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NATIONAL REPORT ON SUSTAINABLE FORESTS, 2020

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Front cover photo:

After heavy rains, McDowell County, NC. (Courtesy photo by Warren Reed)

Back cover photo:

Fall foliage in the Huron-Manistee National Forests, MI. (USDA Forest Service photo by Brendon O'Dell)

LIST OF ACRONYMS

best management practices	BMPs
Bureau of Land Management	BLM
California Air Resources Board	CARB
Clean Water Act	CWA
Collaborative Forest Landscape Restoration Program	CFLRP
Criteria and Indicators	C&I
Food and Agriculture Organization	FAO
Forest Inventory and Analysis	FIA
Global Forest Resources Assessment	FRA
Good Neighbor Authority	GNA
gross domestic product	GDP
harvested wood products	HWPs
International Tropical Timber Organization	ITTO
million metric tons of carbon dioxide equivalent	MMT CO2 Eq.
National Association of State Foresters	NASF
National Forest System	NFS
National Report on Sustainable Forests	NRSF
National Woodland Owner Survey	NWOS
nontimber forest products	NTFPs
Repairing Existing Public Land by Adding Necessary Trees	REPLANT
real estate investment trusts	REITs
Resources Planning Act	RPA
Sustainable Development Goals	SDGs
sustainable forest management	SFM
timber investment management organizations	TIMOs
Timber Products Output	TPO
U.S. Department of Agriculture	USDA
United Nations Conference on Environment and Development	UNCED
United Nations Forum on Forests	UNFF

EXECUTIVE SUMMARY

This National Report on Sustainable Forests (NRSF) presents a comprehensive assessment of sustainability conditions and trends in forests of the United States. It is produced in response to the United States' political and institutional commitment to measure, monitor, and report on forest sustainability at national and subnational levels using the Montréal Process Criteria and Indicators (C&I) for the Conservation and Sustainable Management of Temperate and Boreal Forests (Robertson et al. 2011).

The Montréal Process C&I comprise 7 criteria and 54 indicators that address the ecological, economic, and social dimensions of forest sustainability (https://montreal-process.org/The_Montreal_Process/Criteria_and_Indicators/index.shtml). The United States has been an active member of the Montréal Process since its establishment in 1993. The 12 member countries of the Montréal Process account for 49 percent of the world's forests and 90 percent of the world's temperate and boreal forests.

In keeping with its mission, the U.S. Department of Agriculture, Forest Service leads periodic assessments of the Nation's forests utilizing the Montréal Process C&I framework. This report is the fourth in the series of U.S. assessments going back to 1997.

The assessment of sustainability in this report reflects the work of more than 25 Forest Service and partner scientists who conducted analysis and synthesized research findings to develop reports for individual indicators of the Montréal Process C&I framework. These indicator reports are updated periodically and are available publicly on the USDA Forest Service Sustainability Reporting website (https://www.fs.usda.gov/research/inventory/sustainability).

ARE U.S. FORESTS SUSTAINABLE?

The Montréal Process C&I recognize the complexity inherent in forest processes, society's engagement with forests, and the benefits people receive from forest ecosystems. Application of the Montréal Process C&I framework can result in the identification of areas where forest sustainability measures are yielding promising outcomes, how forest sustainability conditions are changing over time, where these conditions signal areas of concern, and where current and future efforts to achieve sustainability may best be focused.

Nationwide, the amount of land dedicated to forest uses remains relatively stable and wood stocking on these lands continues to increase. Forests continue to supply diverse and highly valued outputs and services, including wood products, recreation opportunities, carbon sequestration, and biodiversity conservation. These findings echo those reported in the 2010 NRSF (Robertson et al. 2011). However, the extent and severity of natural disturbances may pose an increasing challenge to U.S. forest sustainability (e.g., wildfire and insect outbreaks in the West, hurricanes and severe storms in the East).

The confluence of past management legacy, drought, heat, and other extreme weather events are leading to larger and more severe wildfires in the West (Abatzoglou and Williams 2016). The challenge to sustainability from wildfire highlighted here reiterates concerns stated in the 2010 NRSF: "the sheer size of the wildfire problem, combined with the fact that much of the most severely affected areas are under Federal management, means that Federal land management agencies will be struggling with disturbance processes and forest health issues for many years to come" (Robertson et al. 2011). The Forest Service Wildfire Crisis Strategy was recently developed to improve management responses to the expanding size and severity of wildfires (USDA Forest Service 2022).

In addition to the challenge of intensifying natural disturbance, within the wood products industries, there are continuing declines. These include wood products-related employment and incomes in many (but not all) forest-dependent communities—whether from increasing mechanization, dynamic macroeconomic conditions, or changes in timber supply. Finally, the increasing number of forest-associated species considered to be at risk for extinction poses ongoing challenges to biodiversity conservation.

The key findings from the summaries of the seven Montréal Process criteria documented in this report include:

- Forest land area in the United States has increased slightly over the past century. However, modest long-term net gains at a national scale have diminished in recent years as net forest gains principally in the South, North, and Alaska Regions were offset by net decreases in forest land area in the Pacific Coast and Rocky Mountain Regions. (Criterion 1).
- The percent of forest-associated species considered to be at risk of extinction continues to rise (Criterion 1).
- At the national scale, forests continue to grow significantly more wood than is removed or lost to mortality (Criterion 2).
- Disturbances are a vital part of healthy forest ecosystems, but the ongoing, and in some places, increasing extent and severity of biotic and abiotic forest disturbances, often acting in combination, pose increasing threats to ecological, economic, and social dimensions of forest sustainability, particularly in the West (Criterion 3).
- Forests continue to serve as the largest national carbon sink, but forests in several States in the Intermountain West are producing

net carbon emissions at the State scale due to forest disturbance activity (Criterion 5).
- Forest-protected rivers and streams are in relatively good condition in the United States and previously high levels of acidification observed in forest soils have continued to decrease in recent years (Criterion 4).
- Overall, the forest products industry in the United States has rebounded with the recovery in the broader economy over the past decade. This recovery has been strongest in portions of the South Region. In addition, wood production levels remain below their peak from prior decades, and employment levels have continued their long-term decline (Criterion 6).
- Forest recreation is a principal forest output but may be increasingly constrained by forest disturbances (notably wildfire and smoke) and maintenance backlogs on roads, trails, and facilities, particularly on public lands (Criterion 6).
- Sustainable forest management is pursued in the United States through an expanding range of legal, institutional, and economic approaches developed and applied across multiple scales, ownerships, and actors (Criterion 7).

DRIVERS OF CHANGE

Although the Montréal Process C&I can be considered at the individual indicator or criterion level, several key drivers influence a number of indicators and criteria across ecological, economic, and social dimensions of forest sustainability. Continued climate change and increasing extent and severity of climate-related forest disturbance has altered the conditions and trends associated with many of the indicators, highlighting the complex relationships between forest sustainability and climate change. In particular, the role of forest carbon in helping to ameliorate greenhouse gases in the atmosphere has magnified the importance of findings for several sustainability indicators. The spatial patterns in forest ownership across the United States and changes in ownership in the last decade have implications for how forest benefits are distributed, the conditions and productivity in private forests, and relative impacts to public and private forests from natural disturbance. For example, with relatively more Federal forest land located in the Western United States, people living in that region have more ready access to Federal forest recreation opportunities, but those forests also experience more wildfires affecting public access and the health and property of residents. For private lands, the continuing expansion of investment ownership of industrial forest lands has implications for current forest conditions as well as potential future forest productivity. Finally, the C&I collectively highlight the many benefits and opportunities that can arise from sustainable forest management. Increasing public recognition of these benefits can help drive increased investments in management designed to secure these benefits and ensure forest sustainability.

THE CONTRIBUTIONS OF OTHER TREES AND FORESTS

Temperate and boreal forests are the focus of the Montréal Process C&I, and the 2020 NRSF confines its assessment to these forests. Assemblages of trees not meeting standard definitions of forest land (e.g., windrows on agricultural lands or trees and small wooded areas in urban places) are not included in the analyses. These trees do provide extensive benefits, and opportunities for sustainable management aimed at securing and increasing these benefits have been identified in other related reporting efforts (e.g., McGinley et al. 2019b; Robertson and Mason 2016).

