Forest Carbon Inventorying, Modeling, and Policy Linkages: An Assessment of State-level Readiness, Motivations, and Needs in USFS Region 9

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Forests stand to play a multifaceted role in climate change mitigation due to their potential for increased carbon sequestration, storage, and substitution. In turn, forest carbon inventorying and modeling are crucial steps in determining how to effectively manage forests for carbon and assessing the impacts of varied forest policies and management practices on future carbon dynamics. Despite the environmental impetus and increasing political motivation, only a fraction of states has undertaken forest carbon modeling efforts to inform policy and planning. Forest carbon inventorying and modeling at the state level can be both expensive and time-intensive; both require a certain degree of institutional capacity (in terms of expertise and resources) and agency or political prioritization.

As a component of the Forest Carbon Data and Modeling Integration and Evaluation Project, made possible with support from the United States Department of Agriculture, Forest Service Eastern Region (USFS Region 9), Michigan State University's Forest Carbon and Climate Program (FCCP) has undertaken an assessment of state-level experiences, readiness, motivations, barriers, and needs regarding forest carbon inventorying, modeling, communications, and linkages with state policymaking in USFS Region 9. This report lays out the methodological process and key findings from that analysis.

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Introduction

As a component of the Forest Carbon Data and Modeling Integration and Evaluation Project, made possible with support from the United States Department of Agriculture, Forest Service Eastern Region (USFS Region 9), this study has undertaken an assessment of state-level experiences, readiness, motivations, barriers, and needs regarding forest carbon inventorying, modeling, communications, and linkages with state policymaking in USFS Region 9 over the course of 2021-2022. This report lays out key findings from that analysis.

In this report, we first outline the project motivation for, and our methodological approach to the state-level assessment. The bulk of the paper explores our findings. We present a general spectrum of state capacity and readiness for forest carbon inventorying and modeling, followed by a discussion of major aspects affecting where states fall on that spectrum. Next, we discuss key knowledge gaps and identified needs regarding forest carbon inventorying and modeling, including harvested wood products (HWPs) and policy and communications linkages. Last, we explore trends in and observations on, the current motivations behind and interest in forest carbon modeling and forest carbon policy at the state-level.

Project Background and Motivation

Political motivations in response to environmental urgencies have led to national and sub-national climate ambitions, especially surrounding carbon. For example, U.S. states are increasingly developing targets—such as net zero emissions by mid-century—via executive orders or legislative action. Forests stand to play a multifaceted role in climate change mitigation due to their potential for increased carbon sequestration, storage, and substitution. Achieving net zero targets will necessarily incorporate climate-smart forest management (i.e., approaches to forest management that seek to increase the climate benefits from the forest sector) that ensures forest health and resiliency into the future.

As forests are diverse in terms of their species composition and structure, current management practices and goals, stakeholder preferences, and ecological concerns, among other dimensions, there is not one approach to climate-smart forest

management that can be uniformly applied across landscapes. Accordingly, sustainable, climate-smart management of forest ecosystems relies on robust information informed by inventory data and modeled projections. Capturing metrics on forest structure, carbon fluxes, and health and resiliency characteristics and assessing or projecting these measurements over time allows us to understand the impact management practices have had (or stand to have) on carbon and other important forest health indicators. These measurements are integral to managing forest ecosystems within a changing climate. They assist us in continuously adapting management practices and forest policies to maintain healthy and resilient forests capable of meeting the diversity of current and future demands.

Forest carbon inventorying and modeling are crucial steps in determining how to effectively manage forests for carbon and in assessing the impacts of varied forest policies and management practices on future carbon dynamics. Complementary inventorying and modeling approaches, e.g., those with an aim to capture the economic, social, and ecological impacts of forest management, can further inform how to do so efficiently and equitably while minimizing risk to forest health and resiliency. However, despite the environmental impetus and increasing political motivation, only a fraction of states has undertaken forest carbon modeling efforts to inform policy and planning. Engaging in forest carbon inventorying and modeling at the state level can be both expensive and time-intensive; both require a certain degree of institutional capacity (in terms of expertise and resources) and agency or political prioritization.

Our analysis seeks to better understand trends in experience, capacity, and need with regards to forest carbon inventorying and analyses at the state level. We aim to identify both the dominant knowledge, resource, and political barriers to engaging in forest carbon inventorying and modeling analyses at the state level, as well as the motivations and interests that have, or could, propel states and state forest agencies going forward.

In recognition of some of the observed knowledge gaps, and as a complementary component of the Forest Carbon Data and Modeling Integration and Evaluation Project, FCCP has additionally developed a six-part series of “Forest Carbon Resource Guides” aiming to address shared knowledge gaps on the following topics, which can be accessed on the Forest Carbon and Climate Program Open Resource Library:

- Background: Forest Carbon and Forest Carbon Management
- Topic 1: Forest Inventory Data and Complementary Data Sources for Carbon Calculations
- Topic 2: Understanding the Landscape of Modeling Approaches and Best Practices for Addressing and Interpreting Uncertainty
- Topic 3: Accessing and Applications of Forest Inventory and Analysis (FIA) Data for Modeling
- Topic 4: Forest Products Data and Modeling Considerations
- Topic 5: Linking Forest Carbon Modeling with State Decision-Making

We additionally hosted a webinar panel in September 2022 comprised of experts from academia and government to discuss key outstanding questions regarding, and experiences with, forest carbon measurement, modeling, communications, and policy linkages. A recording of the informative discussion is available on the Forest Carbon and Climate Program Open Resource Library.

Methods

We conducted a mixed methods analysis to assess state-level experiences, barriers, and motivations regarding forest carbon inventorying, modeling, and linkages with state policy in USFS Region 9. We conducted a survey of, and interviews with, targeted state-level forest agency employees identified as key informants due to their general expertise and involvement in forest mensuration, management, and planning, including carbon calculations. We conducted additional interviews with outside experts with diverse expertise, including forest carbon inventorying and modeling, policy communications and prioritizations, and state environmental decision-making. While states within USFS Region 9 were prioritized for assessment, states outside this region and topic area experts were included to further inform state-level experiences and readiness. While we did not have representative participation from each Region 9 state in both surveys and interviews, all states save Iowa were represented at least once between the two methods of analysis.

Survey and interview protocol development were informed by scoping interviews among forest carbon modeling experts from government and academia and select state forest agency personnel with known forest carbon modeling experience and developed in coordination with USFS Region 9 and FIA researchers. Coordination with FIA helped to identify current and anticipated state needs regarding forest carbon data, measurement, monitoring, modeling, and reporting, with an aim toward creating or refining effective knowledge-transfer tools tailored to states' data information and future modeling needs.

The multi-method assessment included the following dimensions:

- Exploration of currently available state-level forest inventory data as well as past or ongoing forest carbon modeling efforts
- Assessment of state-level technical and financial capability for inventorying and modeling, including challenges for data access, internal carbon modeling capacity, and potential information needs to improve internal capacity
- Determination of the state-level audience and motivations for carbon management (e.g., identifying linkages to state climate targets, agency policymaking processes, or engagement with forest stakeholders and state legislatures)

Survey

Surveys were conducted between May and June of 2022 and took approximately 30-40 minutes to complete. The survey was sent to 167 state forest agency personnel, of which 21 responded (response rate of 13%). Responses came from 16 states, 13 of

which are in USFS Region 9. The three states with respondents outside of USFS Region 9 were: California, Florida, and Oregon. While the survey was sent to identified forestry agency personnel in all USFS Region 9 states, we received no responses from Delaware, Maine, Maryland, Massachusetts, New York, or Wisconsin.

A diverse set of subject matter and analytical expertise is required to perform forest carbon inventorying, modeling, communications, and policymaking. Accordingly, forest carbon modeling is often a collaborative exercise. As such, the survey was designed to solicit information on "team-level" experiences, expertise, and knowledge. At the beginning of the survey, we defined "team" as: "a group of people who perform interdependent tasks to accomplish a common mission or specific objective, in this case forest carbon modeling and forest inventory and analysis." We noted that "depending on your position and role within your agency, your 'team' could be large (e.g., the entire department, agency, or division) or small (e.g., your immediate workgroup)." We also asked all respondents to briefly describe how they envision "team" for the purposes of the survey to ensure responses spoke to our intended unit of analysis.

The full survey questionnaire can be found in Appendix I. Key topics addressed include:

- Team-level
  - experience with forest carbon inventorying and modeling
  - knowledge about and experience using FIA data, state forest inventory data, and FIA Timber Product Output (TPO) data
  - knowledge about forest carbon science
- Agency-level
  - motivations for forest carbon inventorying and modeling
  - support for a diversity of potential forest carbon policies and initiatives
- Respondent perceptions
  - on forest management and HWPs utilization pathways or scenarios of potential modeling interest
  - on concerns, barriers, and needs regarding forest carbon modeling

Interviews

Interviews were conducted between November 2021 and July 2022. Some interviews were conducted as team interviews to ensure appropriate expertise was represented, while others were conducted individually. In total, we interviewed 30 state personnel. Expertise from nearly all states within USFS Region 9 were represented in the interviews, except for Illinois, Iowa, Missouri, and West Virginia. Out-of-region state forestry personnel from California, Florida, and Oregon were also interviewed.

State agency interviews were semi-structured and sought to understand:

- State-level experiences with forest carbon inventorying and modeling including scale and scope as well as data, software, and frameworks used
- Political, scientific, and other motivations for, and lessons learned from, state-level analyses (for those with experience modeling)
- Barriers, concerns, and needs regarding possible future forest carbon inventorying and modeling

See Appendix II for the interview protocol used for state agencies.

Additionally, seven outside experts from academic, government (USFS FIA), and non-governmental organizations were interviewed. These expert interviews were also semi-structured with their focus depending on the expertise of the interviewee. Collectively, they addressed the following topics:

- Variations in state-level capacity for forest inventorying and modeling
- Scientific and political difficulties and barriers to conducting forest carbon modeling in US states
- Strengths and limitations of FIA data for state-level carbon and modeling needs
- Future needs in forest inventorying and modeling
- Role of government, academia, and the private sector in forest carbon science, policy and management, and voluntary carbon markets

Results

In this section, we detail findings of the state-level survey and interview analysis. As expected, we find a diversity of experience, interest, and capacity levels among USFS Region 9 states.

Current State-Level Forest Carbon Activities

During the interview process, several states were identified as those who have invested in, or are currently investing in, forest carbon estimation and modeling efforts—either internally or through contracts and collaborations. Table 1 provides basic details on some key initiatives.

Regional Initiatives

Further, there are several notable large-scale projects being conducted at the regional level, such as the Landscape Scale Restoration Program and the Securing Northeast Forest Carbon Program.

The Landscape Scale Restoration Program is a competitive grant program funded through the State and Private Forestry mission area of the USFS. It promotes collaborative, science-based restoration of priority forest landscapes and furthers priorities identified in state Forest Action Plans or equivalent restoration strategies. These projects address large-scale issues such as wildfire risk reduction; watershed protection and restoration; and the spread of invasive species, insect infestation, and disease. Projects can encompass multiple jurisdictions, including tribal, state and local government, and private forest land.

The Securing Northeast Forest Carbon Program is a collaborative project of the North East State Foresters Association which includes Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont. It is funded through a grant from the USDA Forest Service. This project focuses on working forestlands,

encouraging private forest owners to secure their forest carbon through carbon sales in voluntary and compliance markets, engaging in climate-smart management practices, and participation in conservation easements.

Table 1. Examples of Key Forest Carbon Estimation and Modeling Initiatives Undertaken by States in USFS Region 9

State	Data and Modeling Approach	Funding and Motivation
Maine	Maine has assessed forest carbon mitigation potential using FIA data, remote sensing, Forest Vegetation Simulator (FVS), and the LANDIS-II forest landscape model. The final Task Force report can be found here.	Funded through the Governor's Forest Carbon Task Force
Maryland, Michigan, Minnesota, Pennsylvania, and Wisconsin	These states are conducting projects to assess alternate GHG pathways in the forestry and forest products sectors using the CBM-CFS3 modeling framework, parameterized by FIA data and other remotely sensed metrics of disturbance and land-use change.	Funded through the United States Climate Alliance (USCA) and carried out by a partnership between American Forests, MSU FCCP, and Northern Institute of Applied Climate Science (NIACS)
Massachusetts	Massachusetts has utilized FIA inventory data and FVS to model forest characteristics through space and time to assess the response of forest dynamics to management decisions.	Primarily focused on more traditional forest planning but includes a carbon component and is intended for internal agency planning, motivated by Massachusetts legislature and regional initiatives
New Jersey	New Jersey developed the Forest Management Optimization Model (ForMOM), a set of tools designed to optimize forest management for carbon and simulated using FIA data and the FVS. ForMOM applies linear optimization to FVS outputs to assess optimal management.	Motivated by internal planning for forest management and stewardship
New York	The New York Forest Carbon Assessment is developing a protocol using high-resolution forest mapping, change detection, and hierarchical forecasting for carbon accounting and future landscape change. This project is ongoing.	Funded by the New York State Department of Environmental Conservation and the New York State Environmental Protection Fund, state funding allocated for climate modeling and climate policy in collaboration with academia
Vermont	Vermont developed a framework to continually monitor forest carbon dynamics following IPCC guidelines (IPCC 2006) using FIA data on forest cover, carbon, and land-use change. The most recent forest carbon inventory findings can be retrieved here.	Motivated by the passage of legislation and by the Governor's office. Forests represent just one part of a statewide carbon budget

State-Level Experience with Forest Inventorying and Mill Data Analyses

Survey data reveal that while all states have utilized FIA summary reports, either internally or via external consulting, states have considerably more mixed experience with more advanced uses of forest inventory data (Figure 1). All states incorporate some level of biomass or carbon reporting, generally from FIA summary reports, into their State Forest Action Plans. These state-level plans, outlined by the 2008 Farm Bill, are comprehensively revised on a decadal time scale. State forest agencies are least likely to have conducted analyses using raw FIA data, with only 21% of respondents reporting having conducted such analyses internally and 62% of respondents reporting any raw data analysis internally or externally. Economic analyses to complement forest inventory analyses are most likely to have been conducted externally (e.g., by consultants or academic partners), with 60% of all reported economic analysis having been conducted externally.

