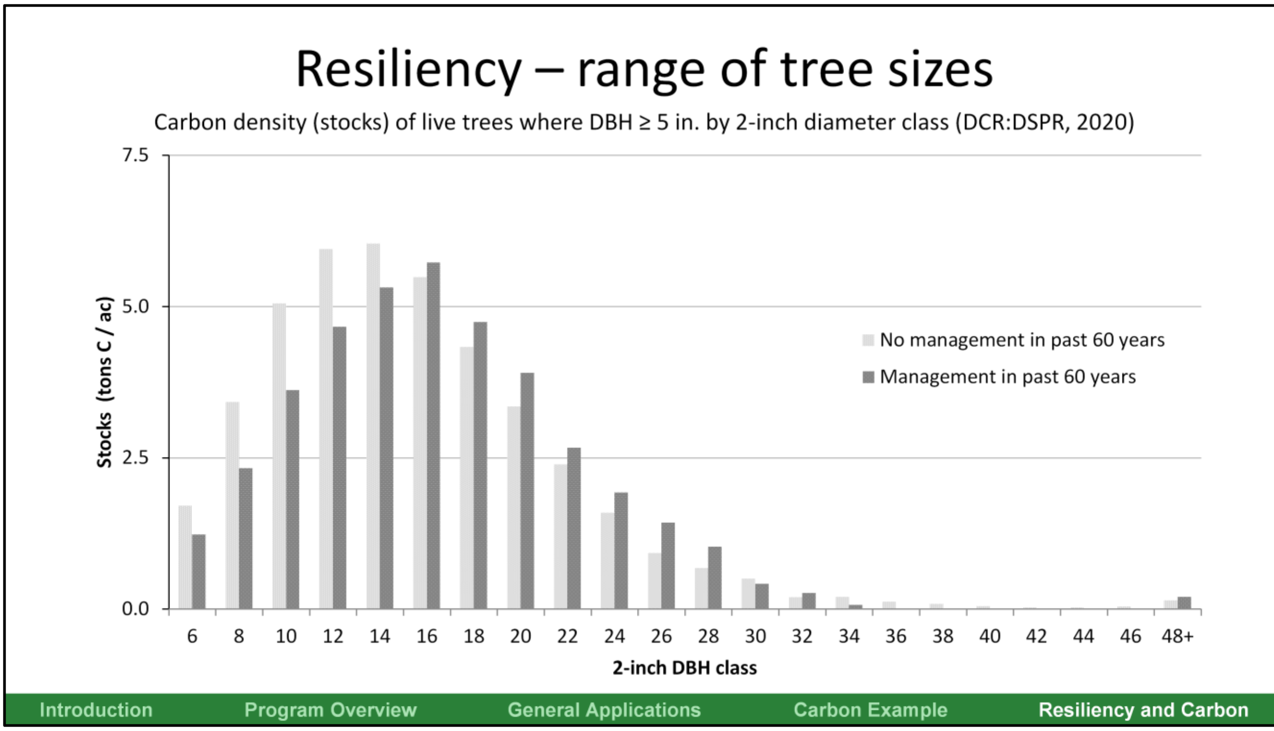
We'll first look at how trees of different sizes are growing. This graph depicts net growth on live trees by 2-inch diameter class. Here we're looking at that growth, in areas where there has not been a history of management. I'd like to pause here and recognize that I am presenting current results across these categories of land – land that has not had some kind of management activity involving the removal of trees, and land that has, over the past 60 years – but I'm not entirely comfortable with this strong dichotomy, for reasons I'll explain later. Roughly speaking, over the 60 year span of our CFI program, approximately 38,000 acres have received some kind of silvicultural treatment – approximately 15% of the nearly 325,000 acres currently stewarded by DSPR.



In areas that DCR manages, the reasoned, deliberate, and careful application of silviculture, and balancing removals with retention appears to help both ingrowth, growing the smallest trees faster; and the growth of larger trees as they are growing faster as well. Trees in the 16-22 inch DBH classes grow 1.8 times as fast, and trees in the 24-36 inch classes grow 1.4 times as fast. It is only in the very largest size classes where we see slightly negative net growth on managed lands – one explanation of this is the trees that we've deliberately retained to live – and die – in place and become biological legacies.



