OREGON STATE UNIVERSITY ■ WASHINGTON STATE UNIVERSITY ■ UNIVERSITY OF IDAHO

Introduction to Forest Carbon, Offsets and Markets

Credit: Adobe stock photo

Jacob D. Putney, Norma Kline, Stephen Fitzgerald, Lauren Grand, Chris Schnepf, Greg Latta, Patrick Shults and John Rizza

Introduction

Forest ecosystems provide many values and services, such as wood products, clean air and water, wildlife habitat and recreation. Forests are also critical in carbon cycling and storage. Forests comprise approximately 750 million acres within the United States, serving as the nation's largest terrestrial ***carbon sink*** (an area with more carbon being stored than released), capturing and storing the equivalent of about 11.9% of U.S. carbon emissions. Clearly, forest ecosystems play a critical role in mitigating climate change.

This feature offers prospects for forest landowners to manage for enhanced carbon storage to reduce ***greenhouse gas (GHG)*** emissions and generate income by participating in forest carbon markets. Carbon markets are evolving rapidly, making it difficult for forest landowners to understand the opportunities and requirements when choosing a carbon market program.

This publication will introduce readers to forest carbon, carbon offsets, projects and markets. It is intended to orient forest owners, land managers, natural resource professionals and others to forest carbon and carbon market terminology and processes, as well as resources for assistance and getting started.

Contents

PACIFIC NORTHWEST EXTENSION PUBLISHING
OREGON • WASHINGTON • IDAHO

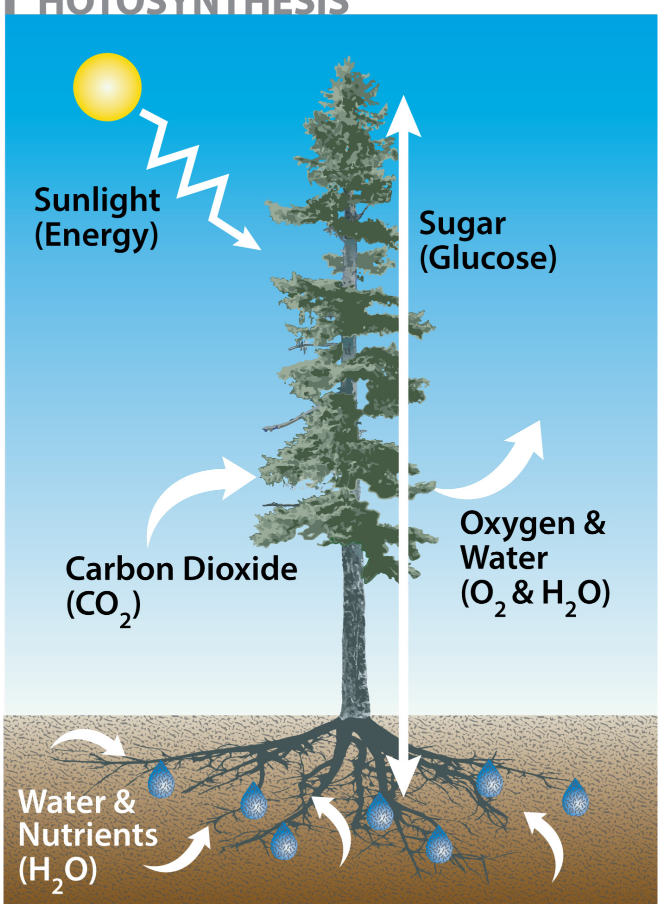
PNW 775
December 2023

Forest carbon

Carbon (C) is the essence of life on our planet. It is the sixth most common element in the known universe and the second most common element in the human body. All living things are made of carbon. Carbon atoms have a unique ability to bond in various formations and structures to form more than a million compounds. One of the most familiar is carbon dioxide (CO_2) — a molecule with one carbon atom and two oxygen atoms. Carbon dioxide is a colorless, odorless gas, and is produced through natural processes (for example, fermentation and respiring animals, fungi and microorganisms) and as a result of human activities. Burning fossil fuels (coal, natural gas and oil, which contain carbon) for energy and transportation is the primary human CO_2-emitting activity, according to the EPA. CO_2 is also considered a greenhouse gas because it traps heat in the atmosphere and warms the planet.

Trees and other plants fix carbon dioxide during photosynthesis, which is the most important biochemical process on Earth. Plants take CO_2 from the atmosphere, water and nutrients from the soil, and use light energy from the sun to produce glucose (a simple sugar), a form of carbon. This process creates the "food" needed

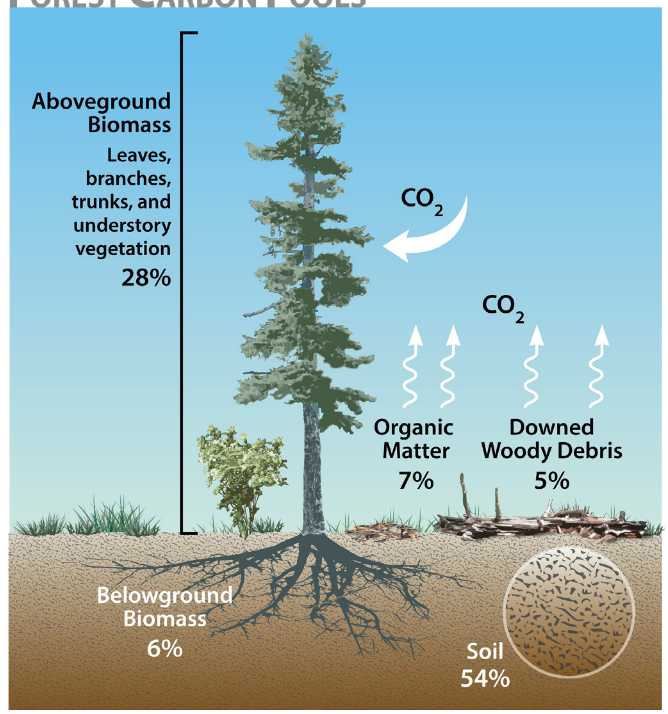
PHOTOSYNTHESIS



Credit: Gretchen Bracher, © Oregon State University

Figure 1. Photosynthetic cycle.

FOREST CARBON POOLS



Credit: Gretchen Bracher, Oregon State University

Figure 2. Estimated percentages of U.S. forest ecosystem carbon stocks for each forest carbon pool (aboveground biomass, belowground biomass, downed woody debris, organic matter and soil). Percentages calculated using 2022 data from Table 6-13 in Chapter 6, "Land Use, Land-Use Change, and Forestry," in *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2021*. EPA 430-R-23-002.

