A FAQ Guide to Different Forest Carbon Inventory Approaches

This document provides answers to frequently asked questions (FAQ) related to two inventories that quantify forest carbon in California:

- the California Air Resources Board's (CARB) Natural & Working Lands (NWL) Ecosystem Carbon Inventory ("the CARB Inventory"), and
- the California Board of Forestry and Fire Prevention's (BOF) Assembly Bill 1504 Forest Ecosystem and Harvested Wood Product Carbon Inventory ("the BOF Inventory"), which was developed in collaboration with CAL FIRE staff and U.S. Forest Service's Forest Inventory and Analysis (FIA) Program.

1. Why do CARB and BOF separately develop their own forest carbon inventories?

CARB and the BOF launched their respective forest carbon inventory efforts in different years in response to different legislative mandates. Both inventory efforts have been shaped by mandates and by interagency consultation.

In **2006, with the passage of Assembly Bill (AB) 1803**, the California Legislature directed CARB to maintain a statewide inventory of greenhouse gas emissions and sinks for all sectors of California. Pursuant to **Senate Bill (SB) 859 (2016)**, which required CARB to develop a natural and working lands (NWL) inventory, CARB began publishing an inventory of ecosystem carbon in all land types across the entire state. The CARB NWL Inventory combines field measurements with satellite data and is geospatially explicit – carbon stocks are estimated for every 900 m^2 pixel of the state, which is about the size of a baseball diamond. The inventory methodology assesses fires and other natural disturbances, human activities, and environmental change. The inventory is used to indicate how California's land base contributes to the State's climate goals.

The annual BOF Inventory began after **AB 1504 (2010)** affirmed that the BOF is responsible for ensuring that the California Forest Practice Rules are sufficient for forests to sequester 5 million metric tons of CO_2-equivalent per year. The BOF Inventory uses U.S. Forest Service (USFS) Forest Inventory and Analysis (FIA) field data and reports carbon stocks in forested lands statewide and at the regional level, rather than at a geospatially explicit pixel level. Information is also provided by carbon pool, landowner, ecoregion, and forest type to better inform forest policy decisions. The BOF Inventory also estimates the carbon stocks in wood products derived from California-harvested wood. It mirrors the methods and data sources of the forest sector in the U.S. National Greenhouse Gas Inventory.

2. How are the scopes of the two inventories different?

The two inventories represent different land types, different time periods, and different stages of the harvested wood product life cycle.

The CARB Inventory estimates carbon stocks in all Natural and Working Lands. This inventory is broken down into categories, one of which is forests. The forest category includes any land ≥ 0.22 acres that is dominated by at least 10% canopy cover of trees or shrubs in the inventory year. This means that, unlike the BOF Inventory, the CARB forest inventory **includes shrub-dominated lands** such as chaparral.

Since the CARB Inventory uses data from satellites that is refreshed annually or biannually, its carbon stock estimates represent a **snapshot** in time.

The CARB Inventory considers harvested wood products only for the purpose of estimating the net transfer of carbon to the atmosphere associated with the oxidation of residues at harvest sites and mills and the decay of discards during the analysis period, without attributing that carbon loss to greenhouse gas type. It does not track the carbon in harvested wood products in the long term. Going forward, for the HWP category the CARB Inventory will instead rely on data generated by the BOF Inventory.

The BOF Inventory focuses on tree-dominated lands using field measurements from the FIA Program. Forest land is defined as any land ≥ 1 acre and 120' wide that has or once had >10% tree canopy cover in the past 30 years, or will be artificially or naturally regenerated, regardless of what is growing there now. **Shrub-dominated lands like chaparral are excluded**.

The BOF Inventory is designed to capture large-scale, long-term trends. Carbon stocks are provided as a **rolling average** over the most recent 10-years of FIA measurements. Carbon stock-changes by pool are provided as an annual average of change on plots measured 10-years apart. This means that changes in carbon stocks are not intended to be attributed to specific years or events, such as a specific wildfire. The measurement cycle is currently transitioning from a 10-year remeasurement cycle to a 5-year remeasurement cycle in California to facilitate more timely detection of changes in forest conditions.

The BOF Inventory includes detailed tracking of the carbon in harvested wood products derived from California **harvests beginning in 1952**. Carbon storage and loss is estimated for each life cycle stage all the way through discard and decay.

3. How is forest carbon estimated in the CARB Inventory and the BOF Inventory, and how confident are we in the two estimates, given what we know about how the estimates are made?