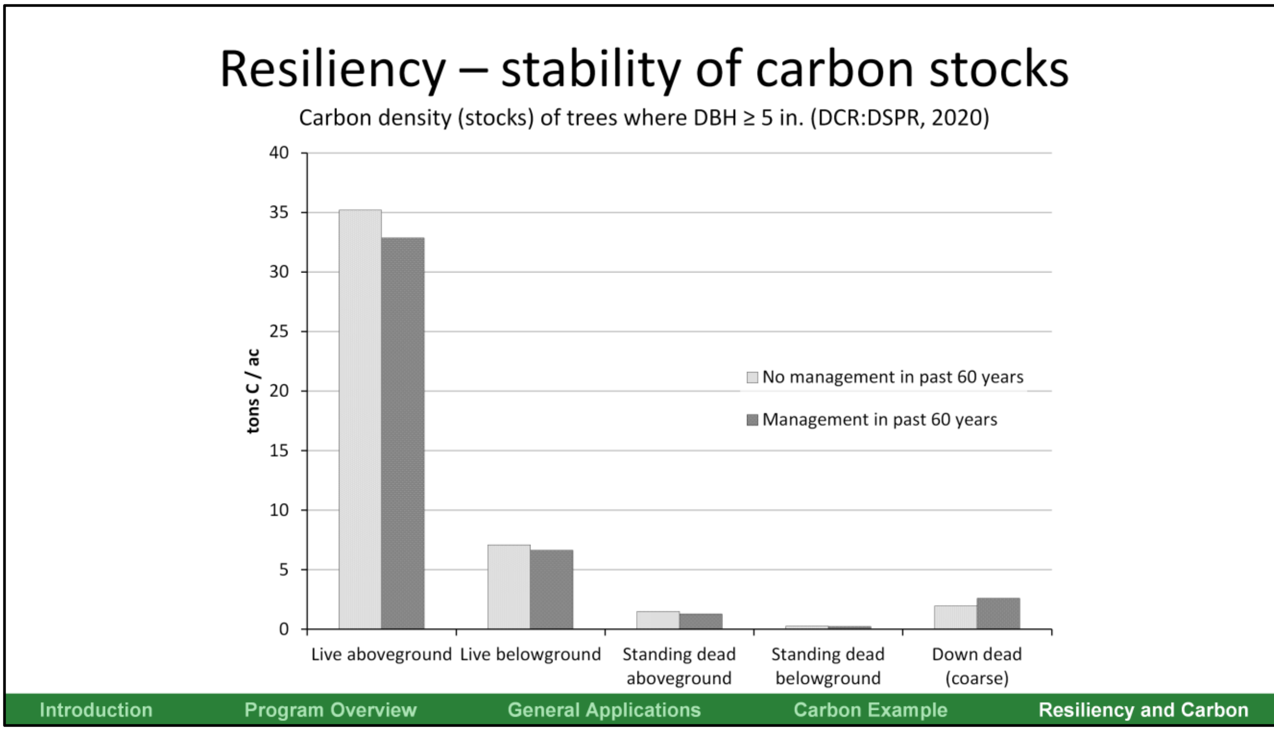
Here, we're shifting from growth on different tree size classes, to stocks per acre – carbon density – in live trees at least five inches diameter at breast height by those same size classes. This represents how much carbon is currently in trees of different sizes, integrating the results of management decisions, disturbances, and stressors over the past 60 years.



Where DCR has applied forest management practices and deliberate silvicultural treatments, these are the results. Treatments are tailored to each site, but we typically remove some trees that are less vigorous and usually smaller, and balance removing with retaining larger trees. The net result is that we have greater carbon density in most classes of larger trees on that subset of lands that have been managed. These results are consistent with both traditional silviculture and recent developments in trying to understand forest resiliency. These also have interesting implications for accelerating the development of late-successional characteristics, where we try to grow big trees faster and achieve complex structural arrangements.

In terms of structure – e.g., numbers of trees by DBH class – we don't see tremendous differences between managed and unmanaged lands using metrics associated with information theory (e.g., Simpsons, Shannons), when comparing within a specific forest or even ecoregion.