REPORT ORGANIZATION

This report begins with a discussion of the recent history of sustainable forest management with specific attention to the emergence of the Montréal Process C&I and related C&I applications (chapter 1). This is followed by a presentation of key findings (chapter 2), and a discussion of cross-cutting issues affecting multiple criteria (chapter 3). The bulk of the report is in chapter 4, where findings and discussion are presented for the seven criteria of the Montréal Process C&I framework. The individual indicator reports serve as the foundation for the entire report and are provided online at on the Forest Service Sustainability Reporting website (https://www.fs.usda.gov/research/inventory/sustainability). These indicator reports are organized by criteria and are designed for easy access to specific information on the ecological, economic, and social dimensions of forest sustainability.

POLICY RELEVANCE

The 2020 NRSF is designed to be a monitoring report describing current conditions and recent trends associated with U.S. forests and their sustainability. The NRSF does not include recommendations for specific policy or practice. Rather, the purpose of the report is to inform policy discussions under the principle that better information results in better discussions and thereby better decisions. The NRSF is designed to serve the information delivery part of this process.

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Flathead National Forest, MT, contains numerous lakes, streams, and rivers. (USDA Forest Service photo by Your Forests Your Future)

CHAPTER 1: HISTORY AND CONTEXT

About one-third of the land base in the United States is classified as forest, constituting the fourth largest forest land base of a nation in the world. Forests provide clean air, fresh water, and wildlife habitat and influence biochemical cycling and climate at local to global scales. They also provide essential goods and services—including timber, food, medicine, recreational opportunities, and cultural and spiritual resources—for building, expanding, and sustaining communities. Understanding the conditions and trends of forests across biophysical, social, and economic factors supports their conservation and productivity now and into the future. Box 5 in this document provides a discussion on how forests are classified and monitored in the United States.

This National Report on Sustainable Forests (NRSF) provides a synthesis of current forest conditions and trends as they relate to the ecological, economic, and social dimensions of U.S. forest sustainability. The report is developed in the context of the U.S. Department of Agriculture, Forest Service mission to sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations. It stems from the U.S. membership in the Montréal Process for the Conservation and Sustainable Management of Temperate and Boreal Forests (Montréal Process). The report utilizes the Montréal Process Criteria and Indicators (C&I)—a comprehensive and internationally agreed upon set of sustainability measures—to organize the various types of information needed to assess the condition and trends of forests in the United States, the many benefits they provide, and their prospects for sustainability in the future.

Across many parts of the world, rising demands for forest resources and arable land—driven by population growth and shifts in public values and preferences—have led to forest loss, forest degradation, and changes in forest composition, natural processes, and ecosystem goods and services. Climate change is also affecting forests globally. For instance, rising global temperatures and shifting weather patterns have increased the incidence and severity of drought and extreme weather events, creating the conditions for longer and more destructive wildfire seasons across most major forest types worldwide (Jolly et al. 2015; Tyukavina et al. 2022). Additionally, expanding global trade and transportation have led to increasing prevalence of nonnative species that are disrupting forest ecosystems at unprecedented scales (Díaz et al. 2019).

Forests also exert an outsized influence on broader Earth system dynamics and processes. They absorb and store carbon dioxide from the atmosphere, helping to ameliorate the elevated greenhouse gas concentrations driving climate change. However, forests can become sources of carbon emissions when they release more carbon dioxide into the atmosphere than they take up. The transition from carbon sink to source often is the result of significant and persistent changes in disturbance regimes. Through strategic forest restoration and efforts that increase tree cover on nonforested lands—such as through urban tree planting or agroforestry practices—forests provide opportunities for additional mitigation of greenhouse gases and reduction in the deleterious effects of climate change. The increased use of sustainable wood products also offers opportunities to mitigate climate change by storing carbon in long-lived harvested wood products (e.g., building materials) and reducing the use of fossil-fuel-based materials or energy when wood is used instead.

SUSTAINABLE FOREST MANAGEMENT IN THE 21ST CENTURY

Forest sustainability relates to forest capacity to maintain desired characteristics and provide preferred outputs now and into the future (Schmithüsen 2013; Siry et al. 2018). Sustainable forest management (SFM) is described by the United Nations (UN) as "a dynamic and evolving concept [that aims] to maintain and enhance the economic, social, and environmental values of all types of forests, for the benefit of present and future generations."[1] The application of SFM has emerged as a primary goal for governments, the private sector, and civil society[2] at local to global scales, expanding significantly since the 1992 United Nations Conference on Environment and Development (UNCED). In addition to binding agreements for signatory countries on climate change, biodiversity, and desertification (i.e., the United Nations Framework Convention on Climate Change; Convention on Biological Diversity; Convention on Combatting Desertification), UNCED produced the "Rio Declaration on Environment and Development;" "Agenda 21," which included a chapter specific to forests and deforestation; and the nonbinding Statement of Forest Principles (UNCED 1993). Together, these outputs underscored the importance of sustaining existing forests, rehabilitating degraded and deforested lands, improving forest utilization, and enhancing human capacity to manage and care for forests.

1 General Assembly 2007: Non-Legally Binding Instrument on All Types of Forests (A/RES/62/98); United Nations: Bali, Indonesia, 2008.

2 Groups and organizations working in the interest of society but outside governmental and for-profit sectors, e.g., nongovernmental organizations, community groups, religious organizations.

The Statement of Forest Principles and Agenda 21, chapter 11, "Combating Deforestation," also underscored the importance of developing and implementing "criteria, norms, and definitions for systematic observations and assessment of forest resources" (UNCED 1993), setting the stage for the development of C&I frameworks to measure, monitor, and assess forest sustainability at multiple scales globally (box 1) (Linser et al. 2018). A global commitment to forest C&I has since been reinforced in the non-legally binding instrument on forests adopted by the UN General Assembly in 2007 (renamed the UN forest instrument in 2015), and in the UN Strategic Plan for Forests 2017–2030, which provides a framework for action to sustainably manage forests and trees outside forests and to halt deforestation and forest degradation worldwide.

BOX 1. — Criteria and Indicators Defined (Montréal Process 2015)

Criteria are the essential elements by which sustainability is assessed. They reflect publicly held values typically framed as a set of descriptive or goal-oriented conditions and processes. An example is Montréal Process Criterion 1: Conservation of biological diversity.

Indicators are key aspects or attributes of a criterion that can be measured and tracked over time. They are quantitative, qualitative, or descriptive elements that, when measured and monitored periodically, indicate direction of change in a criterion. An example is Montréal Process Indicator 1.1a: Area and percent of forest by forest ecosystem type, successional stage, age class, and forest ownership or tenure.

EMERGENCE OF CRITERIA AND INDICATOR FRAMEWORKS

The International Tropical Timber Organization (ITTO) was a trailblazer for SFM C&I developments, publishing its first framework for tropical forests in 1992. Building from agreements made at UNCED, a number of additional initiatives have been established to develop SFM C&I at regional levels and for specific forest types, altogether involving approximately 150 countries worldwide. Examples of these initiatives include the African Timber Organization for humid Africa, Helsinki Process for European countries (now known as FOREST EUROPE), Lepaterique Process for Central America, Montréal Process for non-European temperate and boreal forests, and Tarapoto Process for the Amazon Basin (Castañeda 2000). Among these various initiatives, the FOREST EUROPE and Montréal processes, along with ITTO, have made the most measurable progress to date in establishing permanent working parties, convening regular meetings, and periodically measuring, monitoring, and reporting on forest C&I (Grainger 2012; Linser et al. 2018).

THE MONTRÉAL PROCESS

Following the agreements made at UNCED, several non-European countries with temperate and boreal forests gathered in Montréal, Canada in 1993 to address the sustainable use and development of their forests. From this and subsequent meetings (collectively referred to as the "Montréal Process" [www.montreal-process.org]) member countries produced an agreed-upon framework for measuring and tracking conditions and trends in forest sustainability. That agreement was first presented in the 1995 Santiago Declaration. Today, the Montréal Process includes 12 member countries (Argentina, Australia, Canada, Chile, China, Japan, Republic of Korea, Mexico, New Zealand, Russian Federation, United States of America, and Uruguay) that together represent 90 percent of the world's temperate and boreal forests, 49 percent of all forests, 49 percent of global roundwood production, and 31 percent of the world's population. Member countries meet regularly on a voluntary basis to advance SFM C&I development and forest sustainability.

The Montréal Process C&I framework offers a flexible but explicit set of forest sustainability criteria and indicators that can evolve over time. As originally established, the Montréal Process framework consisted of 7 criteria and 67 indicators. These criteria have remained as originally developed to reflect internationally agreed upon essential elements of forest sustainability. The indicators have been revised over time by the Montréal Process Working Group as recommended by its Technical Advisory Committee based on member country experiences with implementation and evolving understanding and agreement on the elements critical to forest sustainability.