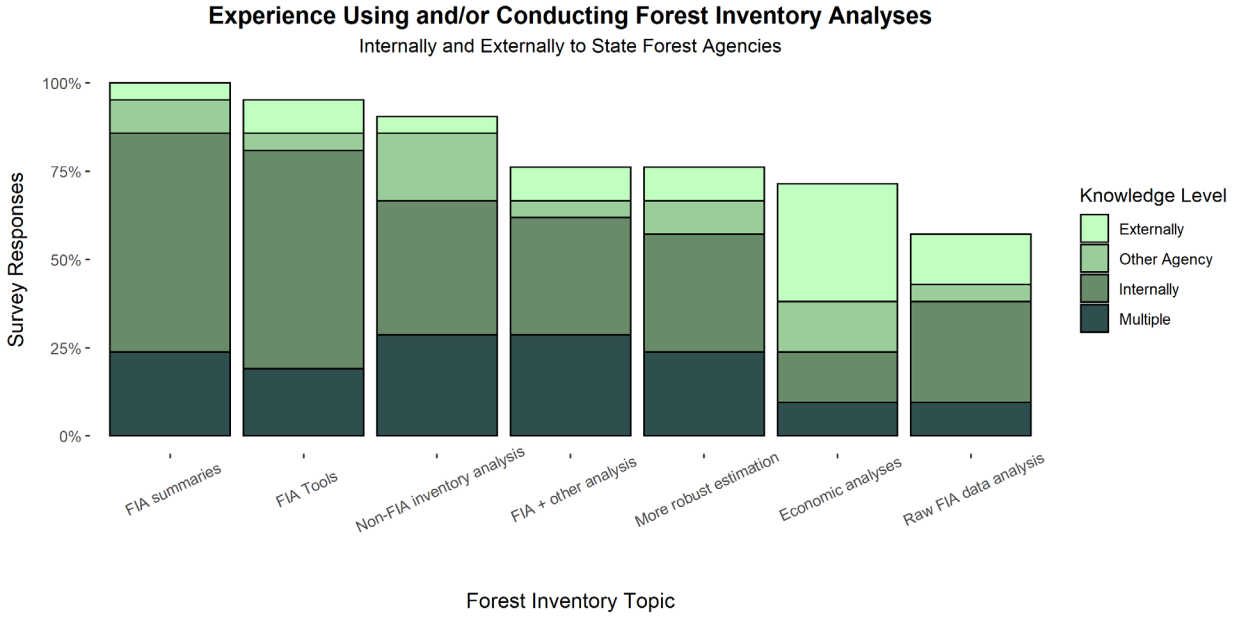

Figure 1. State experience with diverse elements of forest inventory data use and analysis, conducted within state forest agencies, by other state forest agencies, or externally (e.g., with consultants or academic partners). See survey question 6 in Appendix I for survey wording and response categories.

Within the sphere of HWPs, the most common type of mill data engagement reported was the use of state-collected mill data reports or summary estimates. The use of TPO/RPA reports or summary estimates came in third overall and second among those state forest agencies conducting internal analyses. As Figure 2 shows, there is limited experience estimating or quantifying carbon stored in HWPs, with only 33% of respondents reporting state experience with this type of analysis, conducted either internally or externally. Even fewer respondents (24%) reported any kind of analysis looking at the potential for fossil fuel carbon offsetting. There was equally little analysis experience on elements of HWP carbon accounting relying on consumer use and behavior, e.g., product half-lives, end-uses, and retirement (e.g., rates of recycling, landfilling, and burning).

States are, overall, less likely to have engaged in HWP analyses than in forest inventory analyses; even those states that have made good progress with forest carbon modeling have not fully incorporated mill and timber product data into their models. Mill data are more typically used for economic and industry-related applications than for carbon budgeting. Most states surveyed report having used mill and timber product data to conduct economic analysis on HWPs as well as having conducted import and export analysis on HWPs, with 62% and 71% of respondents reporting these activities, respectively. Around 38% of respondents report having conducted product feasibility analyses using mill data, with most relying on external consultants. Relative to other categories, analyses relating to economic dynamics have the highest rate of being conducted externally (e.g., by consultants or academic partners). Of the 62% of respondents reporting any HWP economic analysis, 46% were reportedly conducted externally.

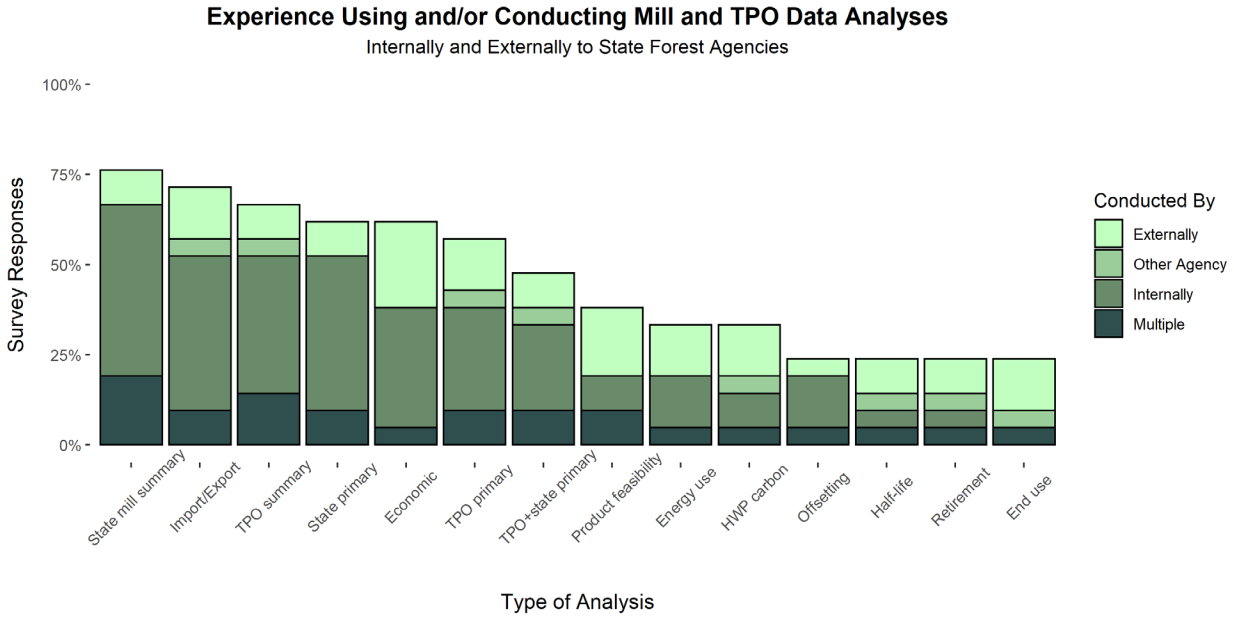

Figure 2. State experience with diverse elements of mill data use and analysis, conducted within state forest agencies, by other state forest agencies, or externally (e.g., with consultants or academic partners). See survey question 15 in Appendix I for survey wording and response categories.

Overview of State Capacities, Strengths, and Needs

States within USFS Region 9 differ in their capacities for engaging in forest carbon inventorying, modeling, and policy linkages. States share common strengths such as expertise regarding traditional forest ecology, management, and planning. However, common barriers to incorporating forest carbon management and climate goals into policy and decision-making were reported across all states, albeit to differing degrees. Common barriers include:

- Insufficient capacity (time and expertise)
- Insufficient resources/funding
- Data limitations
- Not a state priority

Key divergences across states include:

- Knowledge about forest carbon dynamics and carbon accounting of forest sector emissions
- Degrees of state and agency prioritization (as evidenced by personnel, funding, and time dedicated to forest inventorying and modeling)
- Goals for forest carbon accounting (carbon markets vs. GHG reduction targets)
- Strength of forest inventory data (e.g., some states have dedicated resources to inventory additional FIA plots whereas other states, particularly geographically smaller states, may have insufficient plots for reliable projections)
- Knowledge about common forest management practices on private, tribal, and federal lands
- State political context, geographical size, and economic impact of forest sector

Spectrum of State Activity and Needs in Forest Carbon Management

There are three general categories into which USFS Region 9 states fall regarding forest carbon management activity:

1. Those that *have not engaged* in planning or management for forest carbon and climate goals;
2. Those that *have begun to consider* forest carbon management and planning, with additional climate goals; and
3. Those that *have taken concrete action* regarding the assessment of forest carbon management to inform state climate goals.

In Table 2, below, we describe these three categories and lay out their overarching *knowledge-based* needs (each of these groups will have additional needs pertaining to available resources, funding, and personnel). These reflect knowledge-based needs expressed by key informants at their state's particular stage of forest carbon engagement.

Table 2. Three Categories of State Interest and Readiness in Forest Carbon Inventorying and Modeling (Low, Moderate, High)

Group	Description	Knowledge-Based Needs
Low activity: *Have not engaged* in planning or management for forest carbon and climate goals	Often lack directives from the governor or legislators but may have other climate objectives or concerns such as adaptive management for future climate conditions	• General information on forest carbon science, forest carbon estimation, and available tools • General information on voluntary carbon markets to provide improved guidance to landowners • Training on carbon considerations in forest management and how to inform landowners thereon • Communication of the basics of carbon science to landowners
Moderate activity: *Have begun to consider* forest carbon management and planning, with additional climate goals	Actively exploring forest carbon management goals along with interest in voluntary carbon markets	• General information on voluntary carbon markets to provide improved guidance to landowners • More specialized information on forest carbon science, forest carbon estimation, and available tools • Guidance on best practices and technical skills for carbon estimation and modeling • Communication of complex carbon science and modeling results to policymakers, government agencies, private industry, and landowners
High activity: *Have taken concrete action* regarding the assessment of forest carbon management with an objective of informing state climate goals	Actively engaged with forest carbon science to meet their goals of GHG reduction through the forest sector and tend to have clear directives through executive action or legislation	• General information on voluntary carbon markets to provide improved guidance to landowners • Guidance on best practices for and advanced methods of forest carbon estimation and modeling • Continual analyses of forest carbon to update goals and priorities on a regular basis • Communication of complex carbon science and modeling results to policymakers, government agencies, private industry, and landowners

Spectrum of State Capacity and Interest

Surveys with key actors across USFS Region 9 reveal state-level variation in capacity for and interest in forest carbon inventorying, modeling, and communications to support climate mitigation goals. Figure 3 relies on survey index scores across the two dimensions of capacity and interest to visualize where each state falls on this spectrum. To create the index values, eleven and eight survey questions were identified as speaking to state capacity and interest, respectively. Likert scale questions were coded numerically and then averaged to calculate state-level scoring across the two dimensions. Low, medium, and high bins were determined by natural breaks in the data. Note that only those states with at least one survey respondent are represented in the matrix.

Interest \ Capacity	Low	Mid	High
Low	Illinois Ohio Rhode Island		
Mid	West Virginia	Connecticut Missouri Indiana	New Hampshire
High		Michigan Vermont	Minnesota Pennsylvania

Figure 3. In this state capacity and interest matrix, states were identified as being high, medium, or low along each dimension using survey index scores.

Driving Factors of State Interest and Readiness

We identified three major aspects that influence the degree of state-level engagement with forest carbon inventorying, modeling, and climate mitigation goals: 1) state-level policies and political environment, 2) forest landowner preferences, including the role and size of the forest industry, and 3) geographic dimensions. These

three aspects help explain underlying variation across states in state-level motivation and behavior regarding forest carbon inventorying and modeling. Notably, these factors intersect and inform one another. They do not necessarily predict or classify a state's level of forest carbon interest but are dimensions that play a part in shaping varied state levels of engagement with forest carbon management and assessment. It should be noted that the forest carbon landscape is ever changing and that the trend, more recently, is toward states seeing increased awareness and interest in forests more broadly evident in both state and federal actions. The state examples discussed below reflect that status of state experiences in mid-2022 and may not reflect the current experiences as aspects that influence state-level engagement are dynamic and ever changing.

State Politics and Policies

The internal politics of a state—influenced by the preferences of elected officials, government bureaucrats, and the relative strength of civil society organizations and their priorities—help shape state policies for climate change mitigation and adaptation, forest carbon management, and public land management. States considered more politically progressive are more likely to have adopted legislation with targets for GHG reductions and to have allocated funding to use toward combating climate change. These states generally link climate change, forest carbon, and other ecosystem services (such as water quality, reduced air pollution, and climate justice) in a holistic understanding of what systems of change require. For example, Maryland's Greenhouse Gas Reduction Act plan for 2030 states that:

> *When attempting to either qualify or quantify the value of ecosystems, a term commonly used is "ecosystem services". These refer to the benefits and resources afforded to people by the normal and healthy functioning of the ecosystem such as robust fisheries, cleaner air and drinking water, and recreational opportunities. [. . .] People depend on these ecosystem services, and loss or degradation of the ecosystem will have a negative impact on both the quality of life and the economy in Maryland.*

A state's internal political environment also informs the types of public land management goals that are prioritized over others. Publicly owned land (federal as well as state) is under multi-use management, meaning that goals for forest carbon and timber supply exist alongside many other important management objectives such as recreation, wildlife habitat, water quality and supply, non-timber resource extraction, and provision of other ecosystem services. Interviewees across all states reflected on the importance of political *priority.* Where states have low political motivation to implement forest carbon and climate change programs and policies, few resources or opportunities are made available to pursue forest carbon inventorying and modeling exercises.

Where states *had* engaged in forest carbon inventorying and modeling, political leadership and state GHG targets were noted as key motivating forces. See Appendix III for a list of USFS Region 9 states with either executive orders or legislation in place supporting climate targets.

Aside from legal frameworks within state politics, other pathways to achieving climate goals exist such as:

- Formation of councils to guide efforts in achieving climate targets
- Allocation of funding toward carbon initiatives, including forest carbon modeling
- State level planning documents, which communicate values and help set priorities, even without the weight of legislation appropriation, such as the Michigan Healthy Climate Plan
- Internal state agency planning which prioritizes climate targets

Initiatives across states are often directly motivated by the legal and political pathways listed above. For example, interviewees report that ongoing efforts in both New York and Vermont to estimate and forecast forest carbon are primarily motivated by legislative action. Efforts in states such as Michigan are primarily being driven by expectations set by the Governor's office and value-setting documents such as the Michigan Healthy Climate Plan. Interviewees from states that don't have clear policy pathways for forest carbon or GHG reductions, such as Delaware, reported less focus on climate mitigation and more on adaptation efforts. These may include actions such as addressing sea level rise in coastal forests, managing for future species ranges, or for future pest and disease pressures. These activities may have carbon implications but generally prioritize biodiversity, forest health, and resiliency over forest carbon storage.