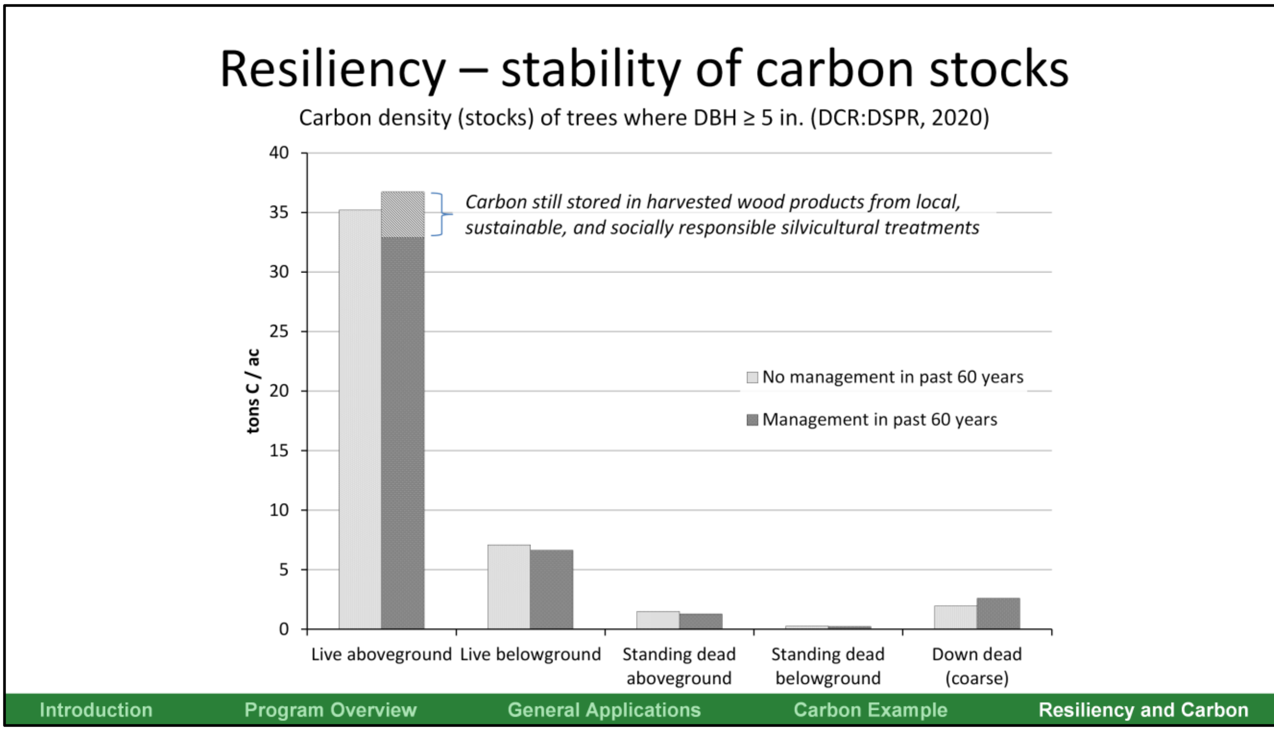
We see 10% more carbon in 16-22 inch diameter trees in managed areas; and this size range contains 37.6% of all live tree carbon. We see 22% more carbon in 24-36 inch diameter trees in managed areas; and this size class contains 10.3% of all live tree carbon. Finally, there is 79% more carbon in >36 diameter trees in unmanaged areas; and this size class represents 0.8% of all live tree carbon on DSPR lands.