The current Montréal Process C&I framework comprises 7 criteria and 54 indicators, which together provide the means for measuring, monitoring, and reporting on the ecological, economic, and social components of forest sustainability (table 1). Criteria 1 through 5 address biophysical forest characteristics. Criterion 6 focuses on economic and social factors associated with forests and their management, and Criterion 7 considers the legal, institutional, and economic arrangements for forest conservation and sustainable management. Taken together, the Montréal Process C&I provide a detailed and comprehensive assessment of forest conditions, trends, and progress toward forest sustainability at national and subnational scales.

The comprehensive yet flexible nature of the Montréal Process C&I allows for the framework to be used and applied by a broad range of users for a variety of purposes. Adoption and implementation of the Montréal Process C&I also may drive improvements in the availability, quality, and comparability of forest-related information across countries and over time (Linser et al. 2018). The Montréal Process C&I also provide a common understanding within and across stakeholder communities of what is meant by SFM. An informed, aware, and engaged public helps to promote forest sustainability, and the Montréal Process C&I help provide the informational foundation for this engagement.

TABLE 1. — Montréal Process Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests

	Criterion	Description
1	Conservation of biological diversity	Nine indicators describing the biophysical characteristics of forests, including forest extent, composition, and diversity of flora and fauna. Conservation efforts are also covered.
2	Maintenance of productive capacity of forest ecosystems	Five indicators describing forest productive capacity, area of planted forests, and current production levels of forest outputs (timber and nontimber).
3	Maintenance of forest ecosystem health and vitality	Two indicators describing (1) biotic forest disturbance processes (e.g., insects and diseases) and (2) abiotic disturbance processes (e.g., wildfire and drought).
4	Conservation and maintenance of soil and water resources	Five indicators describing forest soil and water conditions. Conservation efforts are also covered.
5	Maintenance of forest contribution to global carbon cycles	Three indicators describing (1) forest carbon pools, (2) carbon pools in long-lived forest products, and (3) avoided carbon emissions from using wood to produce energy.
6	Maintenance and enhancement of long-term, multiple socioeconomic benefits to meet the needs of societies	Twenty indicators describing (1) the production and consumption of forest products, (2) investments in the forest sector and related human capital, (3) forest employment and community conditions, (4) forest-based recreation and tourism activity, and (5) cultural and spiritual values associated with forests.
7	Legal, institutional, and economic framework for forest conservation and sustainable management	Ten indicators describing legal and institutional arrangements for forest planning and management, public participation mechanisms, economic incentives, and monitoring efforts.

At the national and local level, C&I reporting can provide a valuable resource for evaluating forest programs and forest-related policies. It also may offer an information base upon which dialogue with forest sector stakeholders, international partners, and others can be fostered (Linser et al. 2018). At an intergovernmental level, C&I reporting can catalyze efforts to exchange ideas and capacities for advancing SFM. Such efforts are often the focus of Montréal Process Working Group meetings. Further, in connection with the many ongoing domestic and international efforts and commitments around sustainable development and climate change adaptation and mitigation (e.g., UN Millennium Development Goals, UN Sustainable Development Goals), the Montréal Process C&I may serve a synergistic function by offering supporting data and analyses. This is discussed further below.

U.S. APPLICATION OF MONTRÉAL PROCESS CRITERIA AND INDICATORS

The United States has been an active member of the Montréal Process since its establishment in 1993 and has made a political and institutional commitment to use the Montréal Process C&I to measure, monitor, and report on forest sustainability at national and subnational levels (Robertson et al. 2011). In keeping with its mission, the Forest Service leads periodic assessments of the Nation's forests using the Montréal Process C&I framework. The NRSF—assembled about every 10 years on a rolling basis—provides a summary update of performance against this internationally agreed upon framework (Robertson et al. 2011; USDA Forest Service 2004).

This report is the fourth in the series of Montréal Process C&I framed reports from the United States and continues to track the Nation's progress against the Montréal Process C&I framework. It synthesizes the best available scientific information on forests and related context to inform and inspire dialogue about the sustainability of U.S. forests. It incorporates many of the advancements in forest measurement and monitoring, models, and analytical methods across a broad range of disciplines and fields of study that have emerged over the past decade.

The data presented in this report draw from many of the Forest Service's foundational research programs, which work across temporal and geographic scales and disciplines to quantify the state of U.S. forests. Much of the information presented in this report comes from the data generated by the Forest Inventory and Analysis (FIA) Program, which, in addition to a nationwide forest inventory, conducts the Timber Products Output (TPO) Survey and the National Woodland Owner Survey (NWOS). This report also builds from a broad range of Forest Service research conducted in collaboration with university partners and other forest research

organizations, as well as data produced by various Federal statistical reporting agencies.

Given the comprehensive and multidisciplinary nature of the Montréal Process C&I, assessment of the results requires a broad synthesis of data of different types and variable quality. Many Montréal Process indicators are quantitative in nature; others are qualitative or descriptive. Some indicators can be readily measured at national and subnational scales (e.g., Criterion 1 indicators that describe area and composition of forests based on FIA data), but others may require the collection of new or additional data, the establishment of systematic sampling, or even basic research and conceptual development (e.g., Criterion 6 indicators that consider community resilience or cultural and spiritual values, or the importance of forests to people). Consistency over time is also an important consideration as change detection is a key aspect of sustainability assessment. Consistently measured and reported indicators allow for examination of both current conditions and recent trends.

Some indicators have a full suite of current data that are national in scope and collected frequently in the United States (e.g., most of the indicators associated with the conservation of biological diversity (Criterion 1) and forest ecosystem productive capacity (Criterion 2) and some additional, mostly biophysical, forest indicators). Others, however, lack complete, current, or regularly collected data for the assessment (e.g., Indicator 2.14: Annual harvest of nonwood forest products; Indicator 6.39: Area and percent of forests used for subsistence purposes). When data are lacking, proxy information is often used to address the indicator. In many cases, these proxy data may have excellent characteristics (e.g., high reporting frequency and national consistency). However, their capacity to address all aspects of the indicator may be limited. For example, Indicator 6.42: Number of visits attributed to recreation and tourism and related to facilities available only reflects recreation on National Forest System (NFS) lands and not those managed by private landowners or other government agencies such as the U.S. Department of the Interior, Bureau of Land Management. This is because the survey data that it primarily draws from (the Forest Service National Visitor Use Monitoring Program) are currently unique among the Federal agencies. Nevertheless, NFS lands are the largest forest land ownership available to the public for recreation and therefore can provide insight on the recreation infrastructure availability and the relationship to current use patterns.

Overall, research, monitoring, and assessment of a wide range of biophysical and socioeconomic data on forests and associated conditions and trends are fairly robust and have improved over time since the first U.S. report on sustainable forests using the Montréal Process C&I framework (Indicator 7.54). The inevitable data gaps and inconsistencies notwithstanding, the Montréal Process C&I provide a basis for reporting on forest sustainability at the national scale as well as a model framework that can be adapted to various other settings and scales. Even where indicators exhibit poor data quality and coverage, their continued inclusion in the Montréal Process C&I and other frameworks serves as a reminder of their importance and as a goal for future reporting.

INTERNATIONAL CONTEXT WITH RENEWED EMPHASIS ON GLOBAL REPORTING OF RELEVANT METRICS

The Montréal Process C&I and this NRSF fit within a broader context of forest reporting at national and international levels. Efforts to describe the state of forest resources and quantify forest sector economic activity and associated socioeconomic effects have been around for decades. Since 1948, the Food and Agriculture Organization (FAO) of the United Nations has published global forest statistics and analysis every 5 to 10 years through its "Global Forest Resources Assessment" (FRA). The FAO FRA program relies on country submissions and issues reporting guidelines in advance of each FRA. Country submissions are peer-reviewed and aggregated for assessment at regional and global scales. Today, FAO's Global FRA incorporates information reported by 236 countries and areas.

Initially, the FAO FRA focused primarily on forest production and basic biophysical variables. Over time, it has evolved to report on a much broader range of environmental and socioeconomic factors associated with forests and their sustainability. Since 2004, FRA reporting has been framed by the United Nations Forum on Forests (UNFF) thematic elements of sustainable forest management (box 2). The development of this framework was supported in large part by the Montréal Process, FOREST EUROPE, and other organizations' work on sustainable forest management. The seven thematic areas align closely with the Montréal Process criteria, and their application allows more streamlined and consistent reporting across multiple international forest reporting mechanisms. The UNFF thematic elements were also enshrined in the 2015 UN forest instrument (originally the 2007 non-legally binding instrument on all types of forests), which encompasses a framework for national action and international cooperation on forests and their sustainability.

