

# U.S. Forest Service Tools for Forest Carbon Estimation

Coeli Hoover\*

[Go to presentation](#)

## Slide 1. US Forest Service Tools for Forest Carbon Estimation

Hi, I'm Coeli Hoover. I am a research ecologist with the U.S. Forest Service, Northern Research Station, and today I'm going to take a little bit of time to introduce you to some of the tools that we have available for forest carbon estimation.

### US Forest Service Tools for Forest Carbon Estimation

Forest And Grassland Carbon in North America: A Short Course for Land Managers

Coeli M. Hoover, Research Ecologist  
US Forest Service  
Northern Research Station  
Durham, NH

## Slide 2. Acknowledgments

I'd like to acknowledge there is a cast of thousands. These are just the folks who worked to develop the tools I'm going to discuss today.

### Acknowledgements

- Jim Smith, Linda Heath, Ken Skog, Rich Birdsey
  - GTR 343, Standard Tables
- Paul VanDeusen, NCASI, Linda Heath
  - COLE
- Jim Smith, Linda Heath, Mike Nichols
  - CCT
- Stephanie Rebin and ESSA Technologies
  - FVS Carbon Reports
- Linda Heath, Mike Nichols, Jim Smith, John Mills
  - FORCARB2

## Slide 3. Key Messages

So, a couple of the key messages is I want to talk a little bit about the foundation of our carbon tools and where they come from, and then go through just a handful of the tools and talk about sort of the benefits and the limitations for each of them. And a few little words of advice on choosing the right tool for the right job, and then finally show you where to find the tools and any other additional information.

### Key Messages

- Foundation of the carbon tools
- Introduction of selected Forest Service carbon tools
  - Summary of benefits and limitations of each tool
- Choosing the right tool for the right job
- Where to find the tools and additional information

\* This document transcribes the presentation given by Dr. Hoover. The presentation is part of General Technical Report NRS-93, "Forest and grassland carbon in North America: A short course for land managers." The full report, comprised of 15 presentations, is in DVD format and can be obtained at <http://nrs.fs.fed.us/pubs/order/40110>. The presentations and related materials can also be accessed at <http://www.fs.fed.us/ccrc/carboncourse/>

## Slide 4. Carbon Tools Background

So, background on the tools. Most of our tools are in fact based on forest inventory and data, so actual field collected data from the Forest Inventory and Analysis Program, which is also known as FIA. And I always think it's important to mention since some of you may work in systems outside the United States that all of our tools are either built on U.S. data or based on biomass and volume equations from the United States. So it's not appropriate to apply them to areas outside the U.S. However, these tools could still serve as a model to help you if you need to develop some methods for use in other countries.

### Carbon Tools Background

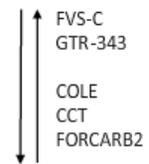
- Most tools are based on forest inventory data from the US Forest Inventory and Analysis Program (FIA)
- All of the tools are based on US data and biomass/volume equations, and so are not appropriate for use outside the US
- However, they can serve as examples for developing inventory and analysis systems for use in other nations

## Slide 5. Tools with Output at Various Scales

So, we do have tools with output in a variety of special scales, from the carbon reports in FVS<sup>1</sup> at the stand level all the way up to the national level. And scale is something I'll talk a lot about today, and in his talk Chris Woodall<sup>2</sup> mentioned that the uncertainty increases as your scale decreases, and that's a really important point I'll probably come back to a few times.

### Tools with output at various scales

- Forest Stand
- Landscape
- County
- State
- Region or ecoregion
- National

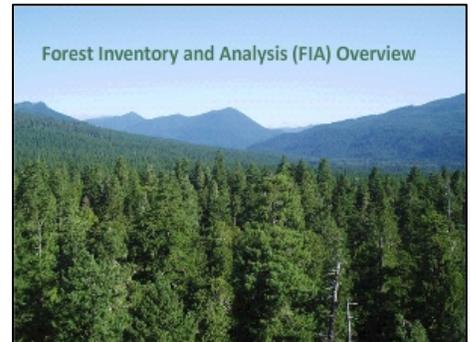


*All tools except FVS-C based on FIA data*

## Slide 6. Forest Inventory and Analysis (FIA) Overview

So just a quick overview of the FIA Program. We are very fortunate in this country to have a forest survey. A lot of nations don't have that legacy of data that's been collected through time.

