Visualizing Forest & Forest Carbon Data
Data Analysis Methodology Explainer

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Why do we need to make calculations in the first place?

The U.S. Forest Service publishes forest carbon stock data and performs all the analysis of forest carbon stocks for the EPA Greenhouse Gas Inventory (EPA GHG Inventory) using Forest Inventory and Analysis (FIA) data. However, they rarely break out carbon stocks or sequestration rates by land ownership category. They are usually focused on national or regional summaries rather than ownership and classification breakdowns. To visualize the crucial contributions of different forest types, we used the Forest Service FIA data and 2020 Resources Planning Act Assessment (RPA Assessment) technical support documents in our own analyses.

How do we use FIA/RPA data to come up with our four forest category acreage totals?

The FIA program and the RPA assessment both use a distinction between forestland and what they call "timberland" (what we call "working forests"). Timberland is a subset of forestland, consisting of forests that (1) are not "reserved" from harvest (by legal means), and (2) meet a minimum threshold for productivity (they can produce at least 20 cubic feet of wood per acre per year). For us to do this analysis, we simply need to use not-so-secret codes in the FIA database that tell us what ownership category owns the land for each FIA plot (such as federal, state, or local government agency, or an unidentified private owner), whether the land is reserved from harvest, and what the productivity class of the forest is. Using those codes, we can get summaries for the private working forests (and the other categories):

Who owns the land?	Does FIA consider the location to be timberland?	
	Yes	No
Privately owned	It's a private working forest.	It's a private non-working forest.
Publicly owned	It's a public working forest.	It's a public non-working forest.

Public and privately owned forests can be split into three classes based on whether or not the forest has contributed, or might contribute, to supplying wood or fiber for products:

1. Forests that have been, or are very likely to be, harvested for wood products.

2. Forests that could be harvested for wood products, but we have no idea whether or not they ever will be.
3. Forests that are unlikely ever to be harvested for wood products.

The first class consists of areas where harvests have been recorded, or areas owned by organizations that have a history of harvesting forest products (land owned by institutional forest managers, county and state forests that have long provided wood to markets, and other such owners).

The second class includes areas of forest owned by private (usually smaller) landowners who (typically) have the right to do what they want with their land. So, there's no way of knowing whether they or their heirs might decide to harvest timber. It also includes large areas of publicly owned land that are available for timber harvest, but where timber harvest only occurs following careful planning, stakeholder input, political influence, lawsuits, and other unpredictable factors.

The third class consists of areas where timber harvest is restricted by law (National Parks and Wilderness Areas, for example) and areas where the growth rate is so slow that the forest cannot support regular harvests (very dry or high-elevation forests, for example).

The bottom line: The FIA program categorizes classes 1 and 2 as "Timberland" (productive forest not restricted from timber harvest) and we use that designation as "working forest" even though we can't predict when or whether harvest will occur on the class two timberland.

How do we compute gross sequestration?

The short explanation is that annual sequestration is estimated by measuring change over time. When a forest plot is measured at two points in time, growth can be calculated by the amount the trees grew between measurements. It is expressed on an annual basis by dividing by the number of years between measurements. We calculated sequestration using data from the U.S. Forest Service Forest Inventory and Analysis (FIA) program. FIA data contain a wealth of information about details such as forest ownership, locations, forest age and type – details that are not included in the summary data provided in the EPA GHG inventory.

For example, consider a plot measured by FIA in 2010, in which there was 100 tons of carbon per acre in living trees. Six years later, that plot was measured again, and the larger trees contained 112 tons of carbon per acre. Dividing the 12 tons of newly sequestered carbon by the 6 years between measurements, we get a carbon sequestration rate for that plot of 2 tons per acre per year.