Forest Landowner Concerns and Preferences

Understanding the relationship between state agency management priorities and landowner input is complex. In some cases, with Vermont as an example, interest in legislative action (such as state carbon targets and forest policies) stems from landowners, foresters, forest advocacy organizations, and other forest stakeholders; however, it is necessary to acknowledge that landowners may influence more than just legislation or policy priorities. Interviewees strongly reinforced the notion that forest landowners, through direct interactions with state foresters or forest agency staff, inform forest agency management priorities and the types of climate-focused projects conducted in a state. Forest agencies are highly cognizant of landowner perceptions during forest planning activities. Where sufficient resources exist, state agencies establish management priorities for forested land based on the perceived needs and desires of its citizens. For example, The Securing Northeast Forest Carbon Program is a result of collaboration between states with direct input from forest landowners regarding their needs and priorities.

While forest landowners both within and across states are diverse, patterns across ownership types and preferences emerge. First, in states where the forest sector is a large piece of the economy, and has corresponding representation (e.g., Maine and Vermont), state interest in carbon modeling tends to be higher. These states also tend to have more developed carbon management and climate goals. These interests and actions are driven in part by the fact that climate conditions in many areas are projected to negatively impact the habitats of valuable timber species, disrupt traditional management practices, and reduce profitability of the sector. Accordingly, management practices that mitigate and adapt to climate change (with resulting positive carbon implications) are a priority for forest stewardship as they lead to

greater forest resilience and stability. Forest carbon inventorying and modeling, particularly of diverse forest management pathways, or scenarios, can help optimize forest management with these concerns in mind.

Among other issues, landowner preferences help to shape prioritization across near- and long-term concerns and in balancing trade-offs between carbon sequestration and storage and other ecosystem services. Some states may prioritize adaptive management techniques that increase long-term forest resilience but result in near-term reductions to carbon storage and sequestration. For example, Connecticut is currently focused on managing for climate resilience in the face of current and predicted pest and disease pressures, rather than solely prioritizing increased forest carbon sequestration rates. Interviews with Connecticut forest managers corroborated that these priorities have been set in direct response to issues faced by landowners. Connecticut is also providing training in forest carbon science to private and public foresters such as is prioritizing climate-smart forestry practices, which theoretically improves both growing-stock and short-term sequestration rates while increasing potential for carbon storage in long-lived wood products so that they can better inform landowners on the tradeoffs between management that prioritizes carbon storage over other goals. These trainings include information on how to advocate for landowners and inform of them of potential opportunities in the voluntary carbon offset markets. According to the interviewees, future steps will include greater focus on managing for multiple goals including climate resilience, mitigation, and adaptation.

An increasing number of private forest landowners at both the large- and small-scale are weighing the market value of their timber against options for carbon credit generation via delayed harvest and other shifts in forest management. Accordingly, many states report an interest in bolstering landowner knowledge about carbon markets and opportunities for engagement. Nearly a third (32%) of survey respondents reported strong interest in assessing or implementing programs that would encourage or support carbon projects on private lands, with another 42% reporting some interest. A similar percentage, 37%, reported strong agency interest in assessing or implementing carbon projects on state lands, with another 37% reporting some interest.

Last, not all climate change initiatives involving forests focus specifically on carbon sequestration and storage. Instead, they may focus on goals such as protection of other forest ecosystem services, increased resilience, and greater adaptive capacity—all of which may be informed by current issues facing landowners. For example, consider the states of Delaware and Vermont. Each of these states has significant interest, driven by a variety of factors, in managing forests for climate change. However, they have taken different actions based on the priorities and perceptions of landowners within their borders. Delaware, a coastal state, prioritizes the future effects of sea-level rise and ensuring the resiliency of coastal forests. By contrast, Vermont is prioritizing the current and future offset potential of GHG emissions via its natural and working forests with a focus on forest resiliency and adaptation. Because Vermont landowners experience fewer effects of sea-level rise, compared to those in Delaware, the state has pursued priorities for forest management accordingly.

Geographic Dimensions

While a state's climate and forest management priorities are informed by the role and size of the forest industry within its borders as well as its particular politics and policies, these factors are also influenced by the specific geographic dimensions of the state. These can include variables such as the geographic size of the state, overall forest extent relative to the states' land area, distribution of forestland ownership (i.e., percentage of small holders versus large industrial owners or percentage of federal land versus state land), and the predicted effects of climate change on forests as influenced by location, physiographic characteristics, hydrology cycles, and other geographic characteristics of the state.

Generally, states with smaller total land area tend to be less influenced economically by forest industry than their larger state counterparts due to their relatively smaller areas of forested land and potentially the subsequent lower forest sector economic contributions, as a percent, of gross state product. However, small states with a high percentage of forest cover, such as Connecticut and Massachusetts (55% and 56%, respectively), maintain strong interest in bettering their understanding of the status and future trends of forest carbon in their state. The spatial distribution of urban cores relative to rural areas may also play a strong role in climate and forest management priorities specifically when a large proportion of a state's population is centered in a few relatively small urban centers consolidating political power, wealth, or ideology. This knowledge can inform best management strategies focused on addressing current management challenges, future forest stewardship, and resilience. Nonetheless, incorporating knowledge of forest management and trade-offs between forest carbon and other ecosystems in GHG inventories remains challenging including guaranteeing all perspectives of the forestry sector (foresters, loggers, truckers, sawyers, etc.) are included in discussions to ensure best management strategies.

For example, Delaware has initiated a climate effort called the Tree for Every Delawarean Initiative (TEDI). The goal of this program is to plant one tree for every Delawarean, improve air and water quality, preserve soil, and support wildlife through climate change adaptation and mitigation. While this program does not include explicit linkages to other climate initiatives focused on GHG emissions reductions, it acknowledges that planting trees increases both the sequestration and storage of carbon across the landscape.

Likewise, Rhode Island does not currently have state legislation showing clear connections between forest management and GHG emissions reductions (despite the fact that, as with other states, the importance of forests and their role in carbon mitigation and improved air quality is made present in many GHG emissions statewide goal reports). In this case, the apparent cause is low awareness of, and visibility for, forest management and climate mitigation actions in the state legislature. This lack of priority for forests is likely due in part to the small size of the forest industry in Rhode Island along with the fact that most landowners own relatively small parcels. A future focus on urban forest management—including non-carbon goals such as stormwater management, energy savings, and community health—and developing resources for

private landowners is of state interest[1]. There are currently efforts underway to inventory and assess urban forests throughout the state in support of a variety of goals.

In each of these examples, the specific context and geographic dimensions of the state are reflected in agency priorities. These priorities are set and informed by landowner perceptions and goals, state politics, and the relative influence of the forest industry.

Knowledge Gaps

Through analyses of survey and interview results, we identified knowledge gaps across four main areas:

1) forest inventorying and carbon estimation,
2) carbon dimensions of harvested wood products,
3) carbon analysis of GHG emissions and pathways to GHG reductions, and
4) communication of results to inform public and private decision-making.

These link strongly to aspects of state readiness to engage in forest carbon management and set climate goals. Therefore, all four areas would be best addressed simultaneously in a holistic and comprehensive manner. Notably, there is overall strong support for building internal capacity for forest carbon modeling, with 40% of survey respondents preferring to build in-agency capacity for carbon modeling rather than rely on, or collaborate with, external experts, and another 30% reporting a preference for both building in-house capacity and working with outside consultants. Only 10% of respondents preferred only hiring outside consultants for future carbon modeling analyses.

Forest Inventorying and Carbon Estimation

FIA collaborates with state agencies, providing detailed information annually on state-level carbon stocks and stock changes. States utilize FIA estimates and reports in their planning and policymaking, but the ability to explore and analyze further questions is limited by technical capacity and time constraints. For states that have shown little interest in forest carbon and climate goals, this is particularly true.

Most respondents reported a high level of team familiarity with the content of the FIA database and their ability to access and interpret FIA data. However, there is an important divide among states when it comes to their ability to use these data for forest carbon and biomass calculations, of particular importance for forest carbon inventorying and modeling (see Figure 4). About half report expert team knowledge on this topic with the remaining half reporting moderate, limited, no, or unknown knowledge about using data for forest carbon and biomass calculations.

[1] Since the time of the interview, fires in Rhode Island have increased interest in forests, resulting in increased staffing support, and a commission to understand the role of state government in helping prevent wildfire occurrences. Additionally, bond monies have been allocated for the first time for state properties to increase active forest management activities.

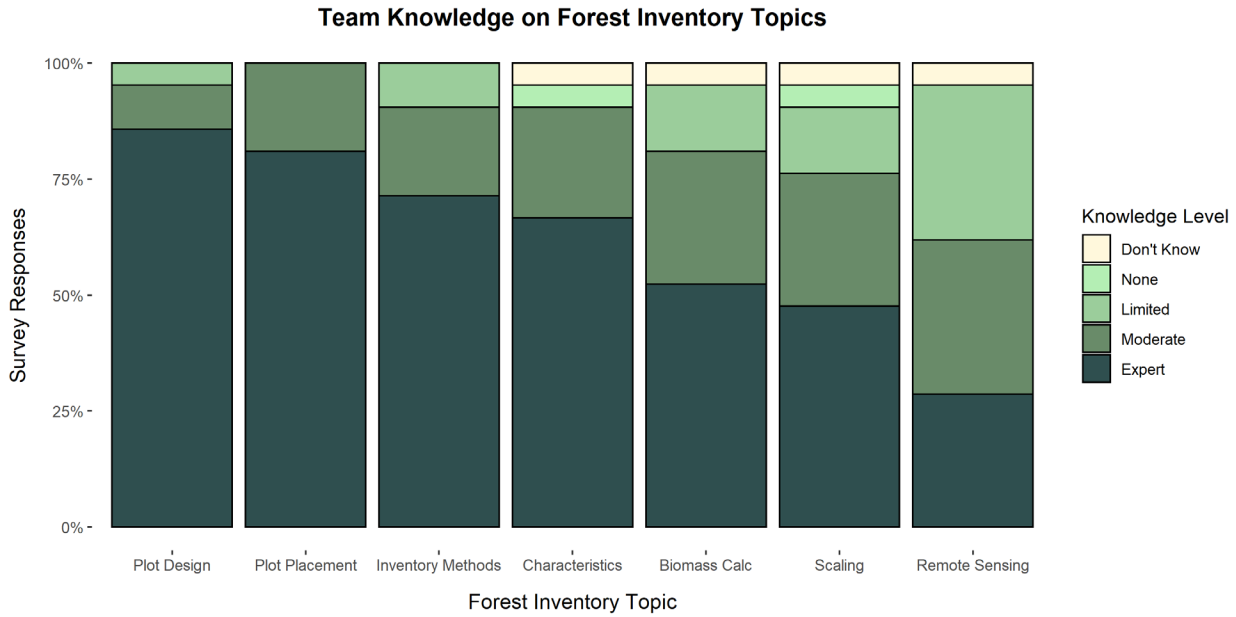

Figure 4. Reported team knowledge on various forest inventory topics. See survey question 5 in Appendix I for survey wording and response categories.

Generally, the weakest area of knowledge on forest inventory topics is around remote sensing. This is true across all states surveyed. Aware of this knowledge transfer need, FIA has goals to bring more understanding to states on how to use remote sensing data. Results from our interviews clearly indicate that while all state forest agencies report carbon and biomass estimations in their Forest Action Plans, as required by the 2008 Farm Bill, those states lacking in higher readiness report only general trends and status reports. Due to capacity constraints, most state forestry agencies are unable to conduct analyses using newer technologies such as remote sensing or to perform such analyses on a continual basis, thereby limiting their knowledge of forest carbon dynamics in their states as well as limiting potential opportunities for improved mitigation and non-carbon co-benefits.

Furthermore, in states that have an active voluntary carbon market, complications and questions exist when attempting a statewide carbon budget because much carbon sequestration is often being earmarked or sold as an offset out of state (leading to concerns of carbon double-counting). Questions remain around how much of the carbon sequestration occurring on private lands can be counted toward a state government's GHG reduction goals.

Forest Management Behavior

Knowledge of state silvicultural methods and activities is a crucial component of forest management pathway, or scenario, analysis. That is, if one wants to model the projected carbon impacts of diverse forest management practices over time, one needs to understand current forest management practices. While all respondents report expert knowledge of activities on state-owned land, knowledge about management practices across other ownership categories (private, USFS,

local/municipality, and tribal lands) is considerably more limited overall and mixed across states (Figure 5).

Perhaps surprisingly, overall knowledge about management practices on USFS land is moderate, with 19% reporting limited knowledge, 38% reporting moderate knowledge, and 33% reporting expert knowledge. Those states which are contracted to manage USFS-owned land, perhaps predictably, have more expert knowledge. When it comes to private lands, there is a division among states with 62% reporting expert knowledge and 24% and 14% reporting moderate or limited knowledge, respectively.

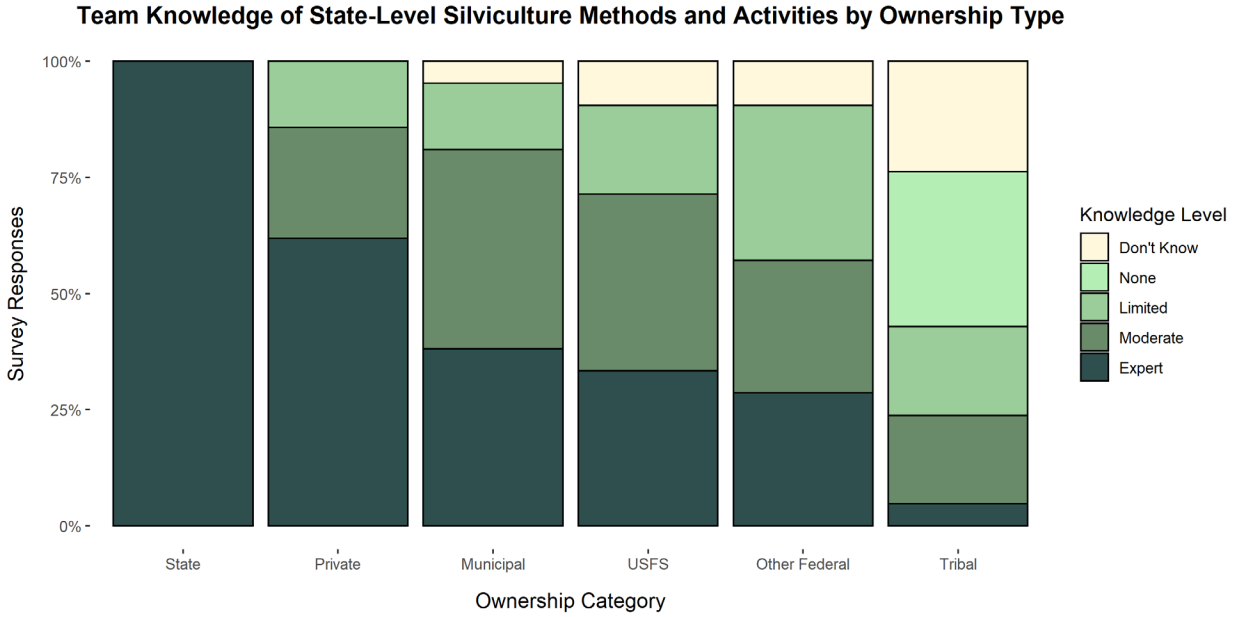

Figure 5. Reported team knowledge on state silviculture methods and activities by diverse ownership types throughout the state. See survey question 11 in Appendix I for survey wording and response categories.