BOX 2. — The Seven Thematic Elements for Sustainable Forest Management (UNFF 2004)

1. Extent of forest resources
2. Forest biological diversity
3. Forest health and vitality
4. Productive functions of forest resources
5. Protective functions of forest resources
6. Socioeconomic functions of forests
7. Legal, policy, and institutional framework

In addition to FAO periodic reporting related to FRA, several goal- and target-based initiatives have been established for forests and for broader global goals that include forests. Building from some degree of measurable progress generated by the Millennium Development Goals, in 2015, the UN established 17 Sustainable Development Goals (SDGs), which are a call to action to "end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity." All UN member nations agreed to monitor progress toward the SDGs. Goal 15, "Life on Land," includes goals related to forests and their sustainable management (box 3). Related efforts to promote and advance reporting on SDGs have reinforced ongoing efforts to develop and apply forest C&I. For example, SDG 15.2 calls for implementing sustainable forest management, for which the Montréal Process C&I provide a fully developed foundation for determining and measuring progress toward this goal.

BOX 3. — United Nations Sustainable Development Goals (SDG) Citing Sustainable Forest Management

- SDG 15, Life on Land: "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss."
- SDG 15.2: "By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally"
- SDG 15.b: "Mobilize significant resources from all sources and at all levels to finance sustainable forest management and provide adequate incentives to developing countries to advance such management, including for conservation and reforestation"

More recently, the UNFF established the "UN Strategic Plan for Forests, 2017–2030," providing a global framework for action to sustainably manage all forest types and trees outside forests (such as those in urban or agricultural areas not meeting the definition of forest), and to halt deforestation and forest degradation by 2030 (UNFF 2017). The strategic plan encompasses 6 global forest goals and 26 associated targets that build from the 4 global objectives in the 2015 UN forest instrument. The goals outline objectives or aims that are critical to sustaining the world's forests and people. Periodic assessment of the global forest goals and the strategic plan relies on voluntary reporting and other contributions by member states, as well as data and reporting submitted to FAO FRA (UN DESA 2021). These voluntary national reports, and the data collection efforts underlying such reporting, are vital for assessing progress towards implementation of the UN Strategic Plan for Forests and the UN forest instrument. And, by design, these efforts support broader reporting towards the UN SDGs and other efforts such as the Aichi Biodiversity Targets and the Paris Agreement adopted under the United Nations Framework Convention on Climate Change.

ABOUT THIS REPORT

This report presents an assessment of current forest conditions and trends in the United States as they relate to forest sustainability. It is a synthesis of a much larger body of information gathered by Forest Service scientists and collaborators to address the Montréal Process C&I. This report draws primarily from published indicator reports for each of the Montréal Process indicators. These indicator reports are brief, written to be accessible to a nonscience audience, and cover a comprehensive range of forest-related information. The indicator reports are available on the Forest Service Sustainability Reporting website (https://www.fs.usda.gov/research/inventory/sustainability).

The forest conditions and trends presented in this report parallel many key elements included in the congressionally mandated Resources Planning Act (RPA) Assessment (https://www.fs.usda.gov/research/inventory/rpaa). The periodic RPA Assessment summarizes the status, trends, and potential future projections of the Nation's renewable resources on all forests and rangelands. While both the NRSF and the RPA Assessment are national in scope, draw from the same foundational research programs and collaborations, and are published at similar intervals, they are distinct in their focus. The RPA Assessment is mandated by law, is geared more toward domestic audiences, offers analyses and projections along various scenarios intended to support policy makers and land managers in resource planning, and considers rangeland conditions and trends. The NRSF applies the Montréal Process C&I to evaluate trends in forest resources and use through the lens of sustainability and emerges from a political and institutional commitment to international reporting through the intergovernmental Montréal Process.

The sun sets through smoke-filled skies at the Happy Camp Complex Fire in the Klamath National Forest, CA, in 2014. (USDA Forest Service photo)

CHAPTER 2: KEY FINDINGS

INTRODUCTION

Evaluating forest conditions and characteristics across ecological, economic, and social dimensions of sustainability requires the collection and consideration of a great deal of information. The Montréal Process Criteria and Indicators (C&I) facilitate the organization and analysis of such information. This report, and other sustainability assessments, are designed to inform dialogue and decisions about forest management and policy and may be used by a wide range of forest stakeholders in discussions and decisions about forest sustainability at national and subnational scales. For subnational reporting, this report uses regions based on those used by the Forest Inventory and Analysis (FIA) Program of the U.S. Department of Agriculture, Forest Service (fig. 1). Minor differences in regions between this report and the FIA Program include naming conventions (e.g., Pacific Coast instead of Pacific Northwest) and the separation of Alaska into its own region.

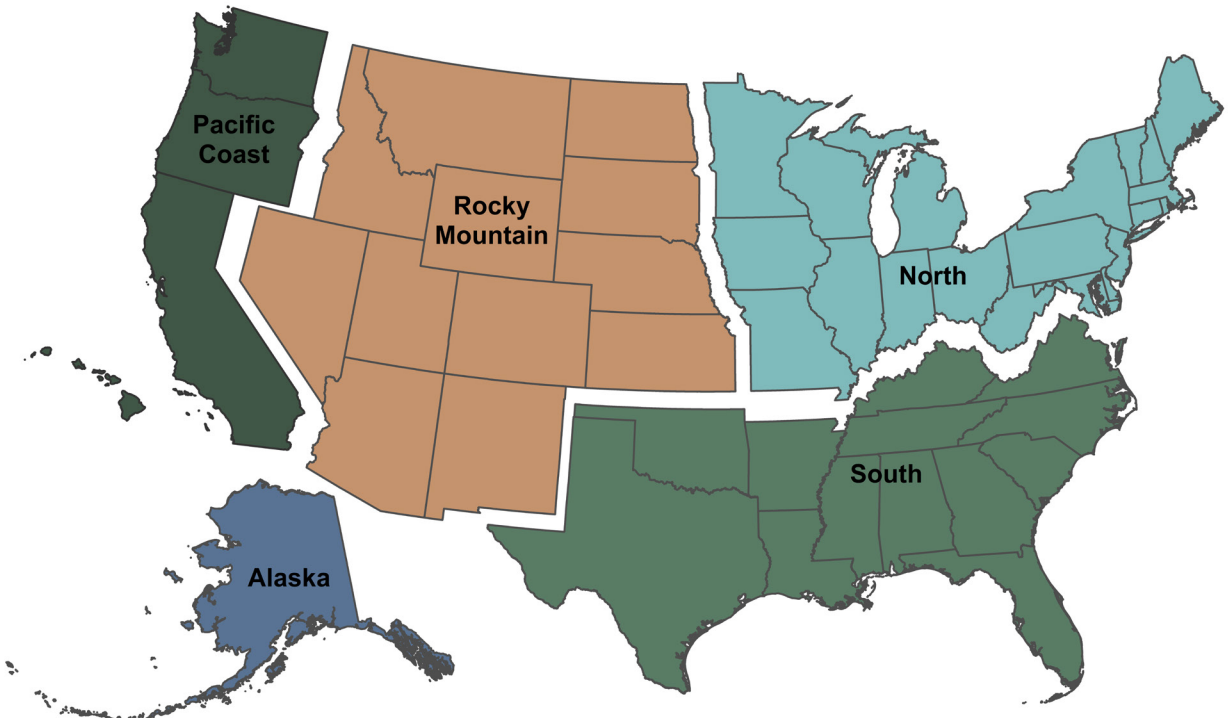
Several key findings for forest sustainability were gleaned from the criterion summaries and associated indicator reports (which are described in detail in chapter 4). These key findings were drawn from a holistic examination of these analyses and associated summaries. Additionally, several issues that span multiple criteria were identified and these pressing and prominent cross-cutting issues influencing forest sustainability are discussed in chapter 3.

ARE FORESTS IN THE UNITED STATES SUSTAINABLE?

At the highest level of summarization lies the question of whether forests in the United States are sustainable. It is formulated as a simple yes-or-no question, but the answer is far from simple. Forest sustainability encompasses a complex mix of ecological, economic, and social dimensions, and the data describing these dimensions are likewise complex, incomplete, and subject to interpretation. As was true in the previous National Report on Sustainable Forests (NRSF) (Robertson et al. 2011), there are both positive and negative indications for progress in forest sustainability, and many of these findings are accompanied by important questions and qualifications.