### Forest Inventory and Analysis (FIA) Overview

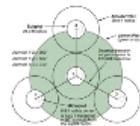


## Slide 7. FIA Sampling Design

So this is just a really quick overview. Chris showed you the grid that goes across the entire country. This picture is what one of those plot clusters looks like. That's how it's set up, a variety of measurements are taken. So our tools are built on what's called the Phase 2 data. This is just your standard forest inventory data that lots of foresters are familiar with. There's another component called Phase 3 and this is the forest health measurement system. It's a smaller subset of plots. At this point we're not using any of that information for our carbon estimates, but it is available and hopefully it will be incorporated in the future. So I just wanted you to know that it's out there and it might be of interest for you to look at.

### FIA Sampling Design

- **Phase 2 - forest mensuration**
  - 1 plot per 2,429 ha
  - visit plot every 5 years
- **Phase 3 - forest health**
  - each 16<sup>th</sup> Phase 2 plot
  - soils, forest floor, down dead wood
  - 1 plot per 38,868 ha
  - soils sampled every 2<sup>nd</sup> visit
- **Phase 1 - remote sensing**
  - reduce variance through stratification



## Slide 8. FIA Data and Tools

So the FIA Web site again, Chris did show it, but here it is if you want to take a look. There are a variety of ways that you can interact with the FIA data. And just to point out the forest health data, there's another data link on the page, and so you might not notice there's a lot of goodies there if you follow that link, including forest health data.

### FIA data and tools at <http://fia.fs.fed.us>

- **FIO** – graphical interface, the next generation web tool with maps
- **Evaluator** – produces population estimates and their *sampling errors* for user designated areas
- **Forest health data** – access from "other data" link on the "data and tools" page

## Slide 9. Carbon Tools Overview

So without further ado, let's take a walk through some of the carbon tools that we have available for you to use.

### Carbon Tools Overview



## Slide 10. Tools Caveats

A couple of caveats, not just these tools, but when you're choosing any tool or model to use in your work, there's a really famous quote, "all models are wrong, but some are useful". It's really important to keep that in mind. There's no Swiss Army knife in the modeling world. No one all purpose tool or model that works every place in the country, every forest type, and it gives you great results every time. I wish it were true, but it's not. There's always tradeoffs, so a lot of our models are based on data, they're empirical models. There are also process models that are driven by ecological processes, but there's always tradeoffs, and the big one is between generality and accuracy. So you can have a model that gives really accurate predictions for the area where it was built, but if you move to another forest type it might not perform as well. You also have models that can be used over a wide area or a wide variety of circumstances, but the predictions are not quite as accurate. So it's always important to get a handle on that, and when you're evaluating any tool you need to consider again the spatial scale, the underlying data on which the model was built. You might not want to use the southern pine model for lodge pole pine. Probably not going to work all that well. And then whatever is the underlying data, underneath the key assumptions and mechanisms that drive that model. You always kind of want to make sure you have a handle on that to be sure you're using the right tool for the right job.

### Tools Caveats

- "All models are wrong, but some are useful."  
-George Box, 1979
- There is no one all purpose tool or model
- Whether a model is empirical or process based, there are tradeoffs
  - **Generality vs Accuracy (and don't forget \$)**
  - **No free lunches!** (i.e. remotely sensed data still need field data for equation development/validation)
- Consider spatial scale, underlying data, key assumptions/mechanisms

## Slide 11. Standard Tables (GTR 343)

So, moving on to the standard tables called GTR 343<sup>3</sup>, and for obvious reasons, that's a picture of the cover, I call it the Green Book<sup>4</sup>. The Green Book is a really nice thing to have. It's based on FIA data, the regional averages. So by forest type group and region of the country you can look in this book in a table and, for example, get an estimate of how much carbon there might be in any one of several different carbon pools for beech, birch, maple that's 50 years old in the Northeast.

There's also a set of tables that could be used in afforestation scenario. So, it's very handy to have, there's some very clear descriptions of the methods in the carbon pools in the beginning, and then also what's nice about the Green Book is it contains a description of the methods that we used to estimate carbon in harvested wood products along with all the tables that you need to do those calculations.

### Standard Tables (GTR 343)

- Forest carbon and carbon in harvested wood from tabular summaries or simple default calculations
- Intended for low cost or limited information applications
- Represent regional averages for common forest types
- Simple and transparent
- Consistent with international methods and Good Practice Guidance



## Slide 12. GTR 343 – Standard Tables CAN

So what can the Green Book do for you? Quick estimate based on regional data. It's a really handy thing to pull off the shelf and kind of give you a reality check. Maybe you have some data, you want to know if you're in the right ballpark, and so you can take a look and compare. And again, it's a general estimate since it has by age class of what you might expect to see over time.