For those states without expert knowledge of silvicultural methods in use on private lands, there is often a basic understanding of land management practices though this is not tracked with data. Interview results corroborate survey findings, underscoring a knowledge gap regarding management of private lands, specifically when looking at small-scale holdings. States that are in a better position to understand the forest carbon implications of management on private land are those that track harvest removals through voluntary mill procurement reports (such as Vermont) or those that track import information and conduct secondary wood producer surveys (such as New York). Knowledge about silvicultural methods on tribal lands is most limited, with only one state reporting expert knowledge and 33% reporting no knowledge; there were no other ownership categories for which any states reported 'no knowledge' of silviculture methods.

Harvested Wood Products

Regarding the forest products sector, most respondents report expert or moderate knowledge about what TPO surveys measure (Figure 6) and most states have

consulted fact sheets on mill data (both TPO and state-collected data, see Figure 2). However, there is moderate reported expertise in using TPO data to support state-level management planning needs, and even less experience conducting HWP carbon analyses (Figure 2). While 35% report expert team knowledge in interpreting TPO data, only 15% of respondents report expert team knowledge regarding TPO data access or understanding data structure and attributes (Figure 6).

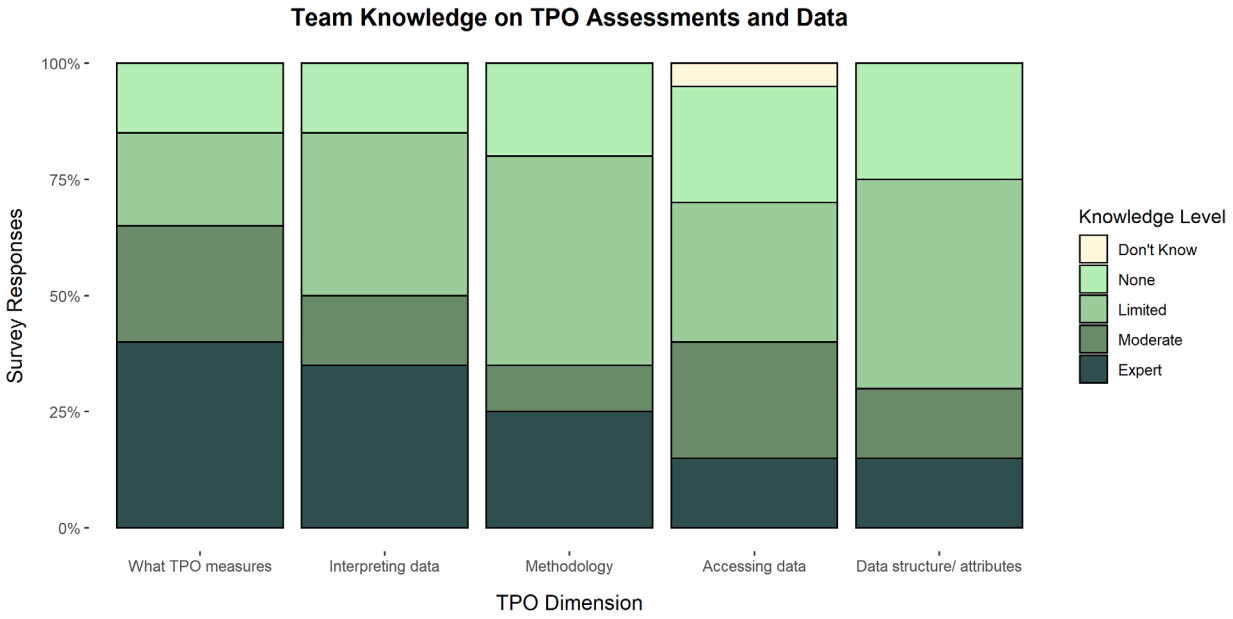

Figure 6. Reported team knowledge on TPO assessments and data. See survey question 14 in Appendix I for survey wording and response categories.

A component of HWP carbon analysis with which interviewees reported uncertainty relates to how to quantify wood (and carbon) moving in and out of a state, both for accurate carbon accounting and realistic scenario development; most timber harvest data are conducted at the state level, while timber markets and wood baskets rarely obey state lines. No state in USFS Region 9 has meaningfully engaged with quantifying potential emissions from state-level product substitution or leakage rates, critical components of HWP carbon analysis that inform the multi-sector carbon impacts of diverse management and wood use pathways.

Carbon, product end uses, product half-lives, product retirement, and HWP energy use were the least reported types of HWP analyses (Figure 2), all of which are important components of HWP carbon accounting and projections for understanding climate implications. Interviews bolster these survey results with participants stating improved knowledge in these areas would significantly boost the capacity of state forestry agencies to understand carbon dynamics in the forest products sector. In particular, such insights would better inform future planning for wood utilization and HWP markets. These findings point to a deep need for knowledge transfer materials, updated trainings, and improved communication tools on HWP uses and carbon cycling.

Carbon Projections and Pathway Assessments for GHG Reductions

Surveyed respondents report a relatively high level of team understanding on the topics of forest carbon pools/stocks and carbon cycling dynamics in forest ecosystems (Figure 7). There is more limited knowledge about forest carbon fluxes and gas exchange and the least knowledge about carbon and biomass accounting.

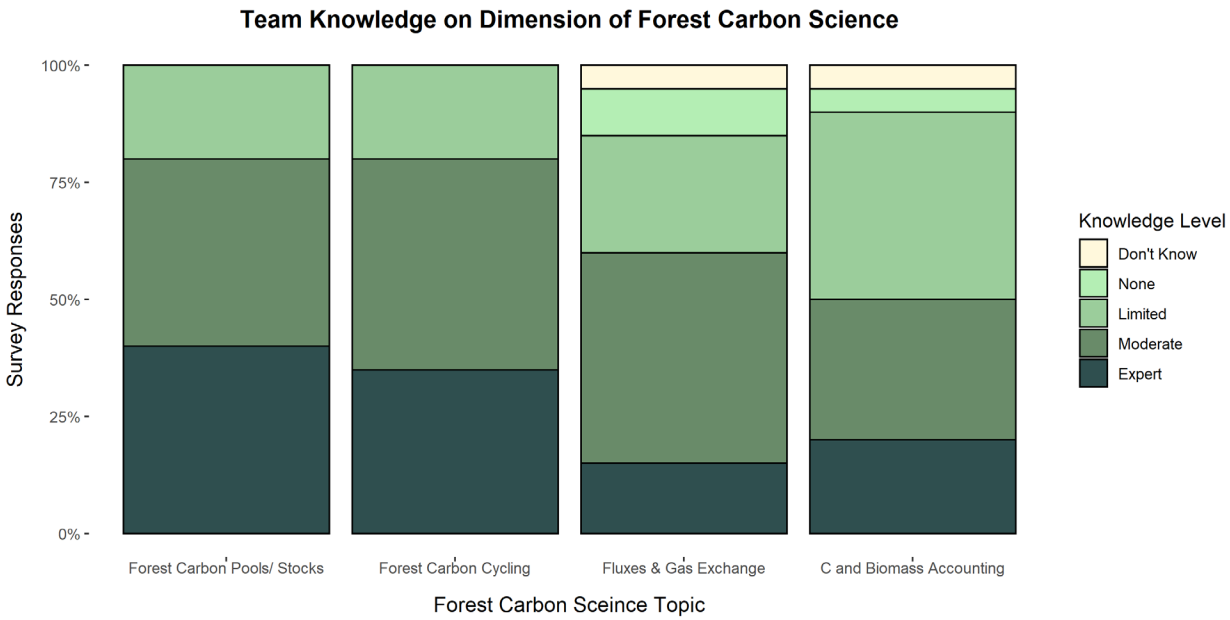

Figure 7. Reported team knowledge on dimension of forest carbon science. See survey question 18 in Appendix I for survey wording and response categories.

Few states have the technical capacity to comprehensively analyze sector-wide GHG emissions (including both forests and HWPs). Higher-capacity states who find themselves further along on the spectrum of state readiness discussed above are proactively seeking guidance on how to achieve this. They are also seeking methods to reliably analyze future pathways for GHG reductions within natural and working lands to support state climate goals.

As Figure 8 visualizes, there is relatively little team expertise on dimensions of forest carbon accounting and modeling. Only 20% and 40% of respondents, respectively, reported expert or moderate team knowledge on what data sources exist that can be used in forest carbon accounting, a prerequisite for engaging in forest carbon inventorying and modeling. Perhaps surprisingly, no respondent reported team-level expert knowledge about which forest carbon modeling frameworks might best suit state or agency goals or about the approaches other states are taking to forest carbon modeling. Most states would benefit from knowledge transfer geared toward the various aspects of carbon estimation shown in Figure 8.

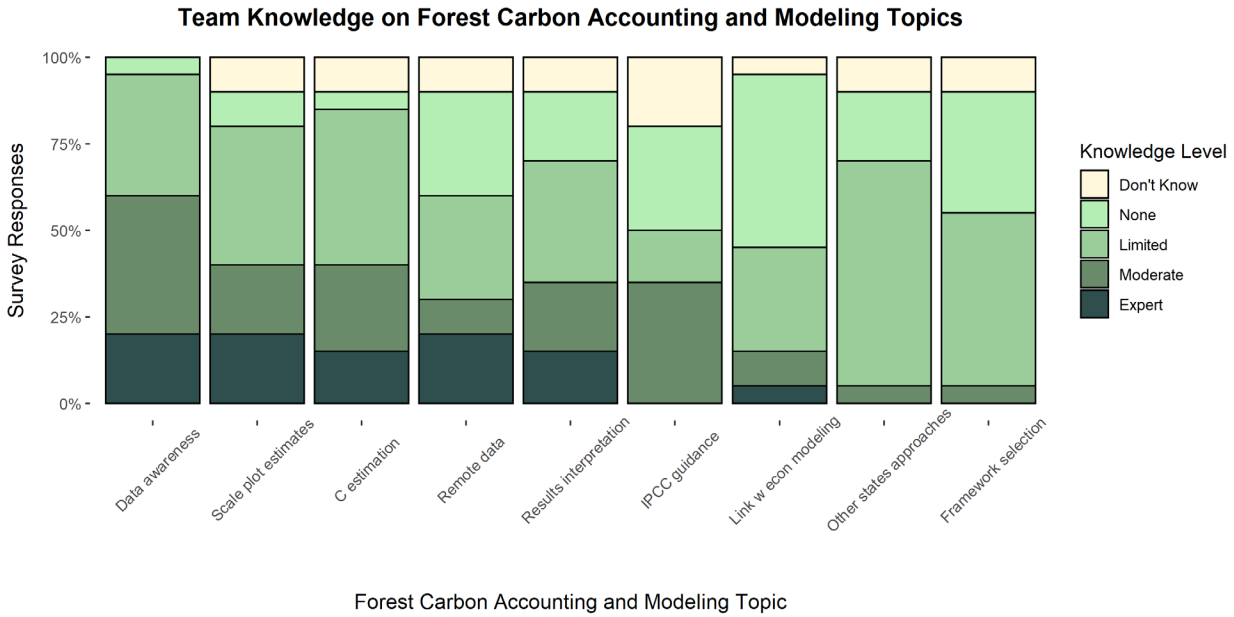

Figure 8. Reported team knowledge on forest carbon accounting and modeling topics. See survey question 20 in Appendix I for survey wording and response categories.

States would benefit from greater awareness of and expertise with methodologies that can be used to forecast and analyze future management decisions to predict how they might impact forest carbon dynamics. Interviews reinforced this deficit. Even high-capacity states that display strong readiness indicators rely on collaboration and support from universities and academia to perform comprehensive analyses and monitoring. Interviews with experts outside of state forest agencies maintained that there is a shortage of people with the training and skills to build and run models specifically for forest carbon dynamics and GHG emissions analyses.

Communication of Results to Inform Public and Private Decision-Making

The need to find ways to effectively communicate information on forest carbon data, management priorities, and climate goals is a unifying theme across states. Forest stakeholders require tailored information relevant to their situations and decision-making needs. Accordingly, state agencies hoping to communicate to diverse forest stakeholders will require a diversity of data, knowledge, and communication strategies. For example, private landowners may need information such as estimated carbon per acre on their property; projections on the ecological, carbon, and cost implications of various management decisions; and guidance on how to navigate public programs and voluntary carbon markets. On the other hand, state-level decision makers, such as agencies, executive departments, governor's offices, and legislators would benefit from statewide estimations of forest carbon stocks and fluxes, as well as projected carbon impacts from shifts in forest management across ownership types (to best inform state forest management as well any potential incentive programs on private lands).

Linking carbon to policy is of bidirectional importance. First, communication of results to policymakers is essential for achieving impacts on the ground; second, policy

awareness among modeling teams can help shape scenario developments for assessment. Of those surveyed, only 15% reported high team-level expertise communicating the links between carbon assessment and modeling results to policymakers and 50% reported either no or limited knowledge in this arena (Figure 9). In the other direction, only 15% of respondents reported team-level expert knowledge on existing state programs and policies impacting state forest management decision-making, with 45% reporting limited or no knowledge. Interestingly, while a consistent 15% of respondents report team-level expertise in each of these domains (communicating to policymakers and understanding state policy), they are not the same respondents; the same is true for those reporting no or limited expertise. Knowledge of other states' policies (and so alternative potential forest carbon policy levers) is even lower, with no respondents reporting expert team-level knowledge and 75% reporting limited or no knowledge.