There is little question, however, that some of the trends around forest health identified as causes for concern in the previous report have deteriorated further in the last decade. Notable among these is the increasing size and severity of wildfires, particularly in the Western United States where drought and heat are intensifying with a changing climate (Abatzolgou and Williams 2016; Jolly et al. 2015). Additionally, the percent of forest-associated species considered to be at risk of extinction continues to rise. Likewise, forest fragmentation, be it from human development (generally considered irreversible) or abiotic and biotic natural processes, continues (although the rate of fragmentation has slowed slightly since the last report). Finally, the modest net gains in forest land area in the United States, described as an important positive sustainability marker in the

FIGURE 1. — Regions used in this report, which are the same as those reflected in the Forest Service's Resources Planning Act Assessment. Due to disparate data sources, some indicator reports may apply different regional delineations.



previous report, appear to have tapered off, as net losses offset net gains at subnational levels.

On the positive side, existing forest lands continue to demonstrate high productivity, providing not only an increasing supply of timber for human use, but also substantial carbon sequestration and other ecosystem services. Forest management decisions were once dominated by debates that pitted wood product production against conservation. In the last decade, we have witnessed a shift where the discourse now highlights forest benefits to society across various objectives including climate change mitigation, the supply of innovative forest products, and recreation opportunities, as well as the preservation of biodiversity and air and water resources.

KEY FINDINGS

- Forest land area in the United States has increased slightly over the past century to 765 million acres.[3] Yet modest long-term forest expansion tapered off in recent years as net increases in forest area in the South, North, and Alaska Regions were offset by net decreases in the Pacific Coast and Rocky Mountain Regions. (Criterion 1) (fig. 2).
- The percent of forest-associated species considered to be at risk of extinction continues to rise. The share of forest-associated species of vascular plants, vertebrates, and selected invertebrates in the United States at risk of extinction (i.e., critically imperiled, imperiled, or vulnerable to extinction) have increased from 28 to 31 percent over the past decade. Conversion of forests to nonforest land uses, alteration of native habitats, introduction and spread of nonnative species, and other biotic and abiotic processes increasingly affect forest-associated species distributions. Changes in data collection methods over time may also account for some changes in reported at-risk species (Criterion 1).
- At the national scale, forests continue to grow more wood than is removed or lost to mortality (annual net growth (i.e., growth minus mortality) is about twice annual removals (i.e., harvests)). Timberland growing stock is nearly evenly distributed between hardwood and softwood species, with about 10 percent (102 billion cubic feet) of total growing stock attributed to planted forests. Increasing tree mortality associated with wildfire, insect infestation, and drought at local and regional scales, particularly in the Rocky Mountain Region, have led to a slowing in national net growth rates, even as removals (e.g., from harvesting, thinning, or land clearing) have decreased since peak average annual harvest rates in the late 1980s (Criteria 2 and 3).
- Disturbances (wildfire, insects, and others) are often a vital part of healthy forest ecosystems, but the increasing extent and severity of biotic and abiotic forest disturbances pose increasing challenges to ecological, economic, and social dimensions of forest sustainability. Over the past 20 years, wildfire intensity and area burned have trended upward at the national scale. Although national-scale, insect-induced tree mortality has decreased since spikes in the 2000s, insects remain the principal biotic cause of tree mortality in the United States, particularly in the Pacific Coast and Rocky Mountain Regions. The increased temperatures and drought attributed to climate change, combined with increasing forest density and insect-induced tree mortality, can create the conditions for increasing wildfire severity and extent. Aggregate statistics on forest disturbances are subject to high temporal and spatial variation and clear trends and reference values are confounded by past management practices and limited historical data (Criterion 3).
- Although forests continue to serve as a carbon sink at the national level, forests in several States in the Intermountain West are producing net carbon emissions at the State scale largely owing to forest disturbance activity. Forest land, harvested wood products (HWP), woodlands, and urban trees represent the largest net carbon sink in the United States, nationally offsetting around 10–15 percent of total domestic emissions annually (Criterion 5).
- Forest-protected rivers and streams

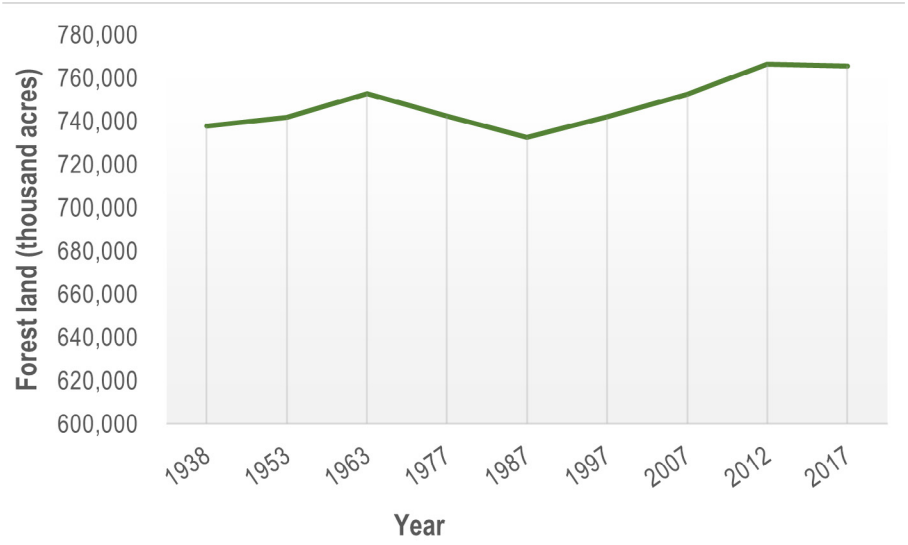


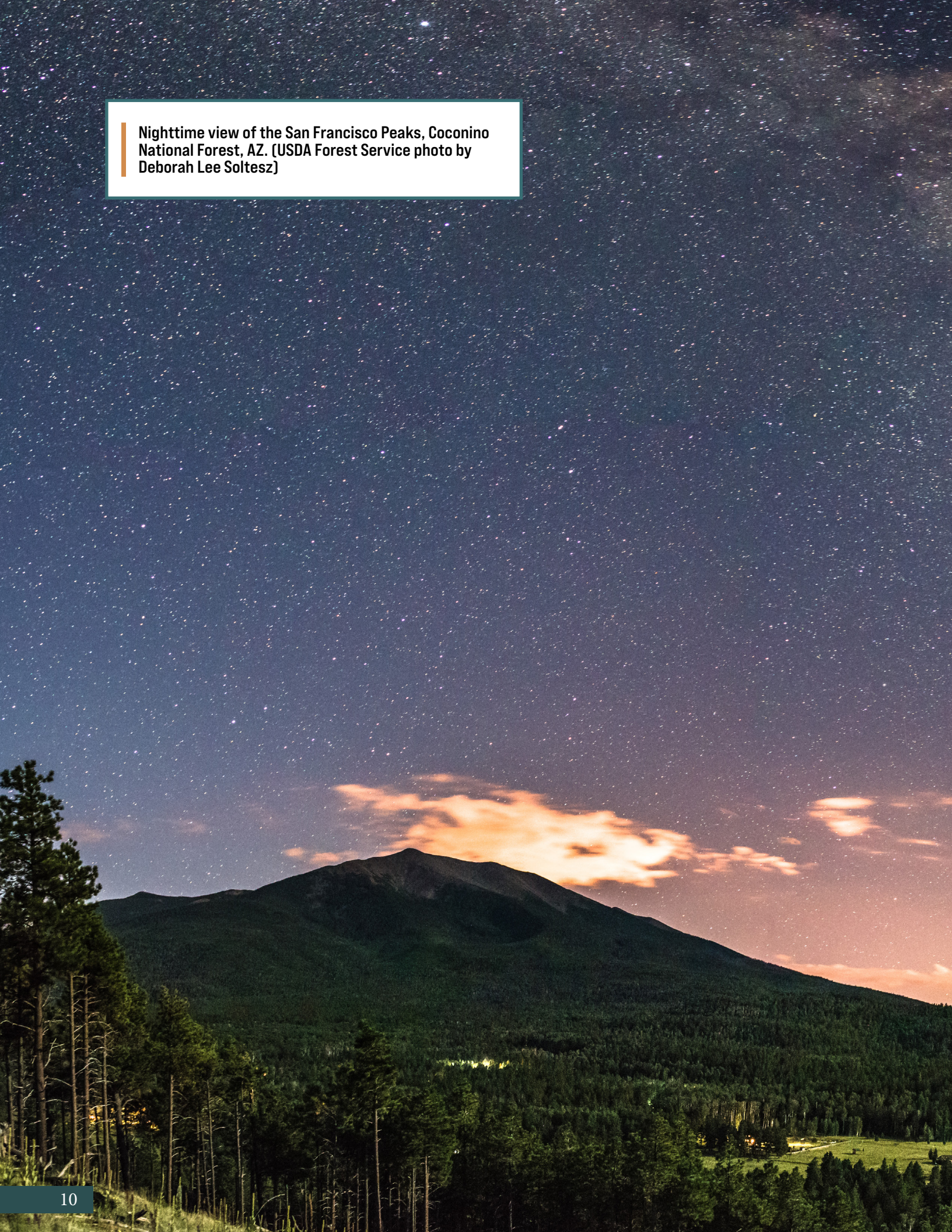
FIGURE 2. — Forest land acre totals in the United States since 1938. Source: Oswalt et al. (2019).