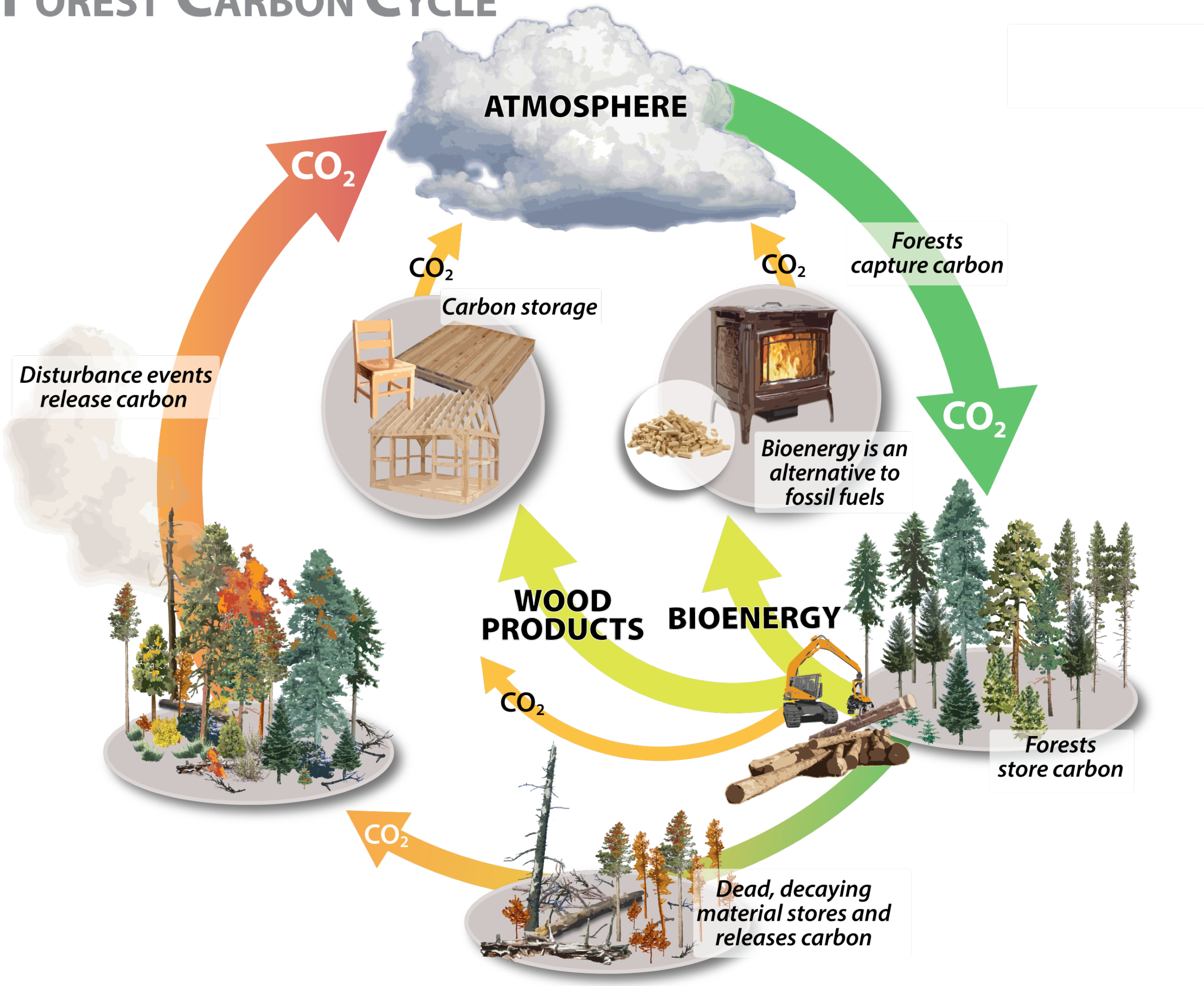
for plant growth, development and reproduction, and releases oxygen (O_2) as a byproduct. CO_2 from the atmosphere enters leaves through tiny holes (called stomates) in leaves. Stomates act as gatekeepers, allowing CO_2 to enter while releasing water vapor and O_2 into the atmosphere (Figure 1).

When glucose produced by plants during photosynthesis is stored, so is the carbon within that glucose. This process is described by the term ***carbon sequestration***. Within a tree's cambium, glucose is converted to cellulose, hemicellulose and lignin, which are the building blocks of wood cells. This conversion of glucose to building plant structures is known as ***carbon storage***. A tree's annual growth, visible as the tree's "rings," is in part carbon that was once in the atmosphere. In fact, for woody plants like trees, roughly 50% of the (dry) weight of wood is pure carbon.

The role of forests

Trees, other vegetation and soils contain the bulk of carbon in terrestrial environments. Carbon in forest ecosystems is stored in various ***carbon pools*** (Figure 2). These pools include aboveground carbon (that is, living and dead trees and plants, litter and duff) and belowground carbon (living and dead roots, fungi, invertebrate animals, other biomass and organic matter in the soil).

Forest Carbon Cycle



Credit: Gretchen Bracher, © Oregon State University

Figure 3. The Forest carbon cycle represents the various forest carbon pools and transfer of carbon between pools as a result of management activities and/or various natural processes (such as, photosynthesis, respiration, decomposition and combustion).

Forests also release carbon back into the atmosphere via respiration, decomposition and combustion. The amounts and rates of this release is referred to as ***carbon emissions***. Large disturbances, such as wildfires, can release large amounts of carbon (and other greenhouse gasses) into the atmosphere by burning plant biomass. Disturbances also hasten decomposition, where carbon is released as fungi and microbes break down dead trees over many decades. Other sources of carbon emissions occur when forests are converted to nonforest land uses (development) or killed by insect or disease outbreaks and left to decay. Harvesting activities include both emissions as well as storage, as harvested wood used for wood products continues to store carbon for decades or longer.

These dynamics define the forest carbon cycle, or the amount of carbon that enters and exits a forest through processes such as photosynthesis, respiration, decomposition, combustion, and harvesting (Figure 3). This cycle of constant change and carbon transfer between different pools is known as ***flux***. Forests play an important role within the broader carbon cycle — or the movement of carbon from land and water through the atmosphere and all living things.

Carbon sequestration and storage rates vary considerably across different forest types, stands and ages, and are influenced by soils, climate and disturbance regimes where forests grow. Sequestration rates in young forests start low, even though individual trees may be growing rapidly. This is because the amount of wood produced every year, creating the annual ring, is relatively small. As a forest matures, sequestration rates increase as growth (and the amount of wood)

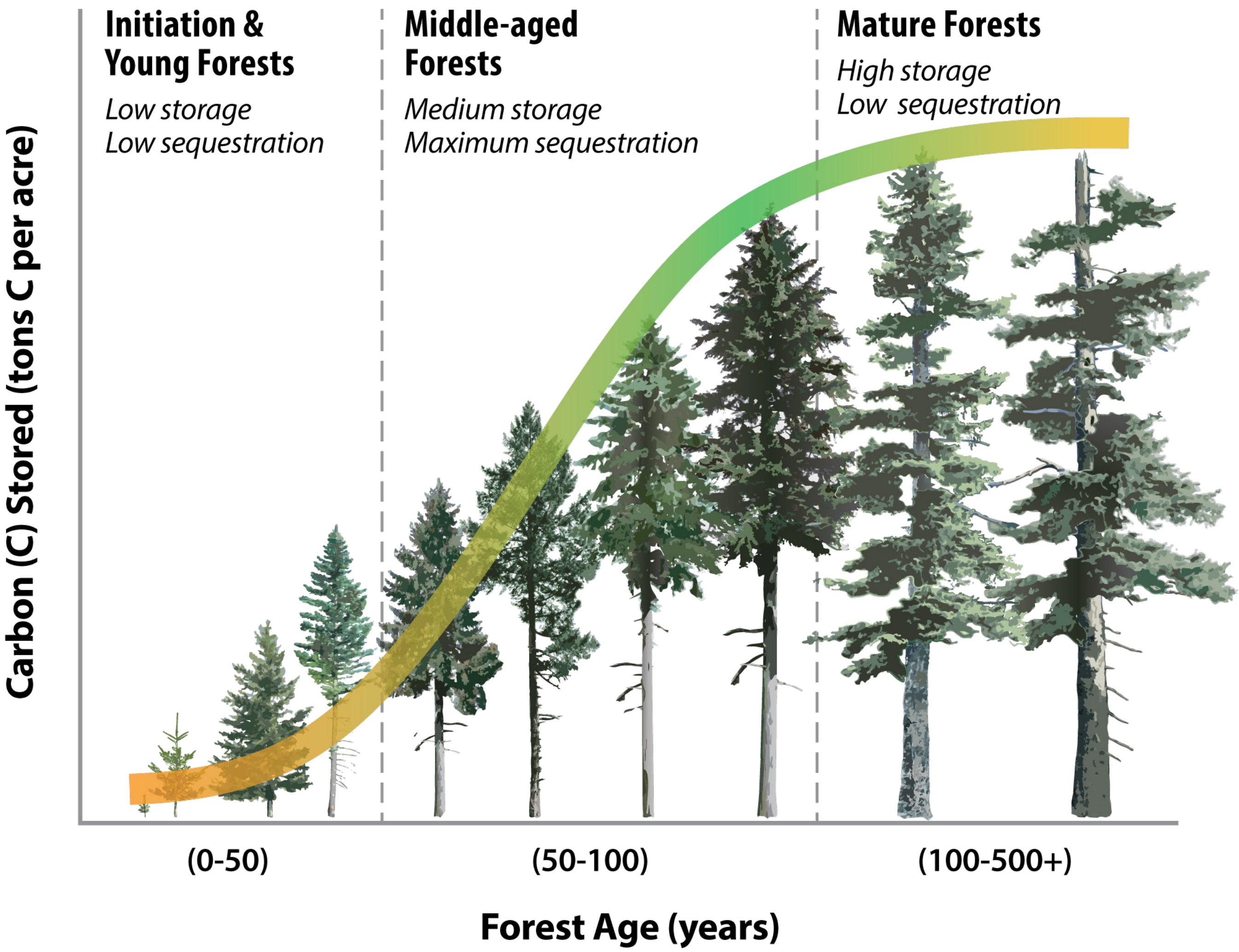


Figure 4. How carbon sequestration rates and carbon storage change over time as forests develop. Note that forest ages (years) listed are relative and may vary considerably depending on forest type and composition.

increases. Older forests may release more carbon back into the atmosphere than younger forests, although net sequestration is still positive (Figure 4).