### GTR 343 – Standard Tables

**CAN**

- Provide a quick estimate, based on regional data
- Serve as a "reality check" against which to compare your estimates
- Give a general estimate of what kind of carbon increases might occur over time

## Slide 13. GTR 343 – Standard Tables CAN'T

Does not substitute for detailed inventory data for your project area. Also not a detailed definitive projection of what you might have in the future. These are general averages and there's no way to look at management implications.

### GTR 343 – Standard Tables

<p><b>CAN</b></p> <ul style="list-style-type: none"><li>• Provide a quick estimate, based on regional data</li><li>• Serve as a "reality check" against which to compare your estimates</li><li>• Give a general estimate of what kind of carbon increases <u>might</u> occur over time</li></ul>	<p><b>CAN'T</b></p> <ul style="list-style-type: none"><li>• Substitute for field inventory data for a specific project area</li><li>• Serve as a definitive projection of future conditions for a project area</li><li>• Reflect possible outcomes of management actions</li></ul>
---	--

## Slide 14. COLE: Carbon OnLine Estimator

Another really popular tool is called COLE, Carbon Online Estimator, and there's also a version called G-COLE the next generation, which works with Google Maps and has some other graphic options. This works directly with the FIA database. Carbon is now a variable in the FIA database,

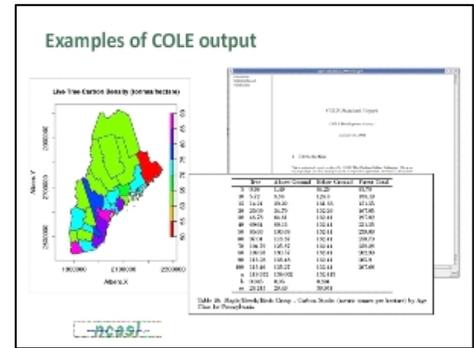
### COLE: Carbon OnLine Estimator



- Works with the FIA database
- Produce a variety of maps and tables
- Reports many C pools
- County, state, and multi-state areas
- Can choose reports

## Slide 15. Examples of COLE Output

... and the nice thing about COLE is you can generate a lot of different outputs, and these are just some of the examples of what you can generate. There's a standard report mode and an advanced user mode which is still very easy to use, and that allows you a lot of flexibility. It's what I would recommend that you use. You can choose a lot of filters and report options.



## Slide 16. COLE and gCOLE CAN

What COLE can do for you, again a quick estimate you can select particular counties in advanced user mode, if you like you can select the entire state. The nice thing is you get estimates of standard error for your selected variables as well as the number of plots your estimate was based on. So this will let you know if you're getting down to too small of a spatial scale and your estimate is based on too few plots, because your error might be so large that you're getting a number now that isn't really useful. And again there are filters. So if I just want to look at spruce-fir in New Hampshire I can apply that filter and just get a report for spruce-fir type.

### COLE and gCOLE

**CAN**

- Provide a quick estimate, based on county/state level data
- Produce estimates of standard errors for selected variables
- Show differences between forest types, age classes, etc. (but watch # of plots!)

## Slide 17. COLE and gCOLE CAN'T

But again, smaller spatial scales at the stand level. This is not an appropriate tool, not a substitute for detailed inventory data for a project area. This gives you stocks, not fluxes and again, as with the green book, there's really no way to look at changes in management.

### COLE and gCOLE

**CAN**

- Provide a quick estimate, based on county/state level data
- Produce estimates of standard errors for selected variables
- Show differences between forest types, age classes, etc. (but watch # of plots)

**CANT**

- Be used for smaller spatial scales (stands)
- Substitute for detailed forest inventory data for a project area
- Estimate fluxes
- Project outcomes from changes in management

## Slide 18. Carbon Calculation Tool (CCT)

One of our newer tools is a Carbon Calculation Tool and this is slightly different. It might be more appropriate if you want to look at your entire state or maybe you work in a multistate area and you want to get a handle on what's happening in your area. It does come with FIA data and you can update to use the most recent data. And again this is state level output.

### Carbon Calculation Tool (CCT)

- Annual carbon pools and change from 1990 to present
- Comes with FIA data for mainland US
- Can download and use new data
- Produces annualized estimates
- State-level output

## Slide 19. CCT CAN

So what CCT<sup>5</sup> can do for you that the other tools I've mentioned haven't is it gives you stock estimates and flux estimates as well. And it gives you annualized estimates. You don't have to do multiple checks and then calculate change. You can update it to use the most recent FIA data. And this will give you the results for every state in the country when you do one run. You can choose particular carbon pools, but you will get every state.