[3] For more information on how forest land area is defined and monitored, see box 5 of this report.

are in relatively good condition in the United States, and previously high levels of acidification observed in forest soils have continued to decrease in recent years. Best management practices (BMPs) for forests focused on reducing the negative impacts of forest management on water and soil resources are widely implemented in the United States and have been shown to be effective. Although nationwide assessments of water bodies paint an overall picture of poor condition, there is evidence that forest-buffered public water supplies are in good condition (75 percent compared to 47 percent of all rivers and streams) and that forestry BMPs and other protections are effective (Criterion 4).

- The wood industry in the United States has rebounded with the recovery in the broader economy over the past decade; however, this rebound had been strongest in portions of the South Region and wood production levels remain below their peak. Per capita consumption of wood and paper products decreased 21 percent since 1965 and production levels are still far below their peak in the late 1980s. Employment in the wood and paper products sectors declined 40 percent since its most recent peak in 1998 (Criterion 6).
- Forest recreation is a principal forest ecosystem service but may be increasingly constrained by disturbances (notably wildfire and smoke) and maintenance backlogs on roads, trails, and facilities on Federal lands. Revenues from forest-based ecosystem services have continued to increase, and nontimber forest products remain important sources of revenue but are more difficult to track over time (Criterion 6).
- Sustainable forest management is pursued in the United States through an expanding range of legal, institutional, and economic approaches developed and applied across multiple scales, ownerships, and actors. These approaches address the ecological, economic, and social dimensions of forest sustainability and increasingly rely on forest-focused collaborations and partnerships that share a common recognition of the importance of forest restoration, wildfire risk reduction, multiple uses, and local forest-based livelihoods. Institutional capacity for traditional forest management activities has declined in some areas, notably forestry research. In addition, wildfire response continues to require significant allocations in land management agency budgets—making forest collaboration and partnerships that address wildfire vital to progress on sustainability (Criterion 7).

Salvaged hardwoods from harvests waiting to be transported to delivery sites for fuelwood use. (USDA Forest Service photo)



Nighttime view of the San Francisco Peaks, Coconino National Forest, AZ. (USDA Forest Service photo by Deborah Lee Soltesz)

CHAPTER 3: CROSSCUTTING ISSUES

The Montréal Process Criteria and Indicators (C&I) framework offers a means to organize forest data for sustainability assessment or other types of analyses. However, several forest issues span criteria and are not easily understood solely in the context of any one criterion. Major crosscutting issues are discussed in this section.

CLIMATE CHANGE AND FOREST DISTURBANCE

As communities across the United States contend with increasingly expensive and damaging natural disasters, there is a growing recognition of the relationships between climate change and extreme events (Funk and Hefferon 2019; Krosnick and MacInnis 2020; NOAA 2023). Forests play a key role in this dialogue given the pronounced effects of climate change on forest ecosystems and forests' role in moderating climate change. Our capacity to track long-term changes in forest conditions associated with climate change is improving (Criterion 4), and there is increasing recognition of the importance of forests in the global carbon cycle and the use of wood as a more sustainable, less greenhouse-gas-intensive building material and energy source (Criteria 5, 6, and 7). Understanding the capacity of forests and wood products to sequester and store carbon relies on understanding current forest conditions, notably growth and stocking levels (Criterion 2).

The complexity of natural disturbance processes makes assessments of shifts in disturbance regimes and their impact on forest sustainability a challenging and multidimensional endeavor. Identifying changes in disturbance patterns from more characteristic variation is difficult given the highly stochastic nature of disturbance over long timespans and the long shadow of precolonial and modern forest management, particularly relating to wildfire suppression efforts over the past century (Barrett and Robertson 2021; Ryan et al. 2013). Moreover, the more subtle and indirect effects of climate change are complex and, as yet, not well understood (Contosta et al. 2019). For instance, subtle changes in wintertime temperature regimes have been associated with changes in tree phenology in temperate and boreal zones, including shifts in the onset of

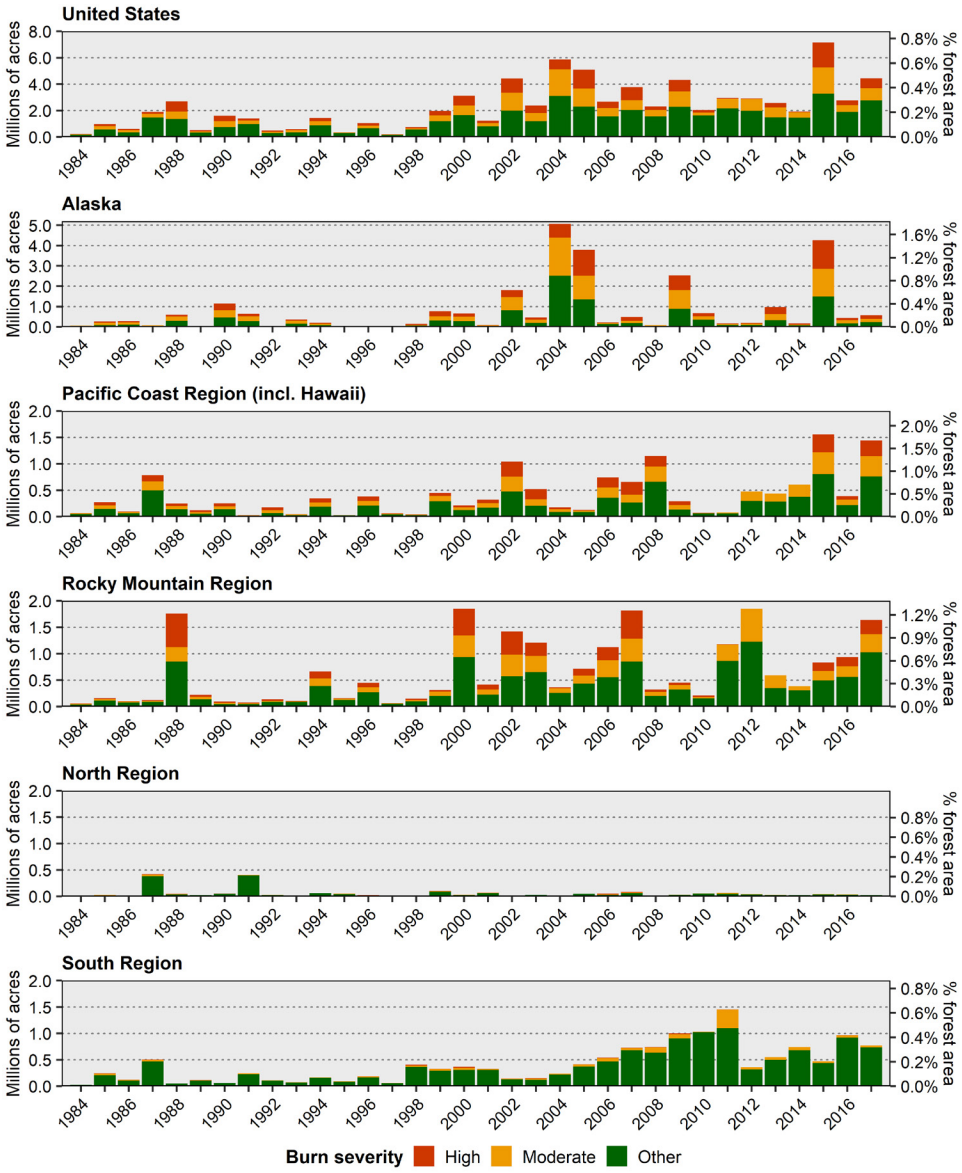
Fall color in Coconino National Forest, AZ. (USDA Forest Service photo by Deborah Lee Soltesz)

spring dehardening, which can result in winter injury to trees and reduced carbon capture and storage (Song et al. 2021; Vitasse et al. 2014).