How carbon is measured

These natural processes produce a tradable commodity that is based on a measurement of carbon and conversion to standardized units of net emissions that are avoided or reduced. Carbon is estimated through tree measurements from a forest inventory, similar to a timber cruise. To describe an entire forest stand, a network of inventory plots is established, and the individual trees within those plots are measured. Relatively simple measurements, such as diameter and height, are collected and entered into equations that estimate the total biomass (including stem branches, bark and leaves) of the trees. These equations are specific to each tree species and the region in which they grow. The biomass is then converted to carbon by taking 50% of the total biomass' estimated dry weight. According to experts at the Vermont Department of Forests, Parks and Recreation, a molecule of CO_2 is 3.67 times heavier than a single carbon atom. Therefore, carbon from wood is converted to carbon dioxide equivalent (CO_2e) by multiplying by 3.67 (See equation call-out box). Thus, 1 metric ton of dry wood is approximately equal to 1.8 metric tons of CO_2e ($MtCO_2e$). Other carbon within the stand, such as dead wood, understory vegetation and soils are important to consider but are difficult to measure and estimate.

Carbon can also be measured using remote sensing — the process of measuring reflected radiation at a distance to detect and analyze the physical characteristics of a specific area of interest, such as a forest. This technology — Light Detection and Ranging (LiDAR), for example — uses specialized cameras and sensors mounted on

Equations: Converting dry wood to CO_2

Wood mass x 0.5 = carbon mass
Carbon mass x 3.67 = CO_2 mass
1 metric ton (Mt) of wood x 0.5 x 3.67 = 1.8 Mt CO_2

Credit: Pixabay

Figure 5. A multirotor unmanned aerial vehicle (UAV), or drone, with a specialized camera attached .

aircraft, drones, or satellites (Figure 5). These cameras and sensors collect high-resolution images to create a forest map from which the size, shape, arrangement and composition of the trees can be analyzed and estimated. Just like the measurements collected from an inventory, these estimates can be used in equations that estimate total biomass and carbon storage. Remote sensing technology can cover large areas, especially areas that are difficult to access, and may be less expensive than other inventory methods, Penn State researchers say.

Carbon sequestration can be measured by projecting growth over time using regional growth and yield models such as the Forest Vegetation Simulator model from the U.S. Department of Agriculture. Models estimate the amount of fixed carbon in a tree's stem and branches while also accounting for tree mortality. Carbon may also be estimated using regional carbon stocking levels. Using Forest Inventory Analysis data, the USDA Forest Service has created regional Carbon Lookup Tables for different forest types and ages across the U.S.

Forest carbon projects

According to the Intergovernmental Panel on Climate Change, a carbon offset is a measured reduction of net carbon emissions using standardized units defined as one metric ton of carbon dioxide equivalent ($MtCO_2e$). Carbon offsets are generated through ***carbon offset projects*** — activities that either avoid emission or remove carbon from the atmosphere that can be used to displace emissions elsewhere. In a forestry context, these activities typically involve removing carbon from the atmosphere through additional carbon sequestration. Activities that constitute an offset project must be registered and verified by a third party and must be approved by a carbon registry. Once approved, generated carbon offsets become ***carbon credits***, which are the verified and registered instruments that can be traded or sold. Note that carbon offsets are generated through carbon offset projects while carbon credits are transacted within carbon markets.

Project types

Three types of forest projects eligible for offsets are currently recognized by major carbon programs in the United States: afforestation/reforestation, avoided conversion, and improved forest management. Each of these project types has different methodologies, commitments, rules, monitoring and verification requirements. Table 1 details each of these three project types.

Project attributes

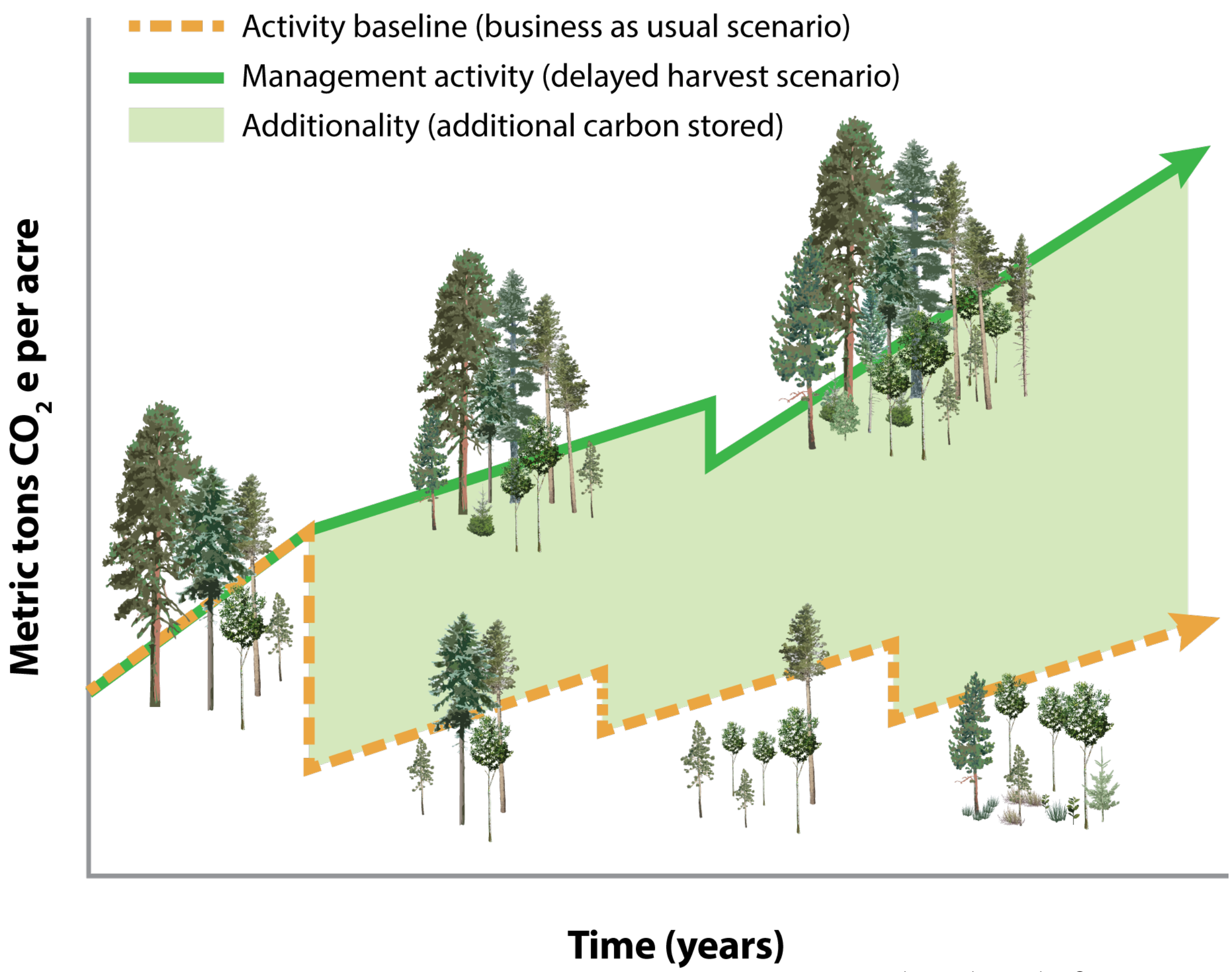
All carbon offset projects must meet certain requirements. To be eligible, projects must demonstrate additionality, ***permanence***, ***measurability*** and nonleakage (Table 2).