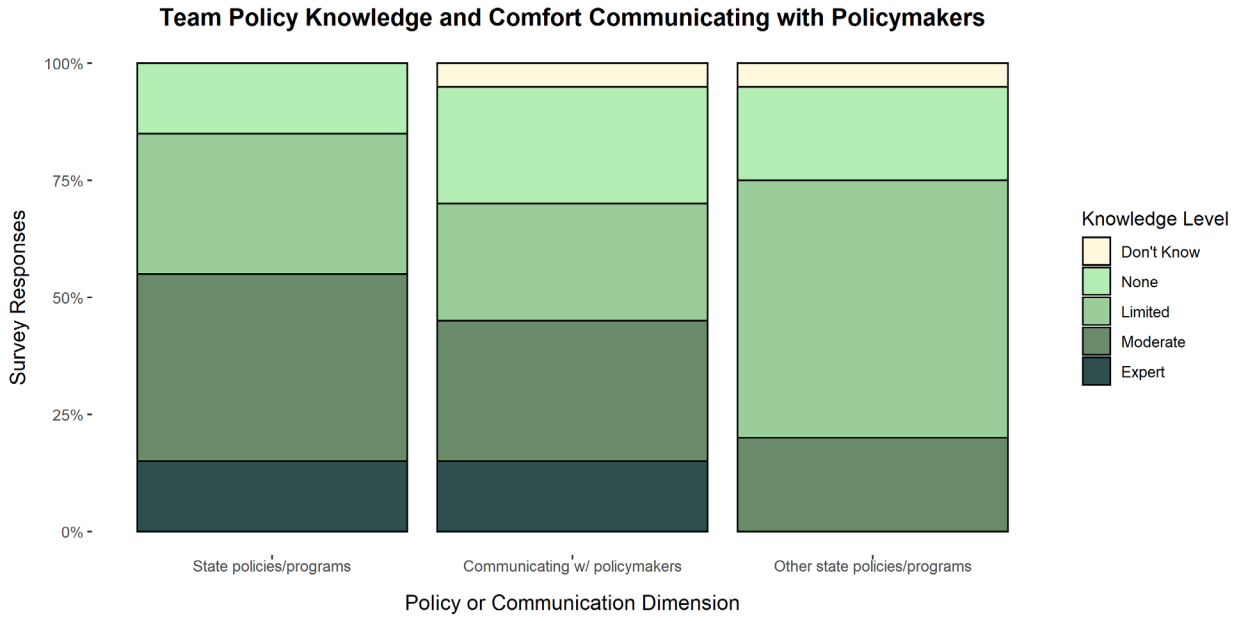

Figure 9. Reported team comfort communicating forest carbon science and results with policymakers as well as reported team knowledge about policies and programs impacting forest carbon, in their state as well as others. See survey question 20 in Appendix I for survey wording and response categories.

There is also generally low knowledge, or comfort, communicating the links between forest carbon and related environmental and policy dimensions (see Figure 10), with communicating links between forest carbon and climate change ranking highest and links between forest carbon and agriculture and other non-forest ecosystems ranking lowest.

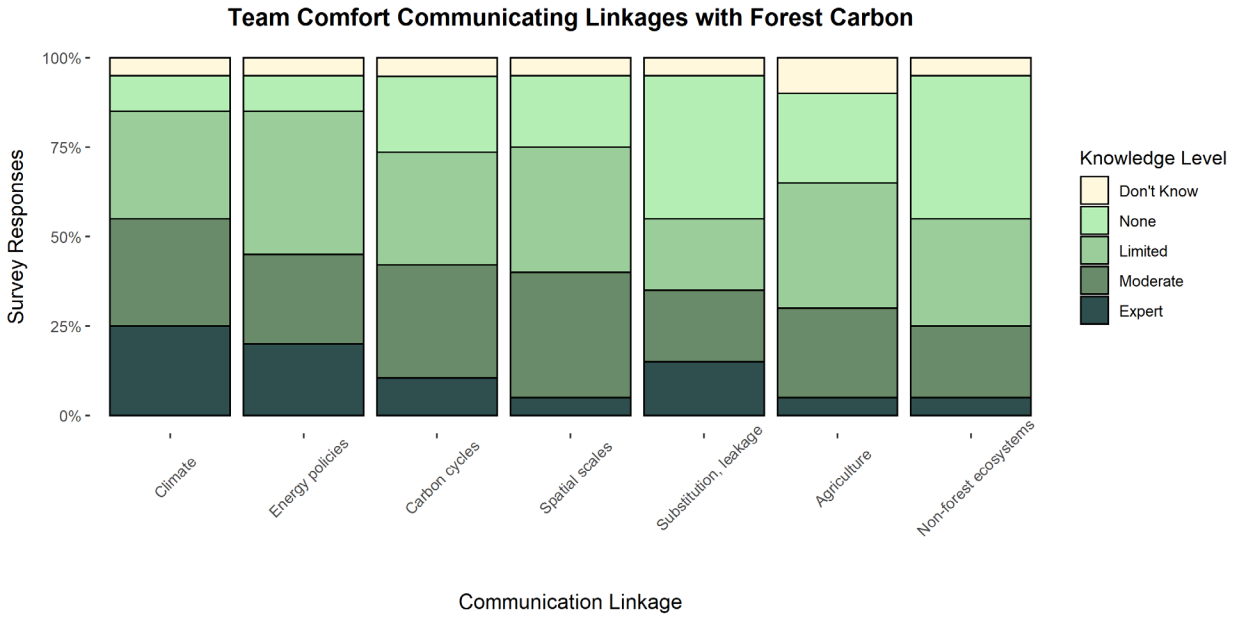

Figure 10. Reported team comfort communicating linkages between forest carbon and related environmental and policy topics. See survey question 20 in Appendix I for survey wording and response categories.

Survey results point to a strong knowledge transfer need within agencies to support their role in more effectively communicating with landowners and policymakers on forest carbon estimation and modeling. This is linked to the need to provide updated and useful information on carbon modeling to inform participation in and decisions regarding carbon markets. Interview results support these survey findings with forestry professionals reporting a lack of clear guidance on how to best inform landowners concerning their land management decisions juxtaposed against the status of voluntary offset markets.

While both state and consulting foresters are comfortable advising landowners in more traditional modalities such as prescribing silvicultural regimes to manage for merchantable timber and ecosystem services, their expertise is limited when landowners seek advice on managing their land for carbon storage and participation in carbon markets.

Needs and Opportunities

While many states have not explicitly engaged in forest carbon management, most states regularly perform analyses of public state forests utilizing annual reports and published data from FIA. How each state uses this data to inform their management priorities is linked to the major aspects of readiness discussed previously: 1) state-level policies and political leaning, 2) forest landowner concerns and preferences, including the role and size of the forest industry, and 3) geographic dimensions.

A state's level of readiness to engage with climate change and carbon management goals is inversely related to its need for support in pursuing forest carbon modeling and forest carbon management. Generally, higher-capacity states have fewer or less

intense needs. However, several areas of opportunity to improve are evident across states at all levels of readiness. These represent areas to focus on in bolstering state engagement with and expertise in forest carbon modeling, analysis, and management, as well as forest carbon science communication, and its effective use in influencing state-level policies. These opportunities involve:

- Updated trainings
- Innovations in tools and data
- Allocation of resources
- Improved carbon science communication

Training

State-level decision makers, foresters, practitioners, and private foresters would benefit from additional training to gain knowledge in forest carbon science. Such training would better inform their own management work and improve their ability to accurately advise landowners considering the potential tradeoffs of managing their forests traditionally versus for participation in carbon markets. Additionally, forestry professionals need training on a variety of methodological approaches to understanding the current state of forest carbon, tracking past and future trends, and performing scenario analyses of management practices to meet future goals. Specific training focus areas would include gaining familiarity with current forest carbon modeling frameworks, assessing trade-offs between modeling results, and the development of statistical and coding skills.

Respondents expressed strong interest in learning more about how to use the FIA database in performing forest carbon and biomass calculations as well as having training on how to effectively use TPO data and resources. Further guidance is needed on best practices, accessing available resources for making estimations, factoring in uncertainty, and scaling measurements. Practitioners are looking for the best and most novel models to help states better manage and meet their goals.

Survey respondents and interviewees alike expressed strong interest in learning more about topics such as forest carbon accounting (75% of survey respondents), links between carbon and economic modeling (75%), modeling carbon in harvested wood products (65%), lifecycle assessment of wood products versus fossil-fuel-based products incorporating substitution and leakage concepts (65%), and scaling plot-level measurements to the landscape or regional level (65%). This points to a need for expert development and distribution of knowledge transfer materials on a wide range of topics and the need to make them readily accessible.

Tools

State-level forestry professionals need a greater understanding of the existing tools that are available for use. This would help in creating more accurate models for carbon estimation. Likewise, landowners need access to simpler tools with a similar function to assist their decision-making around managing forests for carbon with a stronger regional focus specific to the context of the landowner. Forest managers of all levels require training in understanding, utilizing, and applying carbon modeling and data tools to better inform their assessments and decision-making. Professional

forest managers need training in newer approaches to coding and statistical analysis as they are developed to be able to access and use them effectively.

Respondents report EVALIDator, a USFS tool used to produce population estimates and sampling errors from FIA data, as the most used tool for accessing FIA data, with the FIA DataMart tool being the next most common. Most states surveyed have not used rFIA, SQL, the Java based FIADB/EVALIDator API, or other coding language environments. Generally, the more complex a tool is the less use it sees. While respondents expressed a desire to use more advanced tools, they lack the expertise to do so. This is a clear opportunity to provide training and knowledge transfer to increase state capacity. Relevant trainings would allow for more flexibility in the ways data are accessed and used. For example, prescriptive tools such as EVALIDator can become more flexible if one knows SQL and gains the ability to refine EVALIDator queries.

A deeper understanding of the database allows for more diverse use of the data and allows users to extract information in more targeted ways that support modeling, assessments, and decision-making. The FIA database contains greater potential for carbon modeling than is currently being wielded. To realize this potential, a knowledge gap concerning the tools available to access these data effectively needs to be filled. One example of how this can be done is found in the Carbon Budget Modeling tool developed by the Canadian Forest Service and currently being explored by several states (Table 1) as a way to model forest carbon dynamics and possible mitigation opportunities.

Data

Continuous Assessments

Respondents report a need for more advanced tools in analyzing data as well as a need for more regular data updates (continuous assessments instead of periodic assessments). FIA recognizes this need and has accordingly been moving away from periodic assessment to continuous assessment over the past decades. There is a need to effectively incorporate continual estimation on annual timescales into decision-making and to update information on shorter intervals, eventually moving to real-time estimation of forest sector emissions for better informed management and planning. To better inform carbon projections, state agencies need more information on how carbon dynamics behave over time (an increase in longitudinal data).

To inform decision making, there is a need for greater spatial continuity of data, which can be supported with inventories conducted in denser sampling grids. Such data could bolster capacity to update and re-evaluate former planning and management decisions, i.e., to update long-term planning goals and strategies in response to new information. This would better inform decision-making in creating forest management plans that address broader-scale climate goals and GHG emission reduction targets.

Small Area and Small State Estimations

A specific problem for some smaller states is the amount of FIA data available relative the state's land area. Interview respondents from geographically smaller states note that FIA data sometimes struggle to accurately represent forest characteristics due to

sample size as determined by FIA's sampling design. FIA field sample locations are distributed across the landscape in a spatially randomized grid with approximately one sampling location (i.e., FIA plot) every 6,000 acres. This distribution leads to problems with inference as the sampling design does not accurately reflect the status of forests in smaller states. Because FIA was developed as a national monitoring system, its original design was not intended to estimate forest attributes at smaller spatial scales, such as the county level, and has shown reduced accuracy at these scales.

Accurate information on smaller scales is essential for localized planning. Some states remedy this situation by funding supplemental state-level surveys to collect additional and more relevant data. It should be noted that significant advances have been made recently in small area estimation (Stanke et al., 2022). States with a vigorous forest products sector may also access mill surveying results which can augment information gleaned from FIA TPO survey data. However, not all states have sufficient mill data that is regularly updated, representative of existing mills, and with appropriate product categories. Further, urban forest estimations can be made and used to inform local, private landowner decisions. As states begin to adopt and incorporate carbon management considerations there is generally a greater need for smaller-area estimation to better inform decision-making. State Forest Action Plans contain information that is insufficient for more than a cursory overview. More specific and complete data is needed for localized decision-making at smaller scales.

Forest Disturbance Data

Finally, data on forest disturbance is of high importance for many states. This is reflected in state goals for forest management which prioritize forest health and aim to keep forests as forests. While disturbances can have implications for a variety of management goals, they are of particular interest in the context of managing for forest carbon. Figure 11 shows the degree of concern survey respondents have regarding diverse forest disturbance types. States need to be able to navigate across modeling frameworks and understand which will be most effective for modeling the type of disturbance that is of highest concern. Specific focus needs to be placed on integrating different types of disturbance data into a variety of modeling frameworks.

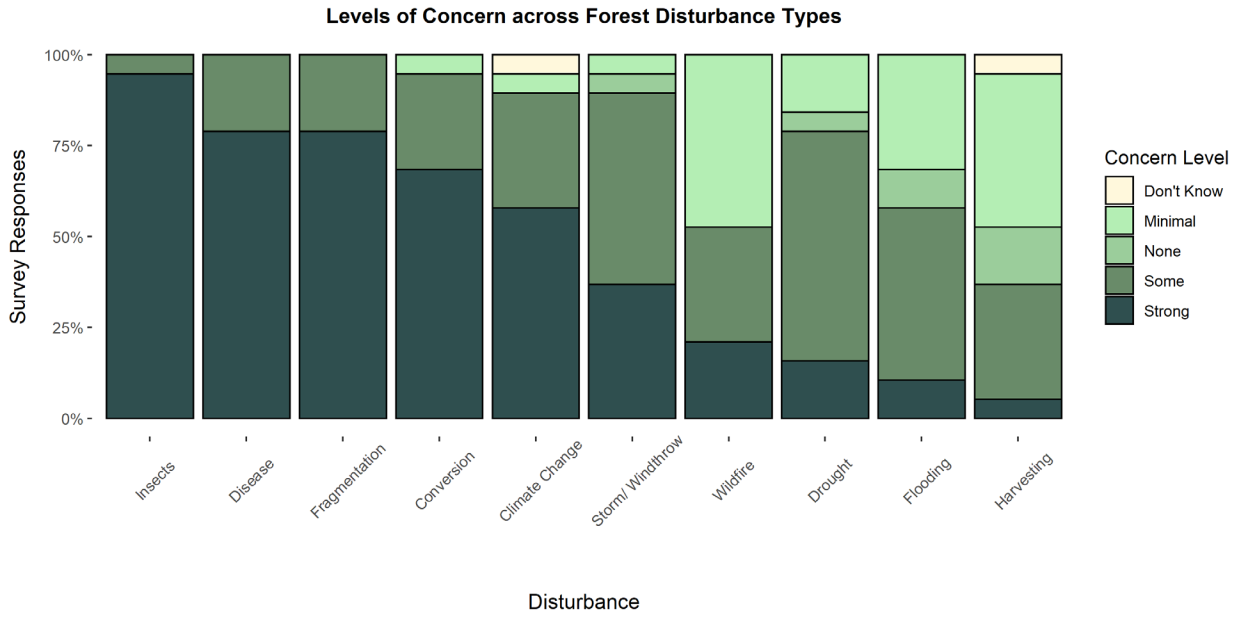

Figure 11. Reported levels of concern across a series of forest disturbance types. See survey question 30 in Appendix I for survey wording and response categories.