Because it is not feasible to continuously monitor and measure every tree, shrub, and acre of soil in the state, any inventory is fundamentally an estimate of an unknown quantity of carbon. Developing estimates of forest carbon stocks is technically challenging and is an area of active scientific research. Both CARB and the BOF use contemporary scientific methods with high-quality data sources, but even the best available data sources contain partial or limited information. Furthermore, quantification approaches are continually evolving, and different methods have their own strengths and limitations that depend on the use case. As a result, different

carbon estimates for the same area of interest are common. Given the uncertainty inherent to any carbon inventory effort, it is useful to have multiple inventory estimates to compare to each other. This helps us understand how close we may be to the true value of the total amount of carbon stored in California's forests. Different approaches also complement each other and help identify ways to further refine future estimation. Verification is an important component of the Intergovernmental Panel on Climate Change's guidance on carbon estimation, and these two efforts serve as two points of reference for understanding the estimates. For both inventories, uncertainty is lower for carbon estimates spanning larger land areas than for small ones.

The CARB Inventory uses a combination of **satellite-based data and ground measurement data** to estimate carbon in forests and other land types. This results in a **map-based estimate of all vegetation types** for a given time period and at a specific spatial scale. Because not all the necessary details can be recorded from the distance of a satellite's orbit, a combination of other ground-measurement data and remotely sensed data is used to inform various assumptions that help fill in the details needed for estimating carbon stored in all lands. The main source of field data that CARB uses is FIA data produced by the USFS. This is the same data source that the BOF Inventory uses, but because CARB combines it with satellite data, uses a different methodology, and has used older vintages of FIA data than the BOF Inventory, the results of the two inventories are not identical.

The BOF Inventory uses FIA data to estimate carbon stored in forest vegetation and timber product output data to estimate carbon stored in harvested wood products. The FIA program uses **a statistics-based sample design** to estimate the characteristics of the entire population of forests. One **permanent field plot** every 6,000 acres is measured every 10 years, with 10% of the entire sample measured each year. Using well-established statistical methods, the FIA program can produce an **estimate of forest conditions for all forests** in California based on measuring a relatively small proportion of the forest with randomly selected plots. As the sample size increases and more plots are measured over time, statistical confidence increases, reducing uncertainty. This approach has been used extensively by the USFS as its scientific and peer-reviewed basis for regional and national reporting on forest conditions since the 1930's.

4. What are the key findings and results of CARB's NWL Inventory and the BOF AB 1504 Inventory?

The CARB Inventory and BOF Inventory report similar amounts of statewide carbon in the form of above-ground live tree biomass. Although it is impossible to compare the two inventories' results apples-to-apples because of their different time scales, the BOF Inventory reports 1,064 MMT C in aboveground live trees for the 2017 reporting period, which includes data from 2008-2017, and the CARB Inventory reports 883 MMT C in the 2012-2014 reporting period for the same pool, after adjusting to the carbon fraction used by BOF (CARB uses a carbon fraction of 0.47; BOF uses 0.5). In general, the BOF Inventory reports slightly higher carbon stocks in live tree and standing dead tree pools than the CARB Inventory and lower carbon stocks in down dead tree and forest floor pools. Other pools are difficult to compare between the inventories because of their different scopes – for example, the CARB Inventory includes shrubs while the BOF Inventory does not.

The BOF Inventory indicates that overall California's forests are a net carbon sink. However, at smaller scales throughout the state, some specific ownerships or forest land bases are experiencing net carbon losses (e.g.,

areas with frequent, recent disturbances). Overall, carbon sequestration is declining as live tree growth rates have decreased and mortality has increased.

The CARB Inventory shows that forest carbon stock (including both tree- and shrub-dominated lands) decreased between 2001 and 2012 due to large wildfires and then increased slightly between 2012 and 2014. The CARB stock-change estimates are sensitive to abrupt changes in vegetation brought about by disturbances such as fires or harvest activities. Additionally, because the CARB Inventory includes shrub-dominated lands in the definition of forests, it captures stock changes associated with fires in chaparral and other shrub-dominated lands.

5. How should these two inventories be used?

The choice of inventory to use depends on one's goals.