Table 1: Types of forest carbon offset projects

Project type	Description
Afforestation or reforestation	▪ Restoring tree cover by tree planting or by encouraging natural regeneration (for example, removing barriers such as debris or competing vegetation). ▪ These projects must be on land that was previously nonforested or were subject to severe disturbance (for example, stand-replacing fire).
Avoided conversion	▪ These projects prevent conversion of forestland to nonforest use. ▪ Projects must demonstrate lands are under significant threat of conversion. ▪ Typically require permanent conservation easements.
Improved forest management	▪ These projects involve management activities that maintain or store more carbon than would otherwise be stored through geographically/regionally common practices and/or what is required by law and regulation. ▪ IFM projects are the most common forest carbon offset projects.

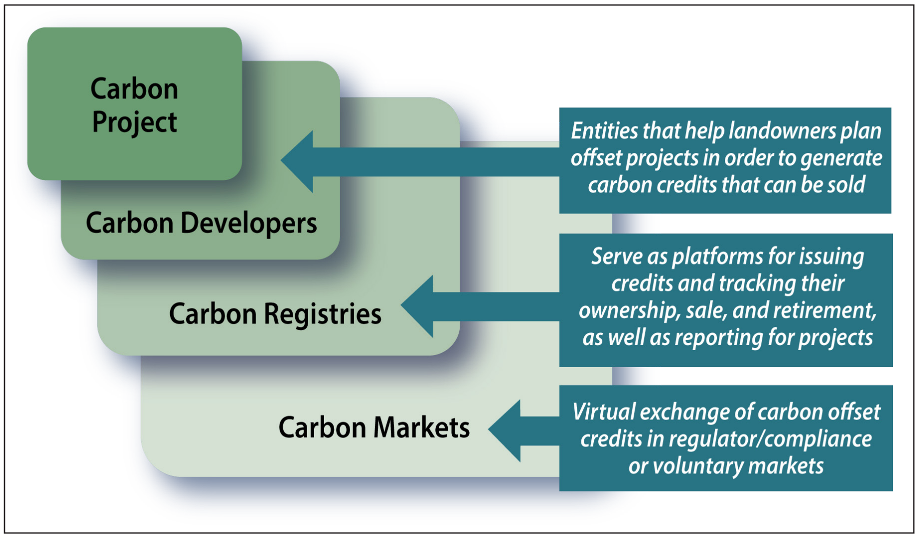
Table 2. Attributes and eligibility for each carbon offset project

Attribute	Description	Eligibility requirements
Additionality (Figure 6)	Project sequesters and stores more carbon than a "business as usual" or "baseline" scenario.	Project must demonstrate that the carbon sequestration would not have otherwise happened without the offset project development.
Permanence	Requires that the removals be maintained and equivalent to the emissions being offset.	The permanence of a project is demonstrated through measuring the length of time carbon is stored, third-party verification of inventory, and periodic auditing throughout the life of the project. This provides evidence that the project will provide long-term carbon benefits. Often, this timeframe is 100-years beyond the project period.
Measurability	Carbon must be accurately measured and inventoried so that benefits can be calculated.	Projects require an inventory conducted through approved methodologies and verified by a third party. Confirmation of protocols and accuracy are essential for project verification.
Nonleakage	Leakage results from reductions of carbon emissions in one area causing an unintended increase in another area.	As part of approved protocol, projects must demonstrate they do not cause excessive leakage.



Credit: Gretchen Bracher, © Oregon State University

Figure 6. For Improved Forest Management projects, additionality is achieved when current forest management practices are changes to store additional carbon. This figure generalizes a "delayed harvest scenario," or postponing harvests instead of the business-as-usual outcome. In this case a retention harvest and two subsequent thinnings (tan line) are delayed to include only one thinning (green line), thus, storing more carbon over time (represented by the light green shading). (Adapted from Breen 2002).



Credit: Gretchen Bracher, © Oregon State University

Figure 7. Carbon market terminology (Adapted from SNFCP 2022).

Carbon project registries and verification bodies

Carbon registries document and track the generation, ownership, transaction and retirement of credits. Registries serve as a database for credits and establish marketplace accountability. This becomes particularly important for those who intend to participate in both the voluntary and compliance markets. Table 3 describes four of the most widely recognized carbon registries in the United States.

They also have carbon offset programs of their own, such as the Climate Forward Program of the Climate Action Reserve. These programs are guided by overarching standards applied across all project types detailing registration, reporting, verification and monitoring requirements. They also have methodologies describing detailed quantification steps for each specific project type. All programs require independent third-party verification ensuring that the project meets the standards, and the methodology has been applied correctly.

Validation and verification bodies are independent, third-party certification bodies that evaluate project documentation and processes to ensure the offset calculation is correct and the project meets the program standards. These third-party verification bodies must meet. International Organization for Standardization principles and requirements for bodies performing validation and verification of environmental information statements. Each registry maintains a list of approved validation and verification bodies on its website.

Project development overview

If you are interested in exploring options related to carbon projects in your forest, here are some of the steps you can take. Typically, a project would begin with contacting a ***carbon project developer*** — a private group, like a forest consultant, that will work with you through each step of the process to develop a carbon project

Table 3. Carbon project registries

Registry	Description
American Carbon Registry (ACR)*	▪ First private, voluntary carbon registry in the United States. ▪ ACR has protocols for each of the three types of forest carbon projects. ▪ Is an approved registry for the California Air Resources Board (ARB) compliance carbon offset program.
Climate Action Reserve (CAR)*	▪ Operates in the voluntary market and is also an approved ARB registry. ▪ CAR has protocols for each of the three types of forest carbon projects.
Gold Standard	▪ An international registry, based in Switzerland, established by the World Wildlife Fund.
Verified Carbon Standard (VCS)*	▪ VCS is the most widely used registry for projects in the voluntary market (described in following section). ▪ VCS has protocols for Improved Forest Management and Afforestation/Reforestation projects and is also an approved ARB registry.

*Note: While ACR, CAR and VCS are approved California Air Resources Board (ARB) registries, projects are still verified against ARB standards and methodologies (as opposed to the ACR, CAR, or VCS standards and methodologies).

for your woodland. This includes feasibility, eligibility, inventory, verification, registration and ultimately marketing offsets as credits. Project developers should be well-versed in multiple programs and methodologies to ensure that the project activities align with your interests, meet your objectives and are most appropriate for your forest. Here is an overview of how a project is developed and implemented:

Feasibility and eligibility

Before a project is started, your forest's eligibility and feasibility will be determined based on a program's standards and methodology requirements. This should also evaluate all anticipated costs and revenues to ensure viability. Following feasibility determination, you will submit to the registry a project listing form with details on the project type, location, ownership, forest types and an initial estimate of the offset generation. There is typically a fee associated with listing a project to a registry. When eligibility is confirmed by the registry, the next stage of the development process may begin.

This listing does not lock you into a project. At this stage, you can still decide not to proceed, and all you would lose would be the listing fee and any development costs. However, depending on the type and size of the project, these upfront fees and costs may be considerable. Prior to starting a project, particularly for smaller ownership sizes, carefully consider the financial costs and benefits of entering a carbon program.

Inventory, quantification and planning

The next stage involves inventorying and quantifying carbon. Much like a timber cruise, this process involves measuring the forest before estimating its carbon and projecting carbon storage over time. These projections must be compared against a baseline to show how much carbon is additional. This baseline is the amount of carbon under the business-as-usual scenario (that is, without entering a project), and is typically predicted or estimated using regional growth and yield models, such as the USDA Forest Vegetation Simulator. The difference between the measured carbon from the inventory and the estimated baseline values is the additional offset carbon.

After inventory and quantification, a forest management plan is developed that outlines the project area, management goals and objectives, and details specific management activities that will maintain or improve carbon storage over time. Based on the project type and anticipated activities, carbon stocking that continues to remain above the baseline can be issued offsets. This is typically done at set periods, where growth is measured and verified.