Resources

Overwhelmingly, the most common barriers states face to engagement with forest carbon modeling are not low interest or unavailable data but, rather, scarcity of funding and a lack of capacity in terms of trained personnel and time (Figure 12). Half of states surveyed report that lack of interest is not a barrier, while 30% report lack of interest as a slight barrier, and only one respondent reported no interest as a significant barrier. The most reported significant barriers were insufficient time/personnel capacity (85% of surveyed states), lack of trained personnel (80% of surveyed states), and lack of funding (70% of surveyed states).

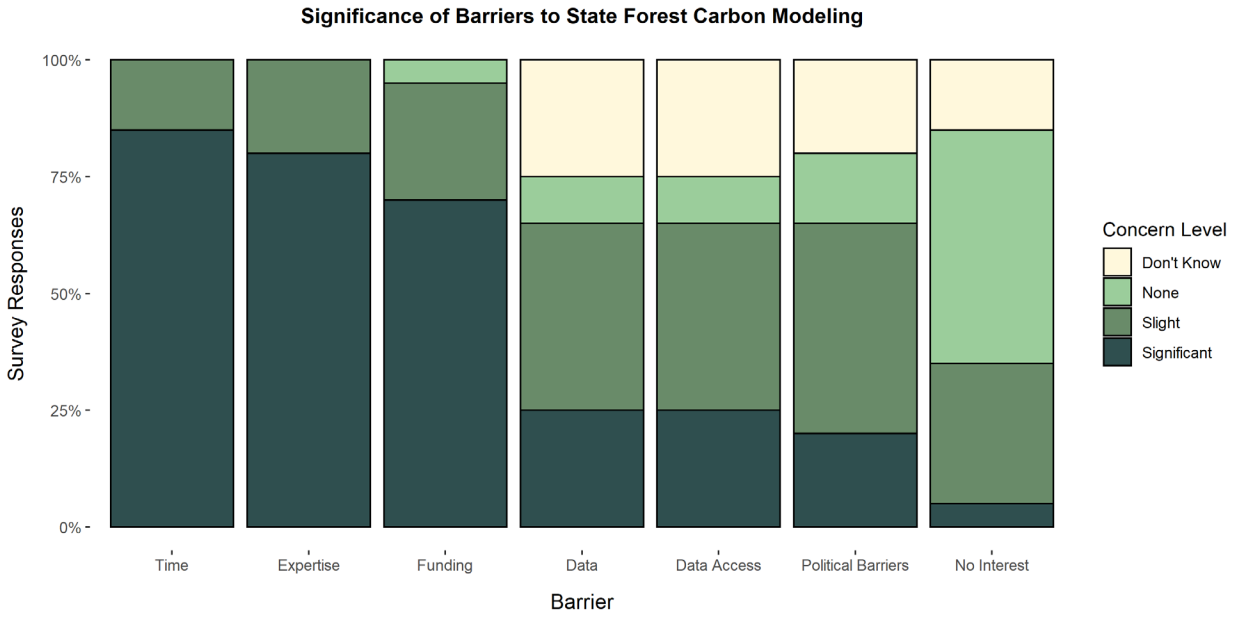

Figure 12. Reported barriers to state forest carbon modeling. See survey question 22 in Appendix I for survey wording and response categories.

While funding is needed to perform more data collection at the state level, either as annual inventories or as repeated estimations of carbon, lack of data is reported as more of a slight barrier than a significant one. Of states surveyed, 40% identified "other" significant barriers. Interviews revealed that even in states that employ biometricians or a "point person" tasked with statewide forest carbon inventory estimation, these employees cannot devote all their time to forest carbon estimation and modeling. Though interest in carbon modeling is high, when it is not elevated as a top management priority, funding for forest carbon modeling is limited and this impacts state capacity to pursue and implement it as a management goal.

Communication

Communicating forest carbon science and assessment results to policymakers, government agencies, private industry, and private landowners is a crucial, and needed, component for achieving GHG ambitions. There is a need for clear and accurate communication tailored to different audiences in order to assist diverse actors in making the most informed decisions while they are setting priorities and formulating management goals.

Across states, there are divergences in carbon objectives and in the types of communication needed. For example, in Rhode Island there is an expressed need to quantify forest carbon in order to help private landowners manage their land for carbon markets. Rhode Island's communication needs (and audiences) will, accordingly, be different from those of a state more focused on meeting state-level GHG emissions targets, like Vermont, whose communication needs center more landowner education on carbon and carbon management practices. Across all states, there is a need for increased knowledge and awareness about carbon market opportunities available to landowners.

Balancing In-House Capacity and External Expertise

Overall, state agencies report anticipating a need for more in-agency expertise on carbon modeling and wish to move away from relying exclusively on outside consultants for this work, though some expect to need both internal and consultant support. Of those surveyed, 40% would prefer to build in-agency capacity for carbon modeling, 10% would prefer to hire outside consultants, and 30% hope to do both. Interviewees echoed these survey preferences. However, along with a strong wish to build internal capacity, interview participants maintained that collaboration between state agencies and university researchers is ideal. These partnerships, leveraging combined resources and expertise, allow for more robust results. Some respondents also acknowledge the advantages outside consultants bring to projects that are more nuanced or politically sensitive—permitting agencies some distance from project findings and the benefit of more neutral third-party observations.

Forest Carbon Scenario and Policy Interest

As discussed earlier, state politics and policies can help motivate GHG targets and forest carbon assessment and modeling prioritization. Further, forest landowner preferences and concerns (including those of industrial, state, and small private landowners) can influence state forest agency priorities. Those concerns and priorities also inform preferences for forest carbon scenario development, i.e., the development of alternative pathways for forest carbon management where carbon implications can be projected and compared. In this section, we report findings on respondent preferences regarding alternative GHG reduction pathways to be tested as well as respondent perceptions of agency-level policy preferences (for either assessment or implementation). These pathway and policy interests can inform needed data inputs and the selection of appropriate modeling frameworks.

Alternative GHG Reduction Pathways

Significant efforts are being made to understand alternative pathways for increased GHG reductions and carbon storage by analyzing projected forest ecosystem and forest products sector modeling results. This is often accomplished by developing and applying a variety of modeling frameworks and methodologies to compare possible forest management scenarios, or changes in management behavior relative to current practice. Such changes could emerge as a result of shifts in disturbances, growth characteristics, and socio-economic policies, among other factors.

Figure 13 shows relative respondent interest in assessing a series of forest management scenarios. Commercial thinning and pre-commercial thinning were of greatest interest, with 68% and 58% of respondents, respectively, reporting high interest. Deferred harvest and reforestation following harvest had the lowest average interest among respondents, with 26% and 37% reporting little or no interest, respectively.

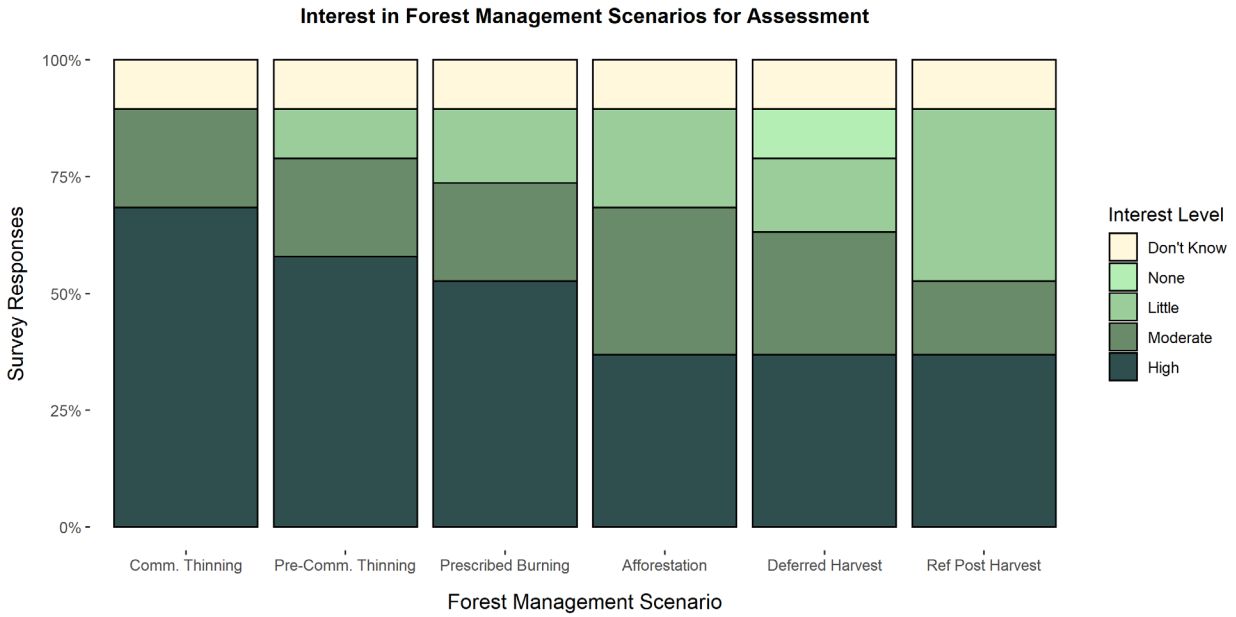

Figure 13. Reported respondent interest in assessing or modeling various forest management scenarios. See survey question 32 in Appendix I for survey wording and response categories.

Regarding the HWP sector, respondents have highest interest in assessing the development of new wood products or wood product industries (e.g., mass timber or biochar) with 74% of respondents reporting high interest. Shifting use of lower value wood (e.g., toward different products) was of second-highest interest with 58% of respondents reporting high interest (Figure 14). The scenario of least interest overall was decreasing the use of wood products for which 74% reported no or little interest and only 11% reported high interest. While there are general trends across all states, a key finding here is that respondents differ significantly in their HWP analysis interests.

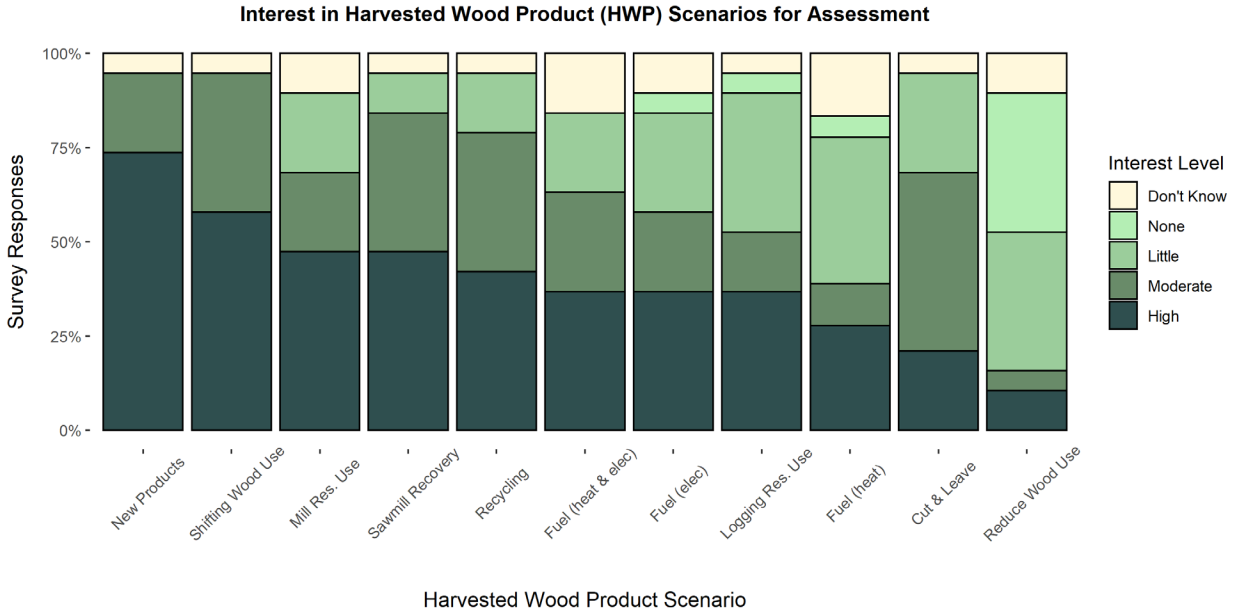

Figure 14. Reported respondent interest in assessing or modeling various HWP scenarios. See survey question 34 in Appendix I for survey wording and response categories.

Policy Interests

State-level interest in both the assessment and potential implementation of carbon policy is strong according to both interviewees and survey respondents. Policies to keep forests as forests have near universal support with 84% and 11% reporting strong or some interest within their agencies, respectively. No other policies received such consistent support across respondents. Figure 15 visualizes respondent's perceived relative interest and disinterest at the state agency level for a host of policy and program types.

Interest and Disinterest in Policy Assessment or Implementation
(% of Respondents)

Policy/ Program	Strong Disinterest	Some Disinterest	Mixed For and Against	Some Interest	Strong Interest
Delayed/ reduced harvest, public lands	22%	17%	39%	11%	6%
Keep forests as forests	0%	0%	0%	11%	84%
Minimize disturbance impact, public lands	0%	0%	37%	16%	37%
Delay/ reduce harvest, private lands	5%	5%	42%	26%	11%
Encourage harvest, private lands	5%	0%	32%	26%	26%
Carbon projects, public lands	0%	0%	26%	37%	37%
Encourage carbon projects, private lands	0%	5%	16%	42%	32%
Green growth/ sprawl limits	5%	5%	16%	26%	26%
Emission reduction targets	11%	0%	16%	26%	32%
Cap and trade program	16%	0%	32%	16%	11%
Carbon tax	26%	11%	16%	11%	11%
Offsetting of public sector emissions	5%	11%	21%	21%	11%
State-level clean fuel standard	5%	11%	21%	26%	11%
Intensify management	0%	5%	21%	21%	32%
Encourage use of biomass energy	5%	11%	42%	16%	21%

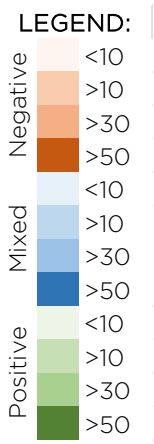

Figure 15. Respondent's perceived agency interest in assessing or implementing various policies or programs at the state level. See survey question 27 in Appendix I for survey wording and response categories.