Because the CARB Inventory is **spatial**, it can be used to identify where changes in carbon stocks are concentrated throughout the state. It can also be used to **show where lands are transitioning** from one vegetation type to another, such as from forests to shrubs, even if it is only a temporary transition while the forest recovers after a disturbance. More permanent transitions will be apparent as more years of data are collected. The CARB Inventory can detect **abrupt changes** in forest cover from disturbances very well and can show what individual **disturbance types and events** led to changes in carbon stocks. The only limitation in timely detection of disturbance events is due to lag-times in availability of satellite data, which are expected to decrease substantially in the future.

Since the satellite data used in CARB inventory is available at biannual time stamps, it is well-suited for detection of changes in carbon stocks and for understanding how forest carbon **changes over time on shorter time scales**. Because the inventory is sensitive to disturbances and year-to-year variation, it may show inconsistent results between years.

The BOF Inventory estimates carbon stored in forest vegetation statewide and across large regional areas and ownerships. Though it is not spatial, the BOF Inventory detects **widespread forest changes such as growth, mortality, and removals, with particular success in detecting low-magnitude changes such as** "light" disturbances like partial harvests or less pronounced bark beetle outbreaks. These changes are more difficult for the satellites used in the CARB Inventory to detect. The BOF Inventory can **evaluate long-term trends** in forest condition and **drivers of change** and has a longer lag-time for **complete estimates** of large-scale, severe disturbances. For example, the effects of the record-breaking 2020 wildfire season will take several years to be reflected fully in the BOF Inventory. As the state moves to 5-year remeasurement cycle, detection of trends will become more timely.

The BOF Inventory also provides detailed information on forest attributes (ownership, forest type, timberland, etc.). Because the BOF Inventory is rooted in USFS sources and methods, it lends itself to **comparisons with USFS inventories** in other states and at the national scale.

6. Is California's land base a carbon source or a carbon sink?

To answer the question of whether our vegetated land base is a net carbon source or net carbon sink, we must define what time period and type of land we are evaluating. For example, many forests are a "source" in the winter – when plant growth is dormant and decay continues – only to become a sink in the spring when growth resumes. A similar pattern can happen year-to-year as fires release carbon and subsequent growth removes carbon from the atmosphere. Thus, the time period we evaluate – e.g. two years versus ten years – can determine whether land is a sink or source. It is also important to define whether shrub-dominated lands are included in the "forest" definition.

The CARB Inventory demonstrates that forests (trees and shrubs) can be either a net carbon sink or source depending on the year(s). With the BOF Inventory focused on decadal trends, the data indicate overall that forests werea net carbon sink from the 2001-2007 measurement period to the 2011-2017 measurement period[1]. However, this inventory also indicates that at smaller scales throughout the state, some specific ownerships or geographic areas are experiencing net carbon losses (e.g., areas with frequent, recent disturbances). Both inventories are showing increased tree mortality associated with wildfires and other forest health issues. The BOF Inventory is also showing decreasing growth rates.

7. What efforts are underway to refine the inventory estimates?

Both the CARB and BOF inventories are under constant improvement as data and methodologies progress. Furthermore, CARB and CAL FIRE staff are working together closely, in collaboration with FIA analysts, to refine the methods for each inventory and learn from each other's work.

CARB staff are working to refine their inventory in several ways. One area of active improvement is better accounting for dead biomass that remains in the forest after wildfire. CARB is also updating the FIA data used in conjunction with satellite data and refining carbon accrual rates in areas that remain tree-dominated.

In the BOF Inventory, temporal **plot intensification** is underway to complete remeasurements of all FIA plots on a 5-year cycle. Historically, FIA plot remeasurement has been on a 10-year cycle in California. This will provide more timely information of disturbances and forest health. The FIA program is also looking to improve estimation of non-sampled plots through small area estimation techniques and leveraging remote sensing data. Improvements to allometric live tree biomass equations are underway, which will improve estimates in the live tree pool. Improvements to dead biomass and soil organic carbon estimates are constantly being explored as well. These efforts

[1] Estimates of average annual net carbon stock change in the BOF Inventory are based on actual growth, removals and mortality on plots and trees initially measured during the first FIA measurement cycle and remeasured in the second measurement cycle (2017 reporting period example: plots and trees initially measured between 2001 and 2007 then re-measured 10 years later between 2011 and 2017; net change from each of the seven re-measured panels is averaged).

ultimately serve to improve both the BOF and CARB estimates.

8. Where can I find more information?

CAL FIRE and CARB staff have worked together to develop a report detailing the similarities and differences between the two inventories. This report can be found here: *https://frap.fire.ca.gov/research-monitoring/forest-carbon-monitoring/*