The completed plan is submitted to the chosen carbon registry. If accepted, the project will be formally registered and moved to the next stage of the process.

Verification and monitoring

Verification is typically completed by a third-party auditor (that is, a validation and verification body) who verifies that the project has met eligibility requirements, adheres to offset protocols, and ensures inventory is accurate and that the planned activities will maintain or enhance carbon storage — which is all set by the carbon standards in which the project is enrolled. Once verified, this verification will be submitted to the carbon registry for final review. After the carbon registry approves the verification, the project will receive verified, registered carbon credits based on the carbon offsets generated from the project. These credits can then be marketed.

Thereafter, a ground-truthing audit is typically required every five or six years, as well as an annual review of ownership records. This typically involves a periodic reinventory and verification, depending on the protocol requirements of the selected carbon registry.

Forest carbon markets

Forest carbon markets are the mechanism by which carbon credits are bought, sold, traded and retired as an alternative to reduce greenhouse gas emissions and mitigating climate change. Verified carbon credits generated through offset projects are monetized and transacted in these markets to be purchased by businesses, municipalities and other entities to offset their own CO_2 or other greenhouse gas emissions. Conceptually, forest owners increase CO_2 sequestration and storage, and these increases are used to offset the emissions of other entities. Ideally, these offsets would result in a balance or an overall reduction in emissions.

Market types

In the United States, three types of markets buy and sell carbon credits generated through carbon offset projects: compliance, voluntary, and incentive programs. The compliance market requires a compliance offset (seller) to be used to meet the regulatory requirement of the purchaser. The voluntary market is more flexible, where a purchaser is free to determine whether they want to use a compliance, voluntary, or incentive program to generate offset. These markets generally coexist. However, offset projects may be eligible to participate within one but not the others, depending on their requirements.

Compliance (regulatory) are projects in which emitters are required by law to reduce emissions to meet greenhouse gas reduction targets. To achieve these efforts, emitters can reduce the pollution they create or purchase offsets from verified carbon projects, as well as transact emission allowances. Cap-and-trade is an example of a compliance market where a regulatory body sets a limit, or cap, on emissions and authorizes a specific quantity of a greenhouse gas that may be emitted as a tradable allowance. These allowances provide flexibility for entities to reach reduction targets, and unused allowances may be bought and sold (the "trade"). These systems have worked very well to reduce other types of pollution, such as those which have contributed to acid rain.

California's Cap-and-Trade Program for carbon is the most well-known in the U.S. and is operated by the California Air Resources Board. The board approves protocols for this market and offset projects must be registered through a board -approved registry. Landowners must also have a long-term management plan and be certified by the Forest Stewardship Council, Sustainable Forestry Initiative, or the American Tree Farm System. If they meet the air resources board requirements, projects in the Pacific Northwest may participate in this marketplace.

Voluntary markets are not required by law or regulation and allow individuals or entities to mitigate their emissions. Typically, private corporations and other entities participate in voluntary markets to meet their own emission reduction, sustainability and social objectives. These markets offer more flexibility than compliance markets, particularly around protocols and guidelines. To this end, these markets include a wider range of factors such as price, types of projects, marketing and demand.

Incentive programs facilitate the participation of landowners who may have otherwise been excluded from carbon markets due to barriers such as high up-front costs and administrative complexities and burdens. There are two types of incentive programs: practice-based and pay-for-performance. Practice-based programs provide technical assistance and financial incentives for landowners to adopt practices that maintain storage, increase sequestration and improve forest health. Examples of practice-based programs include those offered by the Natural Resources Conservation Service, such as the Environmental Quality Incentives Program. Pay-for-performance programs provide compensation for a landowner based on the amount of carbon sequestered and may include tradable carbon credits as a result, much like a carbon offset project. The Family Forest Carbon Program, developed by the American Forest Foundation and The Nature Conservancy, is an example of a pay-for-performance program. This program is intended to address barriers that would otherwise exclude family forest owners from participating in carbon markets (such as minimum acreage requirements and high up-front costs). The program's methodology was approved by Verra, the nonprofit organization that oversees the Verified Carbon Standard, in October 2022. Currently, only landowners in Maryland, Michigan, Minnesota, New York, Pennsylvania, Vermont, West Virgina and Wisconsin are eligible to enroll.

Key defining characteristics of compliance vs. voluntary markets

Market	Description
Compliance	▪ Businesses (emitters) from emissions-capped sectors must enroll if they are emitting more than their allowed amount. ▪ Regulation affects carbon price, emissions targets, and included industries. ▪ Requirements and commitments for sellers are typically more stringent.
Voluntary	▪ Purchasers may be individuals, businesses or other entities seeking to reduce net emissions for ethical, reputational or other motivations. ▪ The flexibility of these markets results in a wider range of demand and price. ▪ Requirements and commitments for sellers are typically more flexible, depending on approved project methodology.

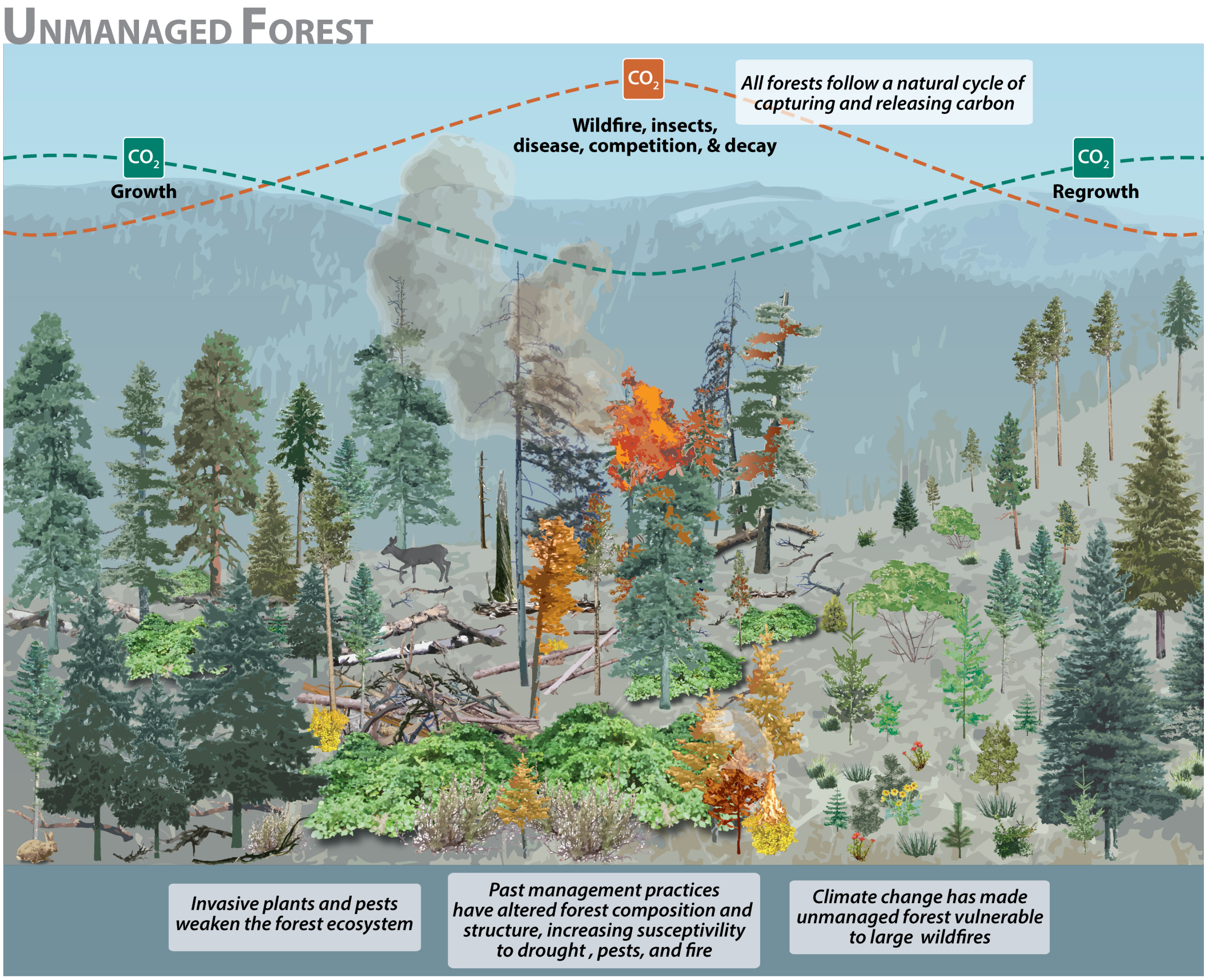
Getting started

Matching projects with objectives

Before initiating a forest carbon project, articulate a vision for your forestland. Understanding your short- and long-term objectives will help you determine if carbon management is suitable for your property. Your harvesting plans are a critical component to consider in this process. Keep in mind other forest management activities like forest health and succession planning.