Many interviewees expressed that motivation for carbon analysis would increase with the presence of active and stable carbon markets. While there is strong interest in establishing carbon projects on state lands (74% reporting either some or strong interest), there is considerably less and more mixed interest for cap-and-trade programs, carbon taxes, and offsetting public sector emissions, each of which might contribute to the growth and stability of forest carbon markets. Interviewees share that some states have begun to explore the feasibility and legality of establishing carbon offset projects on state forestland; however, few have moved into project planning or implementation phases. States also report greater interest in carbon policies that encourage harvest rather than those that require delayed or reduced harvest.

Other Considerations and Themes

Interviews with forest agencies and topic area experts revealed additional considerations facing state forest agency and forest landowners that may have implications for future forest management as well as future carbon assessment and modeling needs and interests.

Federal Support

A recurring theme that arose during interviews is the need for the federal sector to play a larger role in regulating the forest carbon industry in general and voluntary

carbon markets, specifically. Currently, the role of the USFS is to provide the best possible data sets, models, and tools for use by academic, public, and private stakeholders. State-level actors can then utilize to these data to empower forest management decisions for their jurisdictions.

State and private sectors could benefit from greater organization and consistency around estimation and modeling of forest carbon. This would improve the quality of information available to guide landowners in making decisions about managing land for forest carbon sequestration, climate change goals, and participation in carbon markets. Without direct federal guidance, states and private actors feel they are operating within a "wild west" environment lacking in predictability and consistency. States are currently working piecemeal, as are private sector actors such as NGOs, voluntary market administrators, and conservationists.

Growth and Capacity

In the past decade, there has been considerable growth in the worlds of carbon science and carbon markets. To meet the current and future demand within this field, there is a need for more trained professionals in this space along with increases in funding for research. Beyond carbon additionality, focus and attention should be placed on prioritizing carbon resilience, stability, and stewardship as well as on the co-benefits provided by other ecosystem services.

Addressing Changing Public Opinion

A divide exists between those who support pro-forestation policies, which aim to plant as many trees as possible and avoid all tree harvest, and those who support proactive management that includes sustainable timber harvest. This divide persists even in states where legislators have adopted and passed laws with specific goals for the forest sector in reducing GHG emissions. Prioritizing sequestration of forest carbon and forest carbon additionality can create risks for forest health when these goals are pursued instead of other more ecosystem-appropriate management options. Further complicating the policy landscape is the fact that state and federal land is earmarked and managed for multiple uses including (but not limited to) conservation, wildlife habitat, water quality, recreation, timber harvest, and other resource extraction. These management goals can sometimes support but at other times interfere with climate goals.

Role of Forest Products

From an economic standpoint, state governments are interested in bolstering and expanding the forest products sector. They are generally interested in carbon co-benefits resulting from forest products sector expansion. Interest in HWPs in conjunction with carbon sequestration usually occurs once a state has achieved a good estimation and understanding of the carbon within their forests. Because the forest products sector largely helps fund forest management activities, unless the legislator sets aside specific funding for it, the amount of funding available to manage forests for climate change is dependent upon the size and health of the state's forest products sector. This can create unique problems for those states that are net importers of wood (rather than producers) and for those states on the coast that function as pass throughs for re-export. This can also lead to complications in tracking HWPs.

Landowner Decision-Making in Response to Forest Carbon and Commodity Pricing

Household decision-making is a complex driver of forest management. Income generation is an important consideration for families but is often balanced against other ecosystem services such as water quality, cultural services, carbon sequestration, and climate change mitigation. Households may initially want to manage land explicitly for forest carbon goals. However, perturbations to household income (i.e., a death in the family or unexpected expenses and debt) set against changing prices of timber can abruptly reshuffle priorities and change household decisions regarding forestland management.

Carbon pricing has historically been low and carbon markets remain opaque and unpredictable. It is important to acknowledge that sharp increases or decreases in the price of carbon have the potential to alter the entire landscape for both states and private landowners. In considering management of forest carbon—either for income generation or for climate mitigation—landowners must deal with a high level of uncertainty. This is only exacerbated by the lack of federal guidance and regulation within voluntary carbon markets. Actors often perceive carbon markets as a kind of "wild west" with all the risk and opportunity that analogy implies. Juxtaposed against the urgency of the climate crisis, this can create a significant amount of psychological friction in the decision-making process when creating priorities for forest management. This highlights the need for filling knowledge gaps, establishing best practices, and regulating volatile emerging markets.

Trade-Offs and Co-Benefits of Carbon Management

Management of forests has historically included multiple objectives including fuel and fiber, recreation, regulatory ecosystem services, habitat creation, and cultural services. Long-term and short-term management plans need to incorporate an understanding of interdependent goals, balance trade-offs, and maximize co-benefits between carbon-specific management considerations and other management goals. Interviews reinforced the notion that flexible frameworks and alternative management options, informed by scientific expertise and data, including carbon estimation and projections, need to be considered to optimize decision-making.

Interviewees also discussed their interest in other types of climate-smart management, not specifically focused on forest carbon storage or carbon sequestration. These can include strategies such as incentive programs with forest management plans, managing for future resiliency through adaptive measures, managing for disturbance risk, removal of invasive species, and managing for improved soil health. Such strategies can help meet other management goals while also providing additional carbon benefits. These types of management activities can be motivated by programs such as forest certification, tax incentives and disincentives, conservation easements, and establishment of best management practices (BMPs) programs. Programs such as these can influence behavior changes that directly and indirectly influence forest carbon dynamics even if program goals are not explicitly linked to forest carbon. Interviewees stressed that potential pathways to incentivize carbon-specific management considerations can be achieved

through augmenting existing BMP programs or other formal stewardship programs. These considerations strengthen the argument for the development of more flexible and adaptive legislative incentives which expand management programs, increasing desirable outcomes.

Conclusion

This study has assessed state-level inventorying, modeling, communications, and linkages with policymaking regarding forest carbon in USFS Region 9. These assessments were conducted through surveys and interviews. Analyses of subsequent results yielded a rich set of information bringing clarity around state experiences, readiness levels, motivations, barriers, and needs. Key findings point to the need for updated trainings, innovations in tools and data, greater allocation of resources toward forest carbon inventorying and modeling, and improved forest carbon science communication to help inform both state-level policymakers and landowners at all scales.

We found that states generally fall into one of three categories regarding readiness to engage with forest carbon modeling:

1) those that *have not engaged* in planning or management for forest carbon and climate goals;
2) those that *have begun to consider* forest carbon management and planning, with additional climate goals; and
3) those that *have taken concrete action* regarding the assessment of forest carbon management with an objective of informing state climate goals.

Key aspects determining state readiness include:

1) state-level policies and political environment;
2) forest landowner preferences, including the role and size of the forest industry; and
3) geographic dimensions.

We identified four primary areas where knowledge gaps exist, influencing state capacity and readiness to engage with forest carbon modeling:

1) forest inventorying and carbon estimation;
2) carbon dimensions of harvested wood products;
3) carbon analysis of GHG emissions and pathways to GHG reductions; and
4) communication of results to inform public and private decision-making.

Because these knowledge gaps link strongly to aspects of state readiness to engage in forest carbon management and set climate goals, all four areas would be best addressed simultaneously in a holistic and comprehensive manner.

Further, analysis of survey and interview results revealed that four primary areas of need arise across states of all readiness levels. These represent areas to focus on in bolstering state engagement with and expertise in forest carbon modeling, analysis,

and management; as well as carbon science communication, and its effective use in influencing state-level policies. Opportunities to meet these needs involve:

1) updated trainings;
2) innovations in tools and data;
3) allocation of resources; and
4) improved carbon science communication.

Lastly, in surveys and interviews, general state-level interest in forest carbon modeling and management was also gauged. Findings indicate that interest is high across most states, even in those with low levels of readiness. It is in these states that knowledge transfer materials and resource allocation will be particularly impactful. Current political and climate trends indicate that this interest will continue to grow along with the need to support state capacity to engage with the crucial work of forest carbon inventorying, modeling, and communication to policymakers and landowners.

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Appendix I

Online survey introduction

This survey has been designed to assess state-level forest carbon and harvested wood product inventory and modeling needs, including for data interpretation, results communication, and linkages with state policy and goals.

The survey is part of the Forest Carbon Data and Modeling Integration and Evaluation Project, made possible with a grant from the U.S. Department of Agriculture, Forest Service Eastern Region. The project's aims are to assess interest in and build capacity for forest carbon modeling among USFS Region 9 states. You are being asked to complete this survey as your skills, experiences, and perceptions will be helpful in identifying state-level capacities, motivations, and knowledge gaps. Please know that all responses are anonymous.

A couple of clarification notes as you complete this survey:

1) By 'forest carbon', we are referring to any of the five major carbon pools in terrestrial ecosystems (i.e., aboveground live, belowground live, aboveground dead, dead organic matter, and soil carbon), carbon fluxes between terrestrial carbon pools and carbon fluxes between forest carbon pools and the atmospheric carbon pool.
2) Some questions ask about your "team's" level of knowledge or experience, rather than solely your individual knowledge or experience. For the purposes of this survey, a "team" is defined as a group of people who perform interdependent tasks to accomplish a common mission or specific objective, in this case forest carbon modeling and forest inventory and analysis. Depending on your position and role within your agency, your "team" could be large (e.g., the entire department, agency, or division), or small (e.g., your immediate workgroup). Question 4 will ask you to briefly describe your "team" for the purposes of this survey.

We anticipate 30-40 minutes for survey completion and are extremely grateful for your participation.

Online survey questions and possible answers

#	Survey Question	Possible Responses
1	For which state do you work?	Drop-down: all states and DC
2	For which organization or agency do you work?	Open-ended
3	What is your position title?	Open-ended

4	As noted in the introduction to this survey, some of the following questions will ask about your team's level of knowledge or experience. By "team", we are referring to a group of people who perform interdependent tasks to accomplish a common mission or specific objective, in this case forest carbon modeling and inventorying. In a few words, please describe the "team" you work with on matters related to forest carbon modeling and/or forest inventory and analysis.	Open-ended
5	How would you categorize your team's knowledge on the following forest inventorying topics? [rank 1-6]: A. Forest plot designs and how to establish forest plots B. Plot placement and spatial randomization of inventory plots C. Determining appropriate inventory methods and sampling design D. Identifying forest characteristics to be measured and why E. Scaling plot and subplot level measurements to either the stand, landscape, or regional level F. Calculating forest biomass, carbon, basal area, or volume using plot measurements G. Mapping forest biomass, basal area, or volume estimates and uncertainty using remote sensing (e.g., LiDAR, satellite imagery)	1) No knowledge; 2) Limited knowledge; 3) Moderate knowledge; 4) Expert knowledge; 5) Don't know; 6) Don't know what this refers to
6	In which ways has your team used Forest Inventory and Analysis (FIA) and other forest inventory data? [1-5 – check all that apply]: A. Use of annual FIA produced reports and statistics B. Analysis/ estimation of summary statistics and forest characteristics using FIA online tools C. Analysis of forest inventory and measurement data collected outside of FIA (e.g., collected by state, academic, or other organizations) D. Further analysis using FIA data but also incorporating other sources or types of inventory data (i.e., supplemental inventory data, geospatial data, survey data, etc.) E. More robust estimation of forest attributes using FIA or non-FIA data, including but not limited to: *Estimation of forest recruitment, growth rates, annual productivity, age-structures, size classes, species diversity/abundance, or canopy dynamics* F. Economic analyses to complement forest inventory analysis	1) completed internally; 2) completed by other state teams/ agencies; 3) done by external (e.g., consultants or academic partners); 4) Don't know; 5) Not applicable

7	What is your team's level of familiarity about aspects of the FIA database [rank 1-6]: A. FIA database content B. Accessing FIA data C. FIA data interpretation D. FIA sampling and stratification methodology E. FIA database structure, nomenclature, and data attributes F. FIA population estimates procedures G. FIA Quality Assurance and Quality Control (QA/QC) and accuracy standards H. Forest carbon/biomass calculations using FIA data	1) No knowledge; 2) Limited knowledge; 3) Moderate knowledge; 4) Expert knowledge; 5) Don't know; 6) Don't know what this refers to
8	Regarding the FIA program and database: Which of the following would you be interested in learning more about? [choose 1-4]: A. FIA database contents B. Accessing FIA data C. FIA data interpretation D. FIA sampling and stratification methodology E. FIA database structure, nomenclature, and data attributes F. FIA population estimates procedures G. FIA Quality Assurance and Quality Control (QA/QC) and accuracy standards H. Forest carbon/biomass calculation using FIA data	1) No interest; 2) Some interest; 3) Strong interest; 4) Don't know what this refers to
9	Which of following methods have you used to access FIA Inventory data? [choose 1-5]: A. EVALIDator B. DATIM (Design and analysis toolkit for inventory and monitoring) C. FIA DataMart D. FIADB/EVALIDator Application Programming Interface (API) E. SQL F. rFIA G. Other coding language or environment	1) Do not use; 2) Used 1-2 times; 3) Used 3-10 times; 4) Used more than 10 times; 5) Unsure what this is
10	[If 'other', above] What other coding language or environment have you used to access FIA inventory data and with what regularity?	Open-ended
11	How would you classify your team's knowledge of silvicultural methods and activities across the following ownership categories in your state? [rank 1-5]:	1) no knowledge; 2) limited knowledge; 3)

	A. Private B. State C. USFS D. Other Federal E. Local/Municipality F. Tribal Lands	moderate knowledge; 4) expert knowledge; 5) don't know
12	What information, resources or training do you need to improve your ability to access, process, and understand FIA Inventory Data for state level forest carbon inventory and modeling needs?	Open-ended
13	Does FIA meet your data needs to measure or monitor state or program goals? Please explain.	Open-ended
14	How would you classify your team's knowledge about the following items relating to Timber Product Output (TPO) assessments and data [rank 1-6]: A. What TPO surveys measure B. Sampling and stratification methodology C. Database structure, nomenclature, and data attributes D. Where and how to access primary data E. How to interpret data	1) No knowledge; 2) Limited knowledge; 3) Moderate knowledge; 4) Expert knowledge; 5) Don't know; 6) Don't know what this refers to; 7) Don't Use/Not Available
15	In which ways has your team used mill and timber product data? Check all that are appropriate and leave blank if none apply or are not applicable to your team. [1-5]: A. Use of TPO/ RPA reports or summary estimates provided (e.g., fact sheets) B. Primary analysis using TPO data C. Primary analysis using TPO data in combination with supplemental state-level mill or wood products data D. Use of state-collected mill data reports or summary estimates E. Primary analysis of state-collected mill data F. Analysis of harvested wood product export and import data G. Analysis of harvested wood product carbon storage H. Analysis of product end-uses I. Analysis of product half-lives J. Analysis of product retirement (e.g., recycling, landfills, burning for energy capture) K. Economic analyses regarding mills or harvested wood products L. Mill or economic analysis to determine existing or potential product feasibility	1) completed internally; 2) completed by other state teams/ agencies; 3) completed by external (e.g., consultants or academic partners); 4) don't know; 5) Don't know what this refers to