In the West, interactions between severe drought, insects, diseases, and a century of wildfire suppression are increasing the severity, frequency, and impact of forest disturbances (Hessburg et al. 2019; Shaw et al. 2022). For example, overstocked forest stands weakened by climate change-related drought can result in pest outbreaks over wide areas (Shaw et al. 2022). Approximately 90 percent of forests may be subject to higher mortality because they are overly dense (Woodall and Weiskittel 2021). The pervasiveness of this overstocking (Domke et al. 2021) has significant implications on forest health going forward.

During recent decades, fires have burned over larger forest land areas and with greater severity than in the past, presenting a challenge to forest sustainability (Abatzoglou and Williams 2016; Jolly et al. 2015) (fig. 3). This increase in burned area and severity is occurring along with rising temperatures associated with a changing climate, prolonged drought, and increasing extent of dead trees in the forest canopy and on the forest floor. In some Western landscapes, high-severity wildfires undermine the ecosystem's ability to recover, leading to shifts from forest land to shrubland or grassland (Hessburg et al. 2019). In some cases, heat from fire destroys seed sources, and even where seed sources persist, higher temperatures, drier conditions, and shortening wildfire return intervals can lead to a change in ecosystem type and function (Barrett and Robertson 2021; Coop et al. 2020).

FIGURE 3. — Total forest acres (and percent of total forest area) burned annually from 1984 to 2017, summarized by burn severity category. Numbers for Hawaii are included in the Pacific Coast Region. The burn severity category "Other" includes areas of low burn severity as well as areas of green-up (i.e., vegetation regrowth) after fire. Source: Koch and Ellenwood (2020).



Whereas regions in the West (Pacific Coast, Rocky Mountain, and Alaska Regions) drive much of the national forest burned area statistics,[4] the South Region also exhibited increasing fire activity over recent decades. However, most of the fire activity in the South Region is classified as low burn severity or areas of postfire green-up (see fig. 3). In addition to climate conditions in the South Region, this increasing area of low-severity fire extent may be a function of the comparatively greater extent of prescribed burn applications in the South Region rather than an increase in wildfires (Kolden 2019). Prescribed burning is a widely applied management practice on private and publicly owned forests in that region.

Most of the mortality increases since 2010 in the West are attributed to drought, with the forests in the

[4] Fire statistics applied for reporting on Indicator 3.16 are derived from the Monitoring Trends in Burn Severity (MTBS), an interagency program that maps burn severity and extent of large fires. It tracks all large fires, regardless of fire origin or type (i.e., includes prescribed burns that meet large fire criteria). The large fires included in the Western United States are those greater than or equal to 1,000 acres in size and those within the Eastern United States that are at least 500 acres in size. See the MTBS website (https://www.mtbs.gov/faqs) for more details.

Pacific Coast and Rocky Mountain Regions experiencing the most intense drought. Increasing temperatures and changing precipitation patterns associated with climate change exacerbate dry conditions and this has been especially pronounced in California, where drought has been the predominant mortality agent in 48 of the State's 58 counties (Indicator 3.16). Drought and prolonged heat stress also lower the resilience of trees to insects and disease (Shaw et al. 2022). This has been especially evident across western landscapes, which have been the subject of widespread bark beetle infestations. These native insects exist at low levels for many years until triggered by drought (or other factors that induce stress, such as windfall or other pathogens) (Bentz and Klepzig 2014). For example, since 2015, outbreaks of the fir engraver (*Scolytus ventralis*) and western pine beetle (*Dendroctonus brevicomis*) in the Pacific Coast Region have far surpassed 1997–2010 levels, likely triggered by persistent drought associated with climate change (Indicator 3.15).

In contrast to the pattern of insect infestation in the West, the impact of southern pine beetle (*D. frontalis*)—which accounted for nearly all mortality from biotic agents in the South between 1998 and 2002—diminished considerably in the years since 2002. The impacts of pests and disease on tree mortality vary considerably across regions and time, sometimes decreasing or increasing by millions of acres from year to year. For example, between 2006 and 2007, the number of acres with mortality caused by the nonnative emerald ash borer (*Agrilus planipennis*) in the North Region decreased by 4 million acres (Indicator 3.15). This may be a function of the cyclical nature of some pest and disease agents (Nelson et al. 2018), the impact of climate, or limitations in range, as well as the potential positive effects of management actions to promote more resilient or resistant stand conditions. Given the heterogenous nature of insect and pest outbreaks, their regional impact can be difficult to predict. Nevertheless, higher than average winter temperatures improving overwinter survival of insects and persistent drought associated with climate change, combined with overstocked forests, could create conducive conditions for more widespread and severe pest and disease outbreaks in the future.

The impacts of biotic agents differ across geography and time. Mountain pine beetle (*D. ponderosae*), infestations in the Rocky Mountain Region dominated regional and national statistics on tree mortality for much of the past 20 years. At its peak in 2009, damage from mountain pine beetles accounted for 75 percent of total national mortality. This has shifted in recent years toward the Pacific Coast Region's Sierra Nevada, where the native fir engraver and native western pine beetle are associated with increasing mortality rates. By comparison, tree mortality in the North Region was lower than the Pacific Coast and Rocky Mountain Regions but was overwhelmingly dominated by nonnative invasive infestations (attributed mainly to the emerald ash borer). The South and Alaska Regions experienced considerably less mortality from biotic agents, although nonnative species remain a significant issue in the South Region.

The Montréal Process C&I provide a consistent framework to periodically assess disturbance patterns across the United States and how they influence key forest ecosystem attributes and functions. This periodic reporting helps calibrate baseline conditions and demonstrates that while many of the drivers of disturbance across landscapes are fundamental components of landscape health and processes, the rate and scale of disturbance is on the rise.

FOREST CARBON

The capacity of forested landscapes to serve as carbon sinks is of critical concern given the role U.S. forests play in national climate change mitigation strategies and efforts. Collectively, U.S. forests offset approximately 10–15 percent of the total economy-wide emissions annually, and natural climate solutions[5] are a prominent part of the national climate change mitigation and adaptation strategies. This includes reforestation/afforestation efforts, which have been on the rise since 2012 (Indicator 2.12), catalyzed by increased investment from groups and individuals across the public and private sectors, often acting in collaboration.

Criterion 5 of the Montréal Process framework quantifies carbon stocks and their influence on global carbon cycles. Changes in U.S. forest carbon stocks[6] are driven by forest cover changes, forest growth, health, and mortality. Forests are inherently dynamic systems, absorbing and releasing carbon as a result of natural processes and human actions. Many forest ecosystems are adapted to disturbance regimes and generally recover their carbon over time after disturbances occur. Yet it is the confluence of changes in climate, broadscale disturbance regimes, and land use, rather than individual disturbance events, that may result in significant, long-term forest ecosystem carbon loss.

Whereas most forests across the United States continue to absorb and store more carbon than they release, there are notable shifts that highlight the implications of large-scale

[5] Conservation, restoration, or improved land management actions that increase carbon storage or avoid greenhouse gas emissions across forest lands, wetlands, grasslands, and agricultural lands.

[6] Changes to forest carbon sinks refer to emissions of carbon dioxide (CO_2) or sequestration (i.e., absorption/removal of atmospheric carbon), stored in living biomass. Forests become a carbon source when they emit more carbon than they sequester from the atmosphere.

disturbance for carbon storage and sequestration. Forests in several Intermountain States, most notably Colorado and Montana (fig. 4), have become net sources of carbon emissions attributable to diminishing forest health caused by insects, disease, drought, and wildfires. Forest carbon stocks and stock changes in the United States are tracked annually,[7] providing timely insights on where the impact of these disturbance agents pose the greatest threats to the forest carbon sink.

Shifting disturbance patterns and the associated effects on forests are key factors to consider in the design and expected outcomes of policies and commitments that rely on forest ecosystems to grow the national carbon storage capacity. The contribution of forest offsets to total emissions reductions in the United States has remained relatively stable since 2005, despite steady declines in economy-wide CO_2 emissions over that period, suggesting that the strength of the forest carbon sink on existing forest land in the United States may be tapering off (Indicator 5.22).