While harvesting alone may not be a priority for small forest owners, it is typically necessary to achieve certain management objectives, such as those related to economics, forest health, wildlife habitat enhancement and/or aesthetics. Any form of timber harvest will remove biomass, and thus carbon, from a forest. However, this doesn't mean harvesting and carbon management cannot coincide. In some cases, harvesting can benefit carbon management. For instance, in drier forests, thinning and fuel reductions technically reduce the amount of carbon on site.

However, because such practices reduce the catastrophic wildfire risks and can improve forest health, they ultimately result in a net benefit. Similarly, in more moist forests, thinning overstocked stands may reduce carbon on-site in the short term but also restore vigorous tree growth, resulting in more carbon storage over time. Forest carbon programs vary in how they deal with harvesting. Some don't allow any harvesting for the length of enrollment. Others work by establishing a carbon baseline and only allow cutting as long it doesn't



Credit: Gretchen Bracher, © Oregon State University

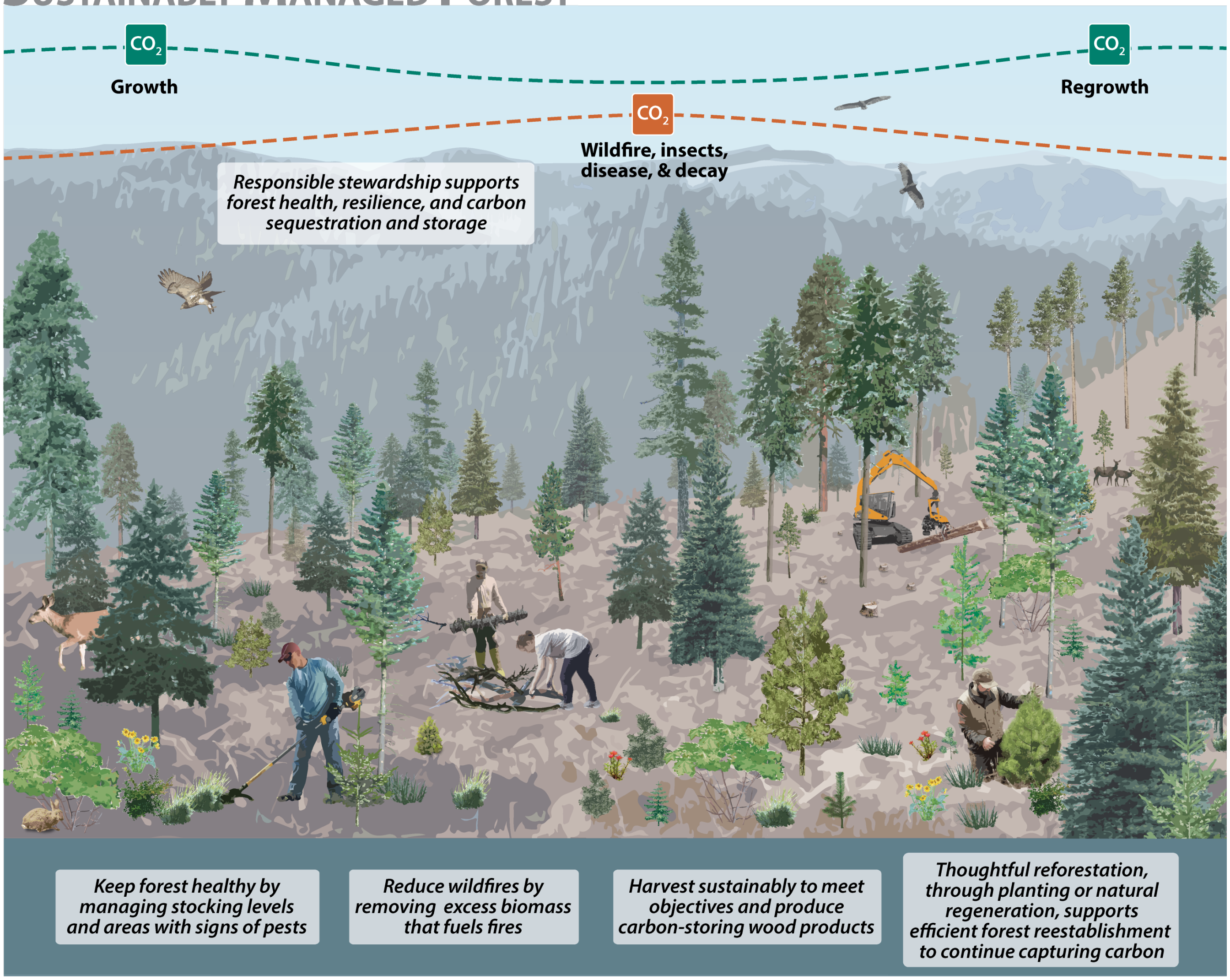
Figure 8A. In contrast to the forest depicted above, healthy forests are more resilient to the effects of climate change and reduce the risk of carbon liberating events such as wildfire, insects, disease, and decay. (Adapted from Dovetail Partners 2022)

mean going below that baseline. This allows partial harvesting on the property. Some programs may elect to work with you and your harvesting plans on a case-by-case basis.

If harvesting is important to you, you will need a plan for the rotation length and type of harvesting you intend to implement while enrolled in a forest carbon program. Shorter rotations (less than 60 years, for example) motivated by financial objectives may not be conducive to forest carbon program goals. Longer rotations (more than 60 years) sequester more carbon and may allow more flexibility for small regeneration harvests, provided the program allows harvesting above a given carbon baseline. Variable-density harvesting techniques can also be favorable to forest carbon management because they leave more tree cover. For improved forest management projects, the overarching intent is to prioritize carbon storage over other objectives (such as timber revenue, wildlife, recreation, etc.) when conducting management activities.

Forest health is an important consideration but can be difficult to plan for. In some cases, it could mean salvage cutting, such as in the case of wildfire or extensive damage from insects and disease. It's difficult to predict what issues a landowner may deal with in the long term, but it's important to know up front how situations like this would be handled in a carbon program. Landowners should be able to proactively manage forest health to prevent issues and build forest resilience. Management for forest health can take many shapes, including timber harvest, thinning and fuel reduction. Having the flexibility to apply these practices is particularly important when dealing with a changing climate (Figures 8A and 8B).

Sustainably Managed Forest



Credit: Gretchen Bracher, © Oregon State University

Figure 8B. Responsible stewardship to promote forest health supports the forest's ability to sequester and store carbon over time (Adapted from Dovetail Partners 2022). .

Forest management is unique because we manage species that are likely to outlive us. This is why succession planning should also be a part of the conversation when considering enrolling in a forest carbon program. The lengths of engagement can vary based on the program but, generally speaking, carbon is a long-term objective. Do you have a succession plan in place? Will it involve splitting the property among your children or other individuals? Do they share your objectives for the land? These are all important questions to answer before committing to a long-term carbon program. For families, it's never too early to have this discussion and lay out a plan in writing with help from an estate lawyer. It's common for landowners to consider passing their land or development rights to a land trust, which generally aligns well with carbon management. For more information about succession planning, there is a comprehensive guide published through Pacific Northwest Extension, *Ties to the Land: Succession Planning for Rural Landowners*.