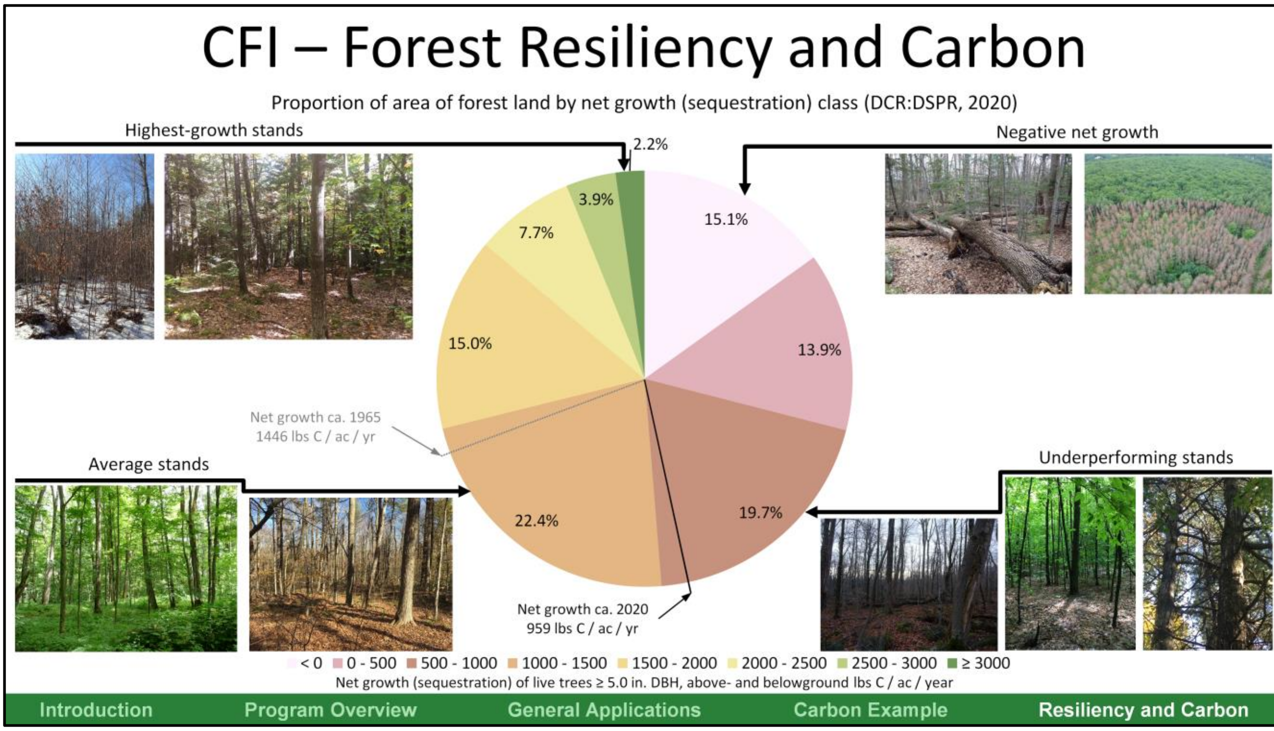
From the last graph of, among other pools, live tree carbon stock by diameter class, we notice that it appears that managed lands have less live tree carbon density. And this does illustrate a tradeoff – by removing less vigorous smaller trees competing for growing resources, we're allowing the bigger ones to grow faster and so may have slightly less carbon stocks overall in managed lands.

Other components of resiliency shown on this graph include standing and down dead trees.

Overall, we can see that the difference in carbon density between areas that have been managed, and that haven't, is not as large as we might expect, after 60 years. Managed lands have 6.6% less carbon in the aboveground part of live trees, and 13% less carbon in the smaller standing dead tree pool; while managed lands have 33% more carbon in down dead trees.



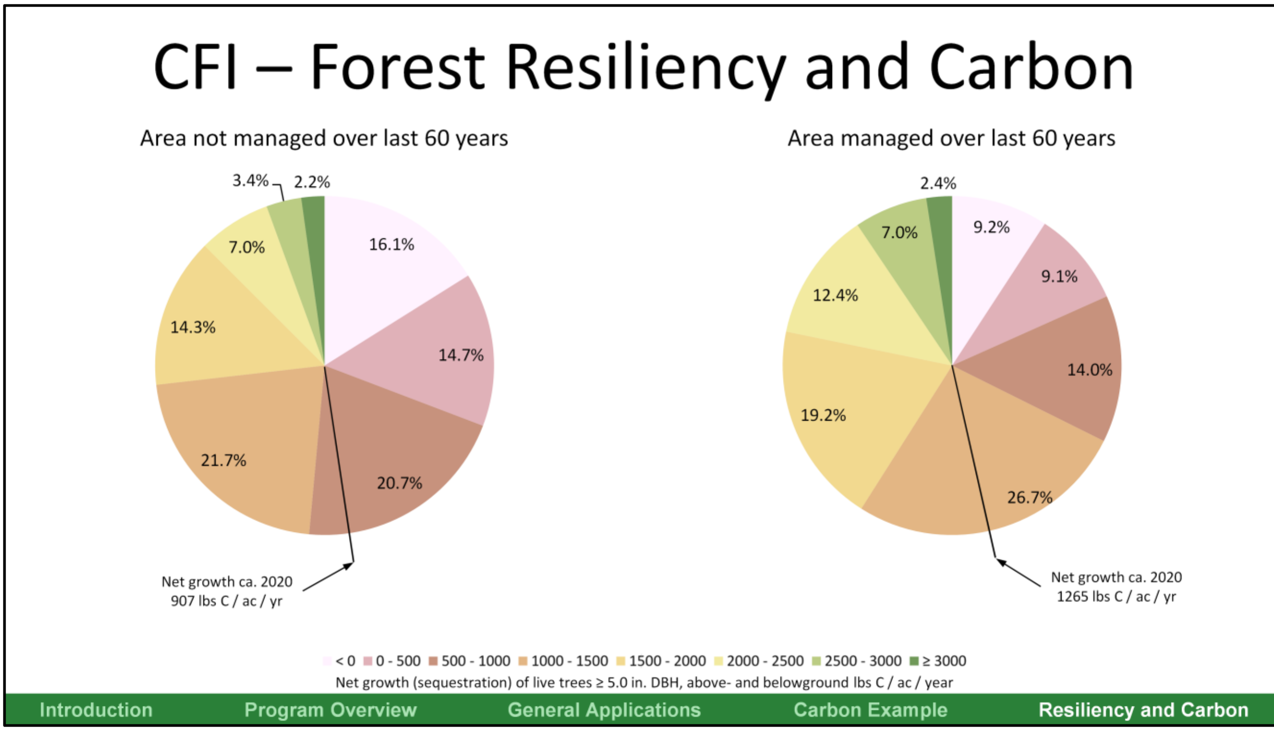
But, when we add back the carbon that is still stored in harvested wood products, estimated using standard US Forest Service and EPA models, and produced - with some of the most robust ecological and social protections in the world – from the above ground portions of live trees, we can see that – over a long time period, and across DCR lands in Massachusetts – there's really little difference at all in carbon stocks.