Here's the simple, yet not-so-simple equation:

$$\text{Gross Sequestration} = \frac{(\text{FIA Measurement of Stocks in 2nd visit} - \text{FIA measurement of Stocks in 1st visit})}{(\text{Year of 2nd visit} - \text{Year of 1st visit})}$$

The longer explanation is that we used forest inventory data from the U.S. Forest Service Forest Inventory and Analysis (FIA) program to compute gross sequestration for U.S. forests. Data were downloaded from the FIA "DataMart" web site by state. Using this data, we computed "gross growth", "mortality", and "removals", following the procedures outlined in the FIA Database User's Guide (Burrill, et al. 2018) and the FIA Population Estimation User Guide (Pugh, et al. 2018). Estimating growth, mortality, and removals requires two plot measurements (two points in time) so that changes from one time to the next can be calculated. Gross growth is the total amount that trees grew from one plot visit to the next. It can be expressed in wood volume (cubic feet) or weight (tons). Wood is 50% carbon (by dry weight), so 1 dry ton of wood has 1,000 pounds of carbon. Therefore, gross sequestration is measured by gross growth, and is the weight of carbon (or CO_2) removed from the atmosphere by growing trees. Annual gross sequestration is computed by dividing by the number of years between measurements. We also compute tree mortality, which is the amount of wood in trees that die between inventories, which equates to a transfer of carbon from living trees to dead trees (a different carbon pool). Finally, "removals" due to harvests represent the amount of wood removed from the forest, most of which is transferred into harvested wood products. Because carbon in the dead tree pool is still part of the forest carbon stock, we included it in the forest carbon stock numbers.

Because every FIA plot has an ownership class identifier, and every FIA plot has a number of acres that it "represents" based on the sampling design, we can summarize all of the growth, removals, and mortality, as well as forest carbon stocks into ownership classes and geographic regions.

The place where this process gets tricky is in the U.S. Rocky Mountain region. States in this region (Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming) got a late start on inventory under the new system design implemented by FIA around 2000. Under this new system, eastern states (from the Great Plains to the eastern seaboard) are remeasured every 5-7 years, while most western states are remeasured every 10 years. Consequently, while most of the eastern states, plus California, Oregon, and Washington, have had two or three measurements since 2000, many of the plots in the Rocky Mountain Region (and in Alaska and Hawaii) have not had a second measurement and there is no way to estimate changes due to growth, removals, or mortality on these plots.

For these states, we went to the most recent RPA assessment (Oswalt, et al. 2019), where growth, removals, and mortality have been reported based on information that is not available outside of the USFS (see Tables 33, 34, 35, and 36). To explain this, we have to explain a little FIA and RPA terminology. FIA calls the total amount that live trees have grown between measurements "gross growth", and this equates to gross sequestration. But then, they deduct from gross growth any volume (or carbon) in trees that have died between plot measurements. They call this number "net growth", so net growth equals gross growth minus mortality. It may have made sense to focus on net growth when the main interest was in wood available for harvest. But when our interest is in carbon, the "loss" to mortality isn't really a loss- that carbon is still there. But the RPA doesn't report gross growth! They *do* report net growth volume and mortality volume, so we add the mortality to the net growth to get gross growth volume. Finally, we have to convert tree volume (in cubic feet of wood) to tree carbon (in tons of carbon or metric tons of CO_2 or whatever). In equation form, it looks like this:

Gross Carbon Sequestration = (Net Growth Volume + Mortality Volume) x Volume to Tons of Carbon Conversion Factors

It's not pretty, but those are the limitations of relying on reports that have kept the same format for decades. Also, to use the RPA estimates, we depend on the assumption that the data published in 2019 still applies to current forest ownership and growth patterns.

Sources:

Burrill, Elizabeth A.; Wilson, Andrea M.; Turner, Jeffery A.; Pugh, Scott A.; Menlove, James; Christiansen, Glenn; Conkling, Barbara L.; David, Winnie. 2018. The Forest Inventory and Analysis Database: database description and user guide version 8.0 for Phase 2. U.S. Department of Agriculture, Forest Service. 946 p. [Online]. Available at web address: http://www.fia.fs.fed.us/library/database-documentation/.