All of what's been discussed in this section can be incorporated into a forest stewardship plan. Developing a plan is a great opportunity for landowners to consider their options, determine their objectives, and set out a course of management for the years or decades to come. Having a plan in place is highly recommended before enrolling in a forest carbon program. In fact, some may require a plan to be accepted. Depending on where you live, there are many resources available to help with this process, including technical assistance, educational programs and even financial assistance. To learn more about developing a forest stewardship plan, reach out to your local Extension office.

How do you decide if a carbon program is right for you?

Carbon programs require commitments of time, management and accounting. The checklist on the next page includes examples of questions that will help landowners determine if their property meets the carbon program's requirements. Most importantly, landowners should carefully consider if the carbon program meets their ownership objectives and how carbon fits within their overall management plan. Consider the tradeoffs based on these requirements compared to your future plans for your forest.

As with any contract or agreement, landowners should diligently review a carbon program's requirements prior to committing to a legal contract. Start by reviewing available information on the program's website. Listen to available webinars and examine Frequently Asked Question sheets. Consider consulting with an attorney experienced in forestry operations to review offer letters and contracts in advance. If your property is taxed in a forest-specific category, confer with the county tax assessor to determine whether a carbon deferment program contradicts the forest taxation management requirements. A tax accountant or even some consulting foresters familiar with forestry-related taxation will be another useful information source to help determine if there are tax implications specific to your situation. While these services come at a cost, they may save you money in the long run by helping you understand the fees, revenues, taxes and other implications of the carbon program contract or agreement. Additionally, ask staff with any easement or land trust programs you already participate in if carbon deferrals are appropriate for areas under agreement with those programs.

Assistance and where to learn more

There are a number of resources and sources for assistance available to landowners interested in completing carbon projects on their forest lands.

Local Extension agent

Managing your property to store carbon, mitigate climate change or enter a carbon incentive program involves knowing what you have, how to keep it healthy and how to keep it growing for the future. Your local Extension agent can help you start or continue your educational journey on forest management, management planning and carbon-ready strategies.

Find your local agent:

Oregon: https://extension.oregonstate.edu/

Washington: https://extension.wsu.edu/

Idaho: https://www.uidaho.edu/extension

Financial and technical assistance

State forestry agencies and federal partners often have landowner financial assistance programs that can help you accomplish management activities that meet your carbon management goals. Funding is often available for writing forest management plans, precommercial thinning, removing invasive species or planting climate-ready seedlings after a natural disaster such as fire, ice storms or severe drought.

- Oregon Department of Forestry grants and incentives: https://www.oregon.gov/odf/aboutodf/pages/grantsincentives.aspx
- Washington Department of Natural Resources financial assistance for forest health: https://www.dnr.wa.gov/LandownerAssistancePortal
- Idaho Department of Lands assistance: https://www.idl.idaho.gov/about-forestry/assistance-for-forest-landowners/
- Natural Resources Conservation Service assistance programs: https://www.nrcs.usda.gov/

Project developers

Carbon project developers have a wealth of knowledge about carbon credits, carbon estimation tools and ways to generate income on your property via carbon sequestration. However, remember that project developers and carbon credit providers are salespeople. Make sure you understand all the terms of your contracts and are prioritizing the decisions that best meet your personal objectives for your property.

Your peers

Word of mouth is the age-old system for advice. Use all your resources, including your neighbors and peers in landowner organizations. What have their experiences been? People are usually more than happy to tell you about their experiences using a particular resource, especially bad experiences. Just remember that they may have different objectives or have not been enrolled long enough to have encountered potential issues. If the research seems overwhelming, asking someone you know can help ease you into where to start. If you don't have a neighbor doing a carbon project, reach out to your local landowner assistance program to find out if they can connect you with someone.

- Oregon Small Woodlands Association: http://www.oswa.org/
- Washington Farm Forestry Association: https://www.wafarmforestry.com/
- Idaho Forest Owners Association: https://www.idahoforestowners.org/

Additional educational resources

There is a growing amount of information on managing forests for carbon and starting carbon projects on private forest lands. Make sure the resources you are looking at are research-based and peer-reviewed. Below is a selected list of resources that can help you on your carbon-smart forestry journey.

Forest Owner Carbon and Climate Education, Penn State University. https://sites.psu.edu/focce/: *Program for helping forest owners make smart decisions about engaging in the carbon economy.*

Forest Carbon and Climate Program, Michigan State University. https://www.canr.msu.edu/fccp/: *Program aimed to increase understanding and implementation of climate-smart forestry.*

An Introduction to Forest Carbon Offset Markets, North Carolina State Extension. https://content.ces.ncsu.edu/an-introduction-to-forest-carbon-offset-markets

Fact Sheets, Consortium for Research on Renewable Industrial Materials. https://corrim.org/factsheets/: *Published summaries of consortium's research results.*

Climate Change Resource Center, USDA Forest Service. https://www.fs.usda.gov/ccrc/: *Provides land managers and decision-makers with climate change and carbon tools. Select your state and search for carbon.*

The Climate Toolbox. https://climatetoolbox.org/: *A collection of web tools for visualizing past and projected climate and hydrology.*

Adaptation Library, Adaptation Partners. http://adaptationpartners.org/library.php: *Strategies to mitigate the impacts of various climate change effects.*

Climate Adaptation Strategies for PNW Forests, Northwest Natural Resources Group. https://www.nnrg.org/climateadaptation/: *List of climate-concious resources for land managers.*

Forest Soil Carbon, USDA Forest Service. http://www.fs.usda.gov/ccrc/topics/forest-soil-carbon

Is a carbon program right for you?

Use this checklist of typical carbon program requirements to assess whether a carbon program is a good fit based on your objectives and your forest. Look over program materials and offer letters closely for specific program requirements. Program webinars and frequently asked questions sheets are also helpful sources of information.

Below is a selected list of questions to help determine if a carbon program is right for you	Program requirement	Does the property meet program objectives?	Does the program requirement meet your objectives?
Is there a minimum acre threshold?			
Is there a minimum stand age requirement?			
What is the required timeframe for program participation? (for example, contract length)			
Does the program have fees? (for example, registration fee, verification fee, trading fee, etc.)			
What are the penalties if you would like to withdraw early? (for example, repayment of credit value of removed tons)			
What are the costs/benefits of program participation? (that is, is it economically feasible?)			
Does the program require a forest management plan? (Is there a requirement for review and sign-off?)			
Are areas excluded from the carbon program if already protected from harvest by regulation or legal easement? (Stream buffers required by state forest practice regulations, Conservation Reserve Enhancement Program (CREP), easements with land trusts that restrict harvesting.)			
Who is responsible for establishing initial baseline inventory?			
Who is responsible for ongoing monitoring?			
Does the program require the applicant to bid on the value of the credits?			
Is there a waiting period before landowners can enroll in another carbon deferral program after the contract ends?			
Is there a renewal option?			
What obligations will your heirs have to continue the program?			
What happens in the event of catastrophic fire or insect/ disease? (that is, accidental release)			
What happens if land is sold?			
What are the tax implications of enrolling in a carbon program? (Can landowners participating in a special tax program such as Oregon's Small Tract Forestland Severance Tax program participate in a carbon deferral program?			
Additional questions based on any unique circumstances.			

Acknowledgments

The authors would like to thank the following:

• Mike Cloughesy, for providing initial feedback on this publication.

• Autumn Ellison of Oregon State University, for administering the peer review process, as well as the three anonymous reviewers.

• Gretchen Bracher for the graphic design of the figures used in this publication.

This publication was made possible with funding from the Oregon Forest Resources Institute, in cooperation with the Forestry and Natural Resources Extension Program at Oregon State University.

Authors

Jacob D. Putney, Assistant Professor (Practice) and Extension Forester, Forestry and Natural Resources Program, Oregon State University

Norma Kline, Associate Professor (Practice) and Extension Forester, Forestry and Natural Resources Program, Oregon State University

Stephen Fitzgerald, Professor and Extension Silviculture Specialist, Forestry and Natural Resources Program, Oregon State University

Lauren Grand, Associate Professor (Practice) and Extension Forester, Forestry and Natural Resources Program, Oregon State University

Chris Schnepf, Professor and Area Extension Educator — Forestry, University of Idaho

Greg Latta, Associate Research Professor of Forest Economics and Interim Director of Policy Analysis Group, University of Idaho

Patrick Shults, Extension Forester, Washington State University.