I'd like to reinforce these ideas further by illustrating that not all forest land performs the same when it comes to net growth and sequestration in live trees. With the pie chart in the center of this graph, I'm showing the proportion of forest land in different classes of net growth, or sequestration, rates, in live trees. What we see here is that statewide, about 15% of forested land has negative net growth – in other words, in those areas, carbon is leaving the live tree pool faster than it is entering. And – as illustrated in the earlier series of carbon slides, net growth has declined, over the past 55 years, by nearly a quarter ton of carbon per acre per year.

On the low-performing end of this spectrum, we might have stands with widespread mortality events; or tracts in a state of transition where larger trees are dying and the growth of residual live trees aren't enough to offset that loss.

On the high-performing end of this spectrum, we might have stands comprised mostly of younger pole-size trees, vigorously growing in a race toward the sky; or, older stands with a complex mixture of trees of different ages, sizes, and species, all photosynthesizing at different light levels, with complex canopy structures and arrangements, using all the available growing space to the greatest extent possible.



If we look at the proportion of land by sequestration class by management status, we see less land in the classes with lowest current sequestration rates, and more land with greater sequestration rates. The proportion of land sequestering carbon at a rate greater than one ton of carbon per acre per year in areas with a history of management is nearly double that of areas without management.

Again – our foresters are working toward stability of both high rates of sequestration, and carbon stocks.

And this gets at a core element of what my colleagues in the Management Forestry program are working toward: identifying areas at risk of poor outcomes, including low rates of sequestration, evaluating alternative courses of action, and deciding on a program of treatment to try to provide a better outcome. In some cases, no treatment is the best treatment; but it may not be the best course of action in all cases, especially from a carbon perspective. In this example, the outcome is carbon, but it could be habitat or one of any other ecosystem services.

Continuous Forest Inventory

- CFI helps us understand status and trends, and project future conditions and evaluate tradeoffs
- CFI help us learn about forest resiliency, forest carbon, and other ecosystem services, and can provide feedback on our management

So as I start to wrap up here, I want to reinforce first, that CFI is an important tool to help understand what is happening on the forest land the Division stewards; and learn about how and why it is changing, and plan for the future.

And the data are used to learn how to better apply management practices to our forests. These data seem to show that working, over the long term, to identify, assess, and improve metrics of resiliency at the stand and landscape scale, can provide long-term benefits as well in the form of high, stable rates of carbon sequestration and storage.