**CCT**

**CAN**

- Produce stock and flux estimates
- Produce annualized estimates
- Be updated with current FIA data by user
- Produce nationwide estimates

## Slide 20. CCT CAN'T

You can't unfortunately at this point, work at a level smaller than the state level, it only goes to 1990, and there's no way to use your individual site data or look at scenarios.

**CCT**

**CAN**

- Produce stock and flux estimates
- Produce annualized estimates
- Be updated with current FIA data by user
- Produce nationwide estimates

**CANT**

- Generate estimates at levels smaller than state
- Provide estimates prior to 1990
- Be initialized with site specific data by user
- Project scenarios

## Slide 21. Forest Vegetation Simulator

The Forest Vegetation Simulator, some of you may be familiar with the tool itself. This is used extensively by national forests in the forest planning process. So it's a collection of stand-level growth and yield models, there's a lot of geographic variance, can be used for all forest types all over the country. And you have the ability with this tool to simulate nearly any kind of management. So we added the capability to do carbon reporting with this tool, and it does include the option if you simulate harvest to look at the carbon in the wood products.

**Forest Vegetation Simulator (FVS)**



Stand-level growth and yield model  
Uses field inventory data  
Simulates nearly any type of management  
Many geographic variants  
Can generate reports on forest carbon stocks

- includes harvested wood products

## Slide 22. FVS Carbon Reports CAN

So what can the carbon reports and FVS do for you? Well this is a tool where you can look at management actions, the carbon consequences and management actions, and because there's a growth and yield model underlying everything, you can project changes through time and look at how that affects your carbon stocks. And this is a tool you can use at the stand and landscape scale, unlike say COLE or CCT.

**FVS Carbon Reports**

**CAN**

- Assess carbon impacts of many management actions, including prescribed fire
- Estimate increases in carbon stocks over time
- Be used at the stand and landscape scales

### Slide 23. FVS Carbon Reports CAN'T

You can't use FVS without detailed inventory data from your project site. The model had some very strict data requirements, and if you know how to use FVS already, generating the carbon reports is very simple. If you're not familiar with FVS, this is not a plug and play tool. The FVS team runs training sessions throughout the year all across the country, and I would highly recommend investing that time in training. And FVS, while it does include the ability to look at harvested wood products, does not include soil carbon estimates unlike our other tools.

**FVS Carbon Reports**

<b>CAN</b>	<b>CAN'T</b>
<ul style="list-style-type: none"><li>Assess carbon impacts of many management actions, including prescribed fire</li><li>Estimate increases in carbon stocks over time</li><li>Be used at the stand and landscape scales</li></ul>	<ul style="list-style-type: none"><li>Be used without detailed inventory data from the site</li><li>Be used in "plug and play" mode – training is required</li><li>Provide soil C estimates</li></ul>

### Slide 24. FORCARB2

FORCARB2 is a really different tool. This was developed for policy support to provide the national estimates that are handed over to the EPA<sup>6</sup> for international reporting. So this gives you stocks and stock changes at 5-year intervals. There's an example there of the kind of output you can generate when you use FORCARB. It does include forest products and these are regional estimates. And the code is available on CD, so if you have a lot of computer skills then this is the tool you might want to use and modify to meet your needs, you do have the ability to do that.

**FORCARB2**

- Produces estimates of C stocks and stock changes at 5 year intervals
- Includes forest products
- Estimates are at the regional level
- Code freely available on CD

**FORCARB2: An Ecosystem Model of the U.S. Forest Carbon Budget Project**

### Slide 25. FORCARB2 CAN

So these are regional projections of stock and stock changes and you can get some broad breakouts there, harvested wood products. And you can look at scenarios. There are some general scenarios that are available and you can look at the impacts. That other figure looked at tree planting programs and what affect that might have.

**FORCARB2**

**CAN**

- Provide regional projections of carbon stock and change
- Allocate estimates by broad classes – region, ownership, forest type
- Include effects of harvested wood
- Be used to explore effects of harvest and land use scenarios

### Slide 26. FORCARB2 CAN'T

What you can't do with FORCARB2 is get any smaller than that regional scale, and it is difficult to modify the scenarios. This is perhaps more of an expert user tool. It was again developed more for policy support than sort of a day-to-day use.