Oswalt, Sonja N.; Smith, W. Brad; Miles, Patrick D.; Pugh, Scott A., coords. 2019. Forest Resources of the United States, 2017: a technical document supporting the Forest Service 2020 RPA Assessment. Gen. Tech. Rep. WO-97. Washington, DC: U.S. Department of Agriculture, Forest Service, Washington Office. 223 p. https://doi.org/10.2737/WO-GTR-97.

Pugh, Scott A.; Turner, Jeffery A.; Burrill, Elizabeth A.; David, Winnie. 2018. The Forest Inventory and Analysis Database: population estimation user guide (Edition: November, 2018). U.S. Department of Agriculture, Forest Service. 166 p. [Online]. Available at web address: http://www.fia.fs.fed.us/library/database-documentation/.

How do we calculate total annual harvest area?

To represent the area harvested annually in the U.S., we calculated an "effective harvest area" based on the amount of timber removed. To the average person, when they hear "harvest" they assume that refers to a clearcut, which is a final harvest where a stand is completely harvested before the area is replanted or regenerated. However, this datapoint includes more than just clearcuts -- it includes any acre of land that had trees cut on it. Some harvests only remove a few trees out of hundreds of trees on an acre of land, some harvest remove a larger percentage of trees to "thin" the forest to give remaining trees more room and resources to grow, and other harvests remove all the trees. We decided to make the harvest number more accurate and not inflate the area where harvests occur in the minds of non-forestry-professional users of this data visualization. To do that we depicted "how many acres would have to have been cleared of trees to provide as much wood as was harvested".

We started with working forest area from the 2018 RPA Assessment, Table 11, by region and ownership class (public/private). Next, we pulled the "growing stock volume" (cubic feet of wood) for those same regions and ownership classes from RPA Table 20. Dividing the second by the first told us how much wood (growing stock volume) was on an "average acre" in each region. Then, we determined how much wood was harvested in a year for those same regions and ownership classes. This came from RPA Table 35, which shows the annual "removals" (harvest) of growing stock from working forests. Dividing this total harvest quantity by the average wood volume per acre gave us how many "average acres" would have been cleared to provide the total quantity of wood harvested. Summing these up totaled 7.878 million acres.

So, in simple, yet not-so-simple equation form, this is:

$$\text{Average volume per acre for region and ownership} = \frac{\text{Total volume for region and ownership}}{\text{Total acres for region and ownership}}$$

Then…

$$\text{"Effective harvest area"} = \frac{\text{Total volume for region and ownership (Table 35)}}{\text{Average volume per acre for region and ownership (from above)}}$$

How do we calculate total area regrown?

We have to back into this calculation. Recall that our estimate of harvest area is really "effective harvest area", which is the acres of "average forest" that would have to be cleared to produce the total volume that was harvested. That doesn't mean that all of those acres were cleared- much of that wood comes from thinning or other partial harvests, and the "regrowing" of the forest in those cases is very subtlethe forest continues to drop acorns and seeds and regenerate itself. So, the actual area that was cleared of trees is smaller.

Where land has been cleared of trees, it's very visible. When a stand of trees in a forest is cleared, one of two things can happen. It can (1) return to forest, either by natural regeneration or by active planting, or (2) it can turn into something else, like a parking lot, an apartment complex, a golf course, a soybean field, or a pasture. We call the latter condition "land use change". It is no longer forest, it has become something else.

RPA data tell us (in table 3) that we have essentially the same amount of forest that we did in 2012, and more than we did in 2007 and more than 1997 and 1987. So if forest area hasn't changed, and we know we have cleared some areas of forest, what does that tell us about how much is regrown? It's simple… all of it has regrown. In reality, we have lost some areas of forest to those other land uses, but then we've also gained forest area where abandoned pasture has given way to trees, or idle farmland has been planted with trees. The net effect is the same: all of the land harvested has regrown, or new forests have been established somewhere else to replace what was removed. That's the only way we can have as much or more forest now than we have had for decades.

So, the bottom line is we use the same number for "regrown" as we do for "effective harvest area" to convey the very real fact that we are not losing forests in this country.

Questions? Contact info@ForestCarbonData.org