	M. Analysis of harvested wood products energy use N. Analysis of harvested wood product fossil fuel emissions offsetting	
16	How would you rank the available mill data in your state (either from TPO or state assessments) for state carbon and harvested wood product modeling needs along the following dimensions? [rank 1-4]: A. Updated with sufficient regularity B. Sufficient representation of existing mills C. Product categories are appropriately and sufficiently categorized or binned	1) Inadequate; 2) Adequate; 3) More than necessary; 4) Don't know
17	What information, resources or training do you need to improve your ability to access, process, and understand mill and harvested wood product data for state level forest carbon inventory and modeling needs?	[open-ended]
18	How would you rank your team's knowledge around carbon cycle science and forest carbon and/or biomass [rank 1-5]: A. Forest carbon cycling and dynamics B. Forest carbon or biomass pools/stocks C. Forest carbon fluxes and gas exchange D. Forest carbon and biomass measurements and accounting	1) No knowledge; 2) Limited knowledge; 3) Moderate knowledge; 4) Expert knowledge; 5) Don't know; 6) Don't know what this refers to
19	How much of your job involves policy or management analysis or decision making related to the following forest carbon topics? [rank 1-3]: A. Forest carbon cycling and dynamics B. Forest carbon or biomass pools/stocks C. Forest carbon fluxes and gas exchange D. Forest carbon and biomass measurements and accounting	1) none; 2) some; 3) a significant amount
20	How would you rank your team's knowledge regarding forest carbon *accounting, modeling, and linkages with policy* [rank 1-6]: A. Knowledge about what datasets/sources exist that can be used in forest carbon accounting B. How to estimate forest carbon from plot-level measurements	1) No knowledge; 2) Limited knowledge; 3) Moderate knowledge; 4) Expert knowledge; 5) Don't know; 6)

	C. How to scale plot-level measurements to the landscape or regional level D. How to use remote sensing data to map or calculate forest carbon E. IPCC guidance and best practices regarding carbon accounting and monitoring within the forest sector F. Which forest carbon modeling frameworks would best suit state or agency goals/ needs G. Other states' approaches to carbon accounting and modeling H. Ability to process and interpret primary results/ data outputs from carbon assessments I. How to link carbon modeling with economic analysis/ modeling J. Awareness of existing state or sub-state policies/ programs that incentivize or discourage particular forest management practices (e.g., incentivizing harvest, incentivizing delayed harvest) *within your state* K. Awareness of state-based policies/ programs/ levers *in use in other states or countries* L. Comfort using the appropriate language to communicate about forest carbon and climate M. Comfort using the appropriate language to communicate about forest carbon and/or energy policies N. Comfort communicating links between carbon assessment and modeling results and policy *for policymakers* O. Comfort communicating links between carbon assessment and modeling results and policy *for general audiences (e.g., including landowner, constituents, business interests)* P. Comfort communicating links between forest carbon assessments and modeling results in relation to other working lands (agriculture) assessments and modeling results and policies. Q. Comfort communicating links between forest carbon, harvested wood products storage, fossil fuel substitution and carbon leakage. R. Comfort communicating links between short term and long-term carbon cycles and their importance in climate mitigation.	Don't know what this refers to
21	Regarding forest carbon modeling, which of the following would you be interested in learning more about? [1-3]: A. Datasets/sources that can be used in forest carbon accounting	1) No interest; 2) Some interest; 3) Strong interest

	B. How to estimate forest carbon from plot level measurements on site carbon C. How to scale plot-level measurements to landscape or regional level D. Forest sector IPCC guidance and best practices regarding carbon accounting and monitoring E. How to model carbon in harvested wood products F. Lifecycle assessment of wood products versus fossil fuel-based products incorporating substitution and leakage concepts G. Other states' approaches to forest carbon accounting and modeling H. Differences between existing modeling frameworks and tools for scenarios and projections I. Links between carbon and economic modeling J. Existing state or sub-state policies/ programs that impact forest management practices *within your state* K. Potential state-based policies/ programs for forest management (e.g., those used in other states or countries) L. How to communicate linkages between carbon modeling results and policy	
22	To what degree are the following barriers to your engagement with forest carbon modeling? [rank 1-4]: A. Insufficient data B. Lack of *access* to data C. Insufficient funding D. Lack of trained personnel E. Insufficient personnel time F. No interest G. Political barriers H. Other	1) not at all; 2) slight barrier; 3) significant barrier; 4) don't know
23	What other barriers to carbon modeling do you encounter?	[If 'Other', above]
24	Do you expect your agency would prefer to build in-agency capacity for carbon modeling or hire outside consultants? A. Building in-agency capacity B. Hiring outside consultants C. Both D. Neither E. Don't know	[Choose one]

25	How would you rank the interest in raising awareness of activities leading to *increased carbon storage* among the following groups within your state? [rank 1-5]: A. Your personal interest B. Executive-level interest (i.e., governor and governor's office/ administration) C. Department or Agency-level interest D. State legislature interest E. Industrial forest sector interest F. Industrial/investor landowner interest G. Family forest landowner interest H. General population interest	1) No interest; 2) Little Interest; 3) Moderate Interest; 4) High Interest; 5) Unsure
26	How would you rank the interest in raising awareness of activities leading to *reduced GHG emissions* among the following groups within your state? [rank 1-5]: A. Your personal interest B. Executive-level interest (i.e., governor and governor's office/ administration) C. Department or Agency-level interest D. State legislature interest E. Industrial forest sector interest F. Industrial/investor landowner interest G. Family forest landowner interest H. General population interest	1) No interest; 2) Little Interest; 3) Moderate Interest; 4) High Interest; 5) Unsure
27	How would you characterize the current interest (for either assessment or implementation) in the following policies and programs *within your agency?* [rank 1-8]: A. Policies for delayed or reduced harvest on public lands B. Policies to keep forests as forests C. Programs to minimize the impact of forest disturbances on public lands D. Incentive programs delayed or reduced harvest on private lands (e.g., via property tax incentives) E. Incentive programs encouraging harvest on private lands (e.g., via property tax incentives) F. Carbon projects on public/ state lands G. Programs to encourage/ support carbon projects on private lands H. Green growth/ sprawl limits I. Emissions reduction targets (including determined at the agency level, legislatively determined, or through an Executive Order) J. Cap and trade program	1) Strong disinterest; 2) Some disinterest; 3) Mixed interest for and against; 4) Somewhat interested; 5) Strong interest; 6) Not discussed; 7) Don't know; 8) Unsure what this means

	K. Carbon tax L. Offsetting of public sector emissions M. State level clean fuel standard N. Programs to intensify management O. Programs to encourage use of biomass energy P. Other	
28	If 'other', what other policies or programs does your agency have an interest (positive or negative) in assessing or implementing?	[If 'Other', above] [open-ended]
29	Has your agency identified any potential issues or barriers to implementing carbon projects on state lands?	[open-ended]
30	To what degree are the following forest disturbances of concern in your state? [rank 1-5]: A. Climate change B. Wildfire C. Insect D. Disease E. Storm/ wind throw F. Harvesting G. Drought H. Flooding I. Conversion to non-forest uses J. Fragmentation	1) No concern; 2) Minimal concern; 3) Some concern; 4) Strong concern; 5) Unsure
31	Are there any other forest disturbances of particular interest or concern in your state? If so, please list briefly here.	[open-ended]
32	Which forest management scenarios would you have the greatest interest in assessing with a carbon model (that is, deviations from current forest management practices on either public or private lands)? [rank 1-6]: A. Deferred harvest B. Pre-commercial thinning C. Commercial thinning D. Reforestation following harvest E. Afforestation F. Prescribed burning	1) No interest; 2) Little interest; 3) Moderate interest; 4) High interest; 5) Unsure; 6) Don't know what this refers to
33	Are there any other forest management scenarios you have an interest in assessing with a carbon model?	[open-ended]
34	Regarding harvested wood products, which of the following would you have the greatest interest in assessing with a carbon model? [rank 1-6]:	1) No interest; 2) Little interest; 3) Moderate interest; 4) High

	A. Increased wood reuse/ recycling B. Development of new wood products or wood product industries (e.g., mass timber, biochar) C. Shifting use of lower value wood (e.g., toward different products) D. Increased use of post-harvest forest residues E. Leaving low-grade wood and residues on-site (cut and leave) F. Increases in sawmill lumber volume recovery G. Increased use of sawmill residues H. Decreased use of wood products I. Increasing the use of wood fuel for heat only J. Increasing the use of wood fuel for electricity generation only K. Increasing the use of wood fuel for combined heat and power	Interest; 5) Unsure; 6) Don't know what this refers to
35	Are there any other harvested wood product scenario you have an interest in assessing with a carbon model?	[open-ended]

Appendix II

Forest Agency Personnel—Interview Protocol:

1. Could you briefly introduce yourself by stating name, title, and roles/responsibilities within your organization?
2. Could you please describe any timber allocation models or timber supply models utilized by your state in planning?
3. Has your agency or state ever conducted any type of forest carbon accounting exercise, either in-agency or with external partners?
4. Has your agency or state done any type of data collection on or analysis of harvested wood products outside of TPO surveys and reports, either in-agency or with external partners?
5. Has your agency or state ever conducted any type of forest carbon modeling exercise to simulate or project future forest sector emissions including any type of scenario assessment of future management practices on forest sector emissions, either in-agency or with external partners?
6. Within your agency, can you briefly describe current capacity and constraints to conducting both forest carbon accounting and forest carbon modeling exercises?
7. In our experience, we have found that some prefer to hire consultants to conduct carbon modeling exercises for a variety of reasons including expertise and agency constraints as well as science communication and credibility. Do you have (or do you expect your agency would have) a preference to conduct such exercises in-house or hire out to consultants? Why?
8. What type of modeling exercise would be most beneficial to your state's and/or agency's goals? What type of results would be most useful? Why?
9. Regarding carbon modeling, what are some of the most important knowledge sets that current and/or future staff will need in the future? Is there a want and/or desire for trainings/materials around these knowledge sets? If so, what is the preferred way to increase agency capacity?
10. Is there or has there ever been a task force, working group, committee etc. at the state level exploring carbon (may include those related to economic, social, political analyses; emissions targets; other carbon)? What motivated that?
11. What policies, programs, or incentive structures (if any) exist that include goals for increasing forest carbon (and for what ownerships or geographies might those cover)?
12. Does your state have an interest in bolstering participation with carbon markets on public or private lands?
13. Does your state have interest in developing or incentivizing new forest commodities?
14. Is there anything else that you would like to share or discuss?
15. Do you have any questions for me?

Appendix III

State	Target	Enabling Statute
Connecticut	Carbon-free electricity by 2040	Executive Order
	Reduce emissions 45% below 2001 levels by 2030	Legislation
	Reduce GHG emissions at least 10% below 1990 levels by 2020 and 80% below 2001 levels by 2050	Legislation
	45% reduction in emissions by 2030	Executive Order
Delaware	Reduce emissions to 80% below 2008 levels by 2030	Executive Order
	Reduce emissions by 24-26% of 2005 level by 2025	Executive Order
Illinois	Goal of 100% clean energy by 2050, with interim targets of 40% by 2030 and 50% by 2040	Legislation
	Reduce greenhouse gas emissions by at least 26-28 percent by 2025	Executive Order
	90% of coal emissions must be captured and stored, requires Illinois utilities and other retail electricity suppliers to purchase at least 5% of their electricity from Clean Coal Facilities	Legislation
Maine	100% carbon free energy usage by 2050	Legislation
	45% below 1990 levels by 2030 and 80% below 1990 levels by 2050	Legislation
	Carbon neutral economy by 2045	Executive Order
Maryland	Reduce emissions 40% below 2006 levels by 2030	Legislation
Massachusetts	Reduce emissions 50 percent below 1990 levels by 2030 and net-zero carbon emissions by 2050	Legislation
	Reduce between 10 percent and 25 percent below statewide 1990 GHG emission levels by 2020; at least 80 percent below statewide 1990 GHG emission levels by 2050	Legislation
Michigan	Economy-wide carbon neutrality by no later than 2050 and to maintain net negative GHG emissions thereafter	Executive Order
	Reduce emissions 26-28% below 2005 levels by 2025, 52% by 2030	Executive Order
Minnesota	Reduce GHG emissions 30% below 2005 levels by 2025 and 80% below 2005 levels by 2050	Legislation
	At least 80% below 2005 levels by 2050	Executive Order
	30% reduction of GHG emissions compared to a 2005 level by 2025	Executive Order
New Hampshire	Goal of reducing fossil fuel use at state-owned facilities by 30 percent by 2020, 40 percent by 2025 and 50 percent by 2030, compared to a 2005 baseline; reducing greenhouse gas emissions from the state passenger vehicle fleet by 30 percent on a metric-ton basis by 2030, as compared to a 2010 baseline.	Executive Order
	80% reduction in greenhouse gas emissions by 2050	Executive Order
New Jersey	100% clean energy profile by 2050	Executive Order
	Reduce GHG emissions to 1990 levels by 2020 and 80% below 2006 levels by 2050	Executive Order

	100% clean energy economy, with an 80% reduction in state-generated greenhouse gases by 2050	Executive Order
	Reduce emissions by 20% below 2006 levels by 2020 and 80% by 2050	Legislation
New York	Reduce emissions 40% below 1990 levels by 2030, 85% by 2050	Legislation
Pennsylvania	26% reduction by 2025 and an 80% reduction by 2050, compared to 2005 baseline levels	Executive Order
Rhode Island	45% reduction of greenhouse gas emissions by 2030; an 80% reduction by 2040; and a requirement of net-zero emissions by 2050	Legislation
	Meet 100% of electricity demand with renewable energy by 2030	Executive Order
Vermont	By 2025, not less than 26% below 2005 emissions; by 2030: not less than 40% below 1990 emissions; and by 2050: not less than 80% below 1990 emissions	Legislation
Wisconsin	100% carbon free energy usage by 2050	Executive Order