John Rizza, former Assistant Professor (Practice) and Regional Fire Specialist, Fire Program, Oregon State University

Glossary

Term	Definition
Additionality	Project sequesters more carbon than a "business as usual" or "baseline" scenario.
Carbon credit	A tradeable certificate representing a verified carbon offset that can be traded or sold within a carbon market.
Carbon emissions	Release of forest carbon into the atmosphere through decay, respiration or combustion.
Carbon offset	A measured reduction of net carbon emissions using the standardized units defined as one metric ton of carbon dioxide equivalent (MtCO2e)
Carbon offset project	A project involving verified activities that aim to reduce, remove or avoid greenhouse gas emissions relative to a baseline, or business-as-usual behavior.
Carbon project developer	Individuals or entities that generate plans for carbon offset projects to generate carbon credits to be sold in a carbon market.
Carbon registries	Platforms that document and track the generation, ownership, transaction and retirement of credits.
Carbon sequestration	The creation of carbon-based glucose in a plant through the process of photosynthesis.
Carbon sink	A system that absorbs more carbon from the atmosphere than it releases.
Carbon storage	The conversion of glucose to cellulose and lignin for building of plant structures.
Flux	The transfer of carbon between carbon pools.
Forest carbon	Carbon-based sugar molecules (that is, glucose, cellulose, lignin)
Forest carbon pools	Pools where forest carbon accumulates: aboveground biomass, belowground biomass, downed woody debris (dead wood), organic matter (that is, litter), and soils.
Greenhouse gases (GHG)	Gases in the earth's atmosphere that trap heat. The primary greenhouse gases include water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).
Measurability	Carbon must be accurately measured and inventoried so that benefits can be calculated.
Leakage	Leakage results from emission reductions in one area causing unintended increase in another area.
Permanence	Requires that the removals be maintained and equivalent to the emissions being offset.
Validation and verification bodies	Independent, third-party certification bodies who evaluate project documentation and processes to ensure the offset calculation is correct and the project meets the program standards.

References

American Carbon Registry. 2023. Validation and Verification.

American Forest Foundation. 2023. The Family Forest Carbon Program. https://www.forestfoundation.org/what-we-do/increase-carbon-storage/family-forest-carbon-program/.

Breen, G. 2022. Advancing Integrity with the New Improved Forest Management Methodology. Family Forest Blog. American Forest Foundation. https://www.forestfoundation.org/why-we-do-it/family-forest-blog/advancing-integrity-with-the-new-improved-forest-management-methodology/.

Cloughesy, M., E. Sonne Hall. 2022. Chapter 1: Overview of Carbon and Forests. In: M. Coughesy, E. Sonne Hall (eds.). Carbon in Oregon's Managed Forests, Science Review on Carbon, Managed Forests, and Wood Products. Oregon Forest Resources Institute, Portland, OR. Pp. 1-23.

Dovetail Partners. 2022. Forest & Forest Product Carbon Benefit Graphics. Dovetail Partners, Minneapolis, MN. https://www.dovetailinc.org/portfoliodetail.php?id=6266a1c168a7b.

Ford, D., S. Zakreski. 2022. Chapter 6: Current and Future Markets for Carbon and Co-Benefits from Oregon Forests. In: M. Coughesy, E. Sonne Hall (eds.). Carbon in Oregon's Managed Forests, Science Review on Carbon, Managed Forests, and Wood Products. Oregon Forest Resources Institute, Portland, OR. Pp. 101-121.

Graves, R.A., M. Nielsen-Pincus, R.D. Haugo, A. Holz, A. 2022. Forest Carbon Incentive Programs for Non-Industrial Private Forests in Oregon (USA): Impacts of Program Design on Willingness to Enroll and Landscape-Scale Program Outcomes. Forest Policy and Economics 141, 102778. DOI: 10.1016/j.forpol.2022.102778.

Hoover, C.M., B. Bagdon, A. Gagnon. 2021. Standard Estimates of Forest Ecosystem Carbon for Forest Types of the United States. General technical report NRS-202. USDA Forest Service, Northern Research Station, Madison, WI. 158p.

IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Core writing team: R.K. Pachauri, and L.A. Meyer (eds.). IPCC, Geneva, Switzerland. 151p.

Kreye, M. 2023. The Potential of Private Forestlands for Addressing Climate Change. In: M. Kreye, C. Norman and K. Brooks (eds.). Forest Owner Carbon and Climate Education Educator Guidebook. Part 1: Carbon Incentives for Forest Owners (prepress). Forest Owner Carbon and Climate Education Program, Department of Ecosystem Science and Management, Penn State University, University Park, PA. Pp. 11-21.

Kreye, M., T. Kowalczyk, C.L. VanderSchaaf, K. Clay. 2023. Climate-Smart Forestry: What is it? In: M. Kreye, C. Norman, and K. Brooks (eds.). Forest Owner Carbon and Climate Education Educator Guidebook. Part 1: Carbon Incentives for Forest Owners (prepress). Forest Owner Carbon and Climate Education Program, Department of Ecosystem Science and Management, Penn State University, University Park, PA. Pp. 33-39.

Kosiba, A.M. 2021a. What is Forest Carbon? Vermont Department of Forests, Parks and Recreation. 9p.

Kosiba, A.M. 2021b. Forest Carbon Markets for Vermont Landowners. Vermont Department of Forests, Parks and Recreation. 12p.

Medina-Irizarry, N., M. Andreu, T. Cushing. 2022. A Landowner's Introduction to the Forest Carbon Market. FOR382/FR453. EDIS 2022(2). DOI: 10.32473/edis-fr453-2022.

Securing Northeast Forest Carbon Program [SNFCP]. 2022. Climate Change, Forest Carbon & Carbon Markets. Securing Northeast Forest Carbon Program, North East State Foresters Association, Concord, NH.

USDA Forest Service. 2023. Forest Vegetation Simulator, Version 20230106-1. https://www.fs.usda.gov/fvs/software/index.shtml

U.S. Environmental Protection Agency]. 2023a. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2021. EPA 430-R-23-002. U.S. Environmental Protection Agency, Washington, DC. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks

U.S. Environmental Protection Agency. 2023b. Overview of Greenhouse Gases. U.S. Environmental Protection Agency, Washington, DC. https://www.epa.gov/ghgemissions/overview-greenhouse-gases#carbon-dioxide

U.S. Geological Survey. 2023. What is Remote Sensing and What is it Used For? U.S. Geological Survey, U.S. Department of the Interior, Washington, DC. https://www.usgs.gov/faqs/what-remote-sensing-and-what-it-used#:~:text=Remote%20sensing%20is%20 the%20process,sense%22%20things%20about%20the%20Earth.

VanderSchaaf, C.L., A. Susaeta, C. Norman, M. Kreye. 2023a. Forest Carbon: Where is it? In: M. Kreye, C. Norman, K. Brooks (eds). Forest Owner Carbon and Climate Education Educator Guidebook. Part 1: Carbon Incentives for Forest Owners (Pre-Press). Forest Owner Carbon and Climate Education Program, Department of Ecosystem Science and Management, Penn State University, University Park, PA. Pp. 40-46.

Vanderschaaf, C.L., A.S. Larrain, S. Tanger, M. Kreye, S. Sharma. 2023b. Methods for Estimating Carbon Within Forests. In: M. Kreye, C. Norman, K. Brooks (eds.). Forest Owner Carbon and Climate Education Educator Guidebook. Part 1: Carbon Incentives for Forest Owners (Pre-Press). Forest Owner Carbon and Climate Education Program, Department of Ecosystem Science and Management, Penn State University, University Park, PA. Pp. 47-50.

Wise, L., G. Marland, J. Hoyle, T. Kowalczyk, T. Ruseva, J. Colby, T. Kinlaw. 2019. Optimizing Sequestered Carbon in Forest Offset Programs: Balancing Accounting Stringency and Participation. Carbon Balance Manage (14), 16. DOI: 10.1186/s13021-019-0131-y.