**FORCARB2**

<b>CAN</b>	<b>CAN'T</b>
<ul style="list-style-type: none"><li>Provide regional projections of carbon stock and change</li><li>Allocate estimates by broad classes – region, ownership, forest type</li><li>Include effects of harvested wood</li><li>Be used to explore effects of harvest and land use scenarios</li></ul>	<ul style="list-style-type: none"><li>Provide specifics related to (sub-region) location or ownership</li><li>Be easily modified – developing and specifying scenarios requires expertise beyond simple application of default settings</li></ul>

## Slide 27. Right Tool for the Right Job

So how do you pick the right tool for the right job? Well it depends on what your job is. Are you looking at multistates? Are you trying to just get a context for what's happening in the area or are you trying to assess the feasibility for a particular project? What's the relevant spatial scale which ties back to what you're trying to do? Do you need stock estimates or do you need stocks and fluxes? Do you need to be able to use your own data or do you want to use FIA data? Do you need the capacity to investigate management scenarios, management practices? Finally, what carbon pools are of interest? Most of these tools have all the same pools, but there are a few differences between soils and harvested wood products. And then how important is ease of use to you? So those are all things to think about when you're choosing a tool.

### Right tool for the right job...

- What is the relevant spatial scale?
- Do you need estimates of stocks, or stocks and fluxes?
- Do you need to use your own data?
- Do you want to investigate management scenarios?
- What carbon pools are of interest?
- How important is ease of use?

## Slide 28. Where Do I Find the Carbon Tools?

Where do you find the carbon tools? This is our Northern Station Carbon Tools Web site. It's a quick gateway on the Web. Also the tools can all be accessed through the Climate Change Resource Center.

### Where do I find the carbon tools?

<http://nrs.fs.fed.us/carbon/tools>

Your gateway on the web for forest carbon inventory tools and information

Tools can also be accessed at: [www.fs.fed.us/ccrc](http://www.fs.fed.us/ccrc)

## Slide 29. Carbon Tools Page

This is what the front part of the “Carbon Tools” page looks like, and every tool, I've given you a little bit of information, every tool has a one page handout that you can download that gives you more information about the tool to help you know if it's the right one for you. Everything on the page is freely available for download, and that little red box is a very exciting title, “Literature Resources for Carbon Inventories”. We should figure out a way to make that more exciting because actually if you're new to carbon inventory, there's a lot of good basic background information that you can find if you follow that link. And there are more tools on this page than what I've discussed. Dave mentioned the i-Tree model that's also available through this gateway.



## Slide 30. Take Home Messages

So finally the take home messages that I have for you today. All tools have strengths and limitations. It's really important to take the time to look at the background information on the tool and to know those design specs because the errors increase the further you move away from what the tool was designed to use or where it was designed to be used, the more you increase your errors. And in some cases you may be

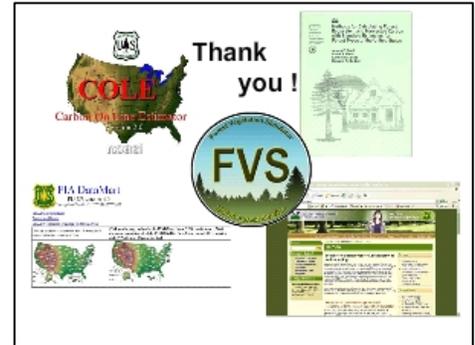
### Take home messages

- All tools have strengths and limitations
  - Know the “design specs”...errors increase when a tool is used outside its intended limits. Modifications may be needed.
- Spatial scale is very important when choosing the right tool for the job
- There are more tools available from the site than those listed here: iTree, cval, and more

able to modify a tool to meet your needs, but in other cases you may simply need to choose a different tool. The spatial scale, once again, the spatial scale is just really important when you're choosing the right tool for the right job. If you're looking at something that's stand level, you don't want to use a tool that was designed to be used at a national level. The errors are just going to be very large. And, as I said before, there are a lot more tools available than what I have mentioned today, i-Tree, CVal, which is an economics tool. There are also other ones and we hope to continue to add to the page.

### Slide 31. Thank You

So with that, I would like to thank you for spending some time with me today, and I hope that you find our tools useful.



### Footnotes

<sup>1</sup>FVS=Forest Vegetation Simulator

<sup>2</sup>See Forests: Trends and Data for the U.S. by Chris Woodall, this report.

<sup>3</sup>Gen. Tech. Rep. NE-343; See Smith et al. 2006 in references.

<sup>4</sup>Gen. Tech. Rep. NE-343; See Smith et al. 2006 in references.

<sup>5</sup>CCT=Carbon Calculation Tool

<sup>6</sup>EPA=Environmental Protection Agency