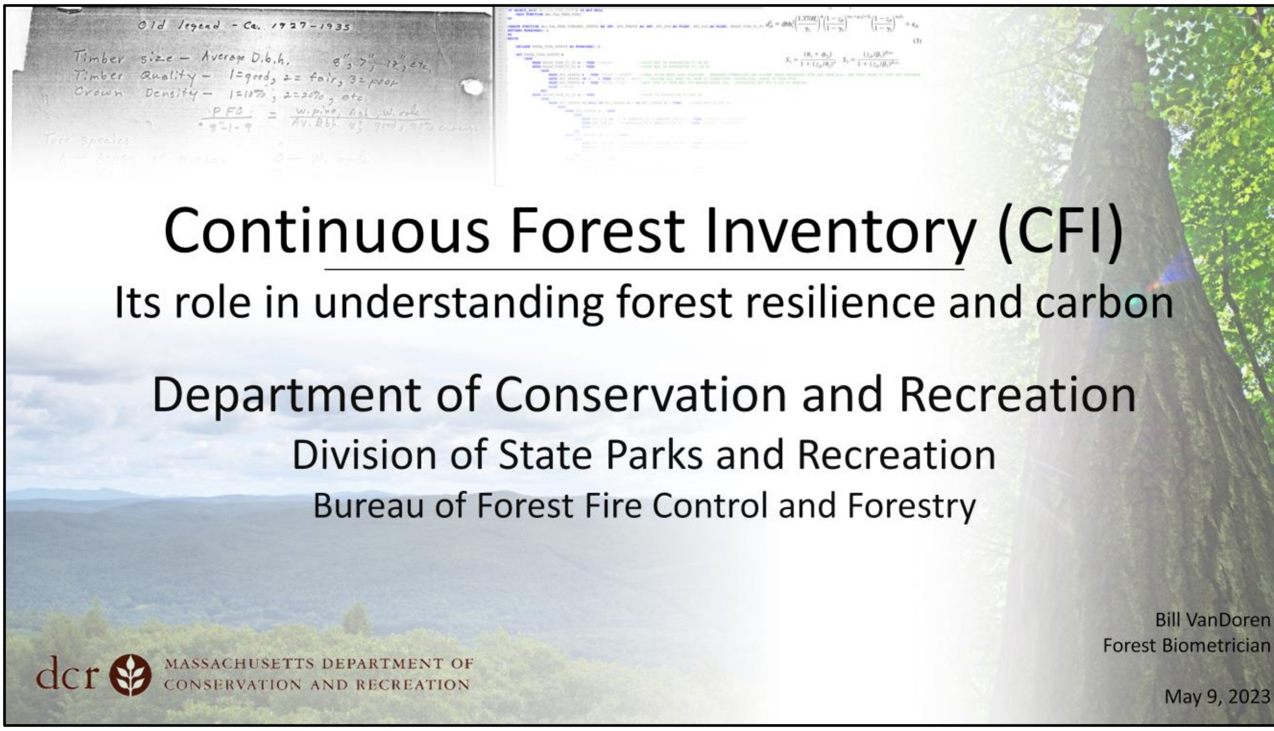
CFI – Forest Resiliency Metrics

- Presenting results by management status – not managed over the past 60 years, and managed – is a false dichotomy
  - ***Not presented like this to say management is better*** – but instead, to explore what the measurements and data tell us about long-term management conducted to high standards, and linkages to emerging science on climate change adaptation and resiliency
- Treatments and practices are integrated in to a series of actions that address the problem from multiple angles
- Always learning from these data in an adaptive management framework

Before I close, I want to point out that I mentioned earlier that I don't particularly like the strong dichotomy of the presentation of data between managed and unmanaged CFI plots, because the question of management versus no management is never that simple. Management versus no management does not equate to harvest versus do not harvest. Our foresters and program evaluate each site in the context of its own ecosystem and surrounding landscape, and carefully consider the site's adaptive capacity and vulnerabilities. In many cases, there may not be a need to apply any silvicultural tools. In other cases, invasive species control may be warranted, or other treatments on a broad spectrum of opportunity. There's also a tremendous amount of variability from site to site – the way these data are presented provide an aggregate view across all the lands stewarded by the Division; but recommendations for increasing resiliency are very site-specific. Recommendations for one site or ecosystem, like a northern hardwoods stand in the Berkshires, may not be appropriate for another, like a pitch pine-scrub oak community in the southeast.

These treatments and practices are always integrated into a series of actions that address the problem from many different angles. This nuance around each site and the Division's goals and objectives, is where compromise lies. It's not presented like this to necessarily assert that management is better in any way. We need a variety of approaches, allowing natural processes to unfold in some areas, while helping others adapt with the tools we have.

It's also done because reducing forests to a single value or attribute, like carbon, is an oversimplification. Maximizing the production of any one value or service provided by forests will almost certainly result in providing less of other services – so we try to simultaneously maximize multiple services to the extent possible by focusing on resiliency first. I've tried to mitigate that by discussing forest carbon here, in the context of what we're learning about forest resiliency and adaptive capacity. Our climate is now changing faster then our forests have ever experienced, and helping it adapt to the urgent change that's occurring, while still providing the benefits on which we rely, is a central challenge – and CFI is one of the tools we can use to learn how to strike that balance.



And with that, I'd like to thank you again for your time and I address you about this topic. Please let me know if you have any questions. I'd be happy to meet you in the field to take a closer look at specific sites; or, to continue this dialogue at any point.