Opportunities for new forest establishment to increase carbon sequestration may be limited because the potential for new forest land is constrained by competing land uses in much of the country. Lacking opportunity for forest expansion, the focus of increased carbon sequestration likely falls primarily to existing forest land. In many forests, stocking levels have been increasing to a point that compromises forest health, and biomass removal (such as through mechanical thinning and/or prescribed burning) may be required to restore forest health and promote stable to increasing carbon sequestration rates (see Criterion 2). In some places, protecting forest carbon sinks in the long term may require lowering carbon stocks in the short term. For instance, stand thinning may lead to immediate carbon losses, but in some cases can increase resilience against drought and severe wildfire, protecting landscape carbon sinks (Ontl et al. 2020).

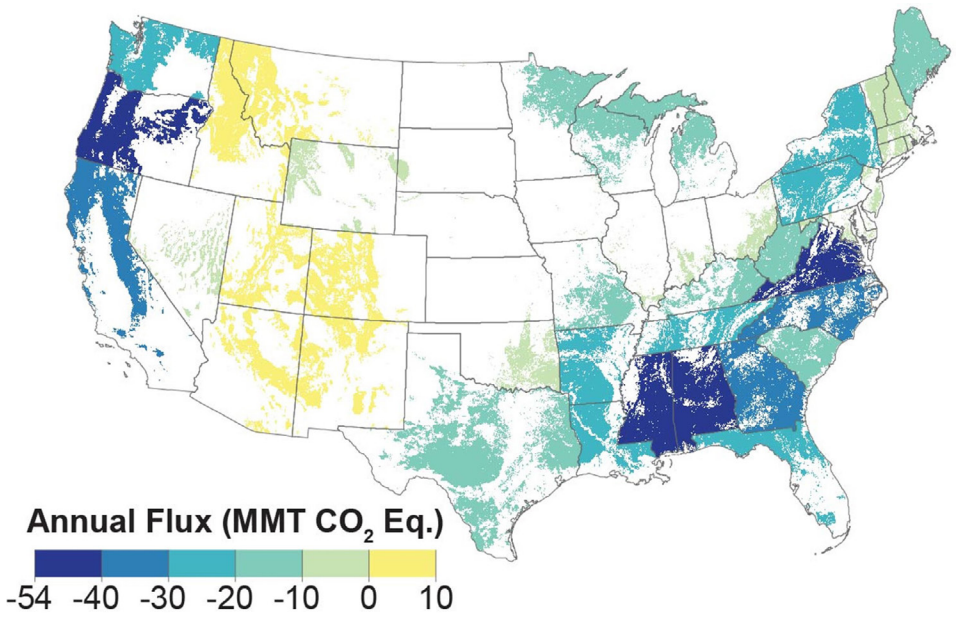


FIGURE 4. — Estimated greenhouse gas emissions and carbon removals (i.e., sequestration) on forest land by U.S. State in 2018. Negative estimates indicate carbon sequestration to forests from the atmosphere. Source: Domke and Murray (2021a). MMT CO_2 Eq. = million metric tons of carbon dioxide equivalent.

OWNERSHIP AND MANAGEMENT TRENDS

Forest ownership patterns differ across U.S. regions, with most private forest land concentrated in the East (81 percent of all private forest land) and most public forest land concentrated in the West (70 percent).

However, land transfers between and within forest ownership categories have been more pronounced in recent decades, particularly among private landowner groups (Butler 2019). For instance, between 2007 and 2017, forest land classified as corporate forest ownership categories exhibited the largest net gain of any ownership category (11.1 million acres) (Sass et al. 2021). This increase occurred mostly through the sale or divestiture of forest land previously owned by vertically integrated forestry companies to timber investment management organizations (TIMOs) and real estate investment trusts (REITs) and from family ownership mostly to small corporate ownership (fig. 5). Shifts in forest ownership patterns may lead to changes in forest management options, approaches, and outcomes, such as timber production, recreation opportunities, and biodiversity conservation.

Most of the productive timberland[8] in the United States is located on private land (70 percent of all timberland) where forest use and management are largely at the discretion of the landowner subject to Federal and State environmental laws, taxation, and other economic instruments (see Criterion 7). Private timberlands supply approximately 89 percent of the total timber volume harvested annually in the United States and are concentrated in the East (Butler 2019; Indicator 2.10). These private lands demonstrate higher average

[7] https://www.fs.usda.gov/research/inventory/carbonmonitoring. (16 January 2023).
[8] Productive timberland is defined as forest land meeting productivity thresholds and not precluded by law or regulation from commercial harvesting of trees.

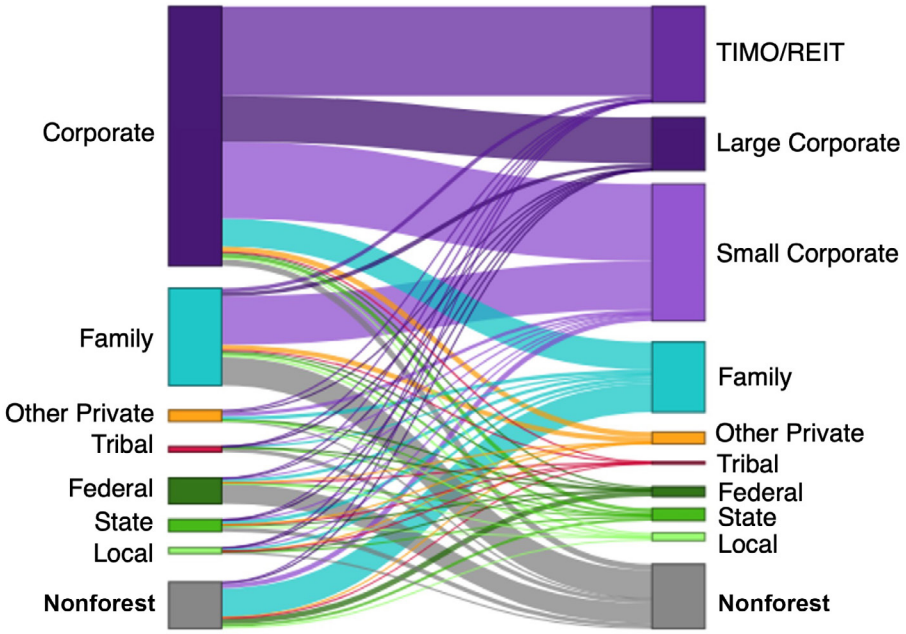


FIGURE 5. — Relative acres that changed ownership categories between 2007 and 2017, conterminous United States. Line colors match the type of ownership that owned the land in 2017. Acres that were held by the same ownership in 2007 and 2017 are removed to allow higher resolutions of the transitions. Ownership boxes in 2007 and 2017 and line weights represent acreage relative to the total. Source: Sass et al. (2021).
TIMO = timber investment management organization; REIT = real estate investment trust.

annual growth and lower average annual mortality than public lands, owing in part to varying regional forest conditions and to more active management.

Forest management goals and objectives vary widely across and within private ownership categories, as do the reasons for owning forest land. Noncorporate forest owners emphasize the importance of scenic beauty, wildlife, protecting nature, passing land on to heirs, and privacy as the primary reasons for owning their forested land (Butler et al. 2021). Other, less commonly cited reasons include recreation, timber production, and firewood production. Corporate forest owners prioritize timber production and land investment but also identify the provision of ecosystem services such as clean water and wildlife habitat among their primary management objectives, reflecting increasing awareness and adoption of corporate strategies, branding, and actions that highlight sustainability accomplishments and best practices throughout their production processes (Lister 2011; Sass et al. 2021).

Public forest lands (i.e., Federal, State, and local government; 74 percent, 21 percent, and 5 percent of total public forest land, respectively) are typically managed for a variety of uses. They are regulated by an expansive legal framework that determines their protections, management approaches, permitted uses, planning procedures, and public involvement in forest planning and management (Indicator 7.45). However, some public forest lands, especially those in State and local ownership, are subject to specific management objectives or goals, such as public water supplies, revenue generation for schools, endangered species conservation, and wilderness protection. About 48 percent of public forest land nationwide is classified as timberland, which supplies about 11 percent of total timber volume harvested annually. Although the share of harvested timber coming from public forest lands is relatively small nationally, timber harvested from public forests is an important (and sometimes the only) source of wood and forest sector employment in many locales, especially in the West. On average, public forest lands tend to be located in more remote areas with more limited operability and relatively low annual growth rates on a per-acre basis compared to private forest land.

OPPORTUNITIES AND BENEFITS FROM SUSTAINABLE FOREST MANAGEMENT

In contrast to some of the crosscutting issues and related findings that may pose challenges to forest sustainability, positive trends and clear opportunities for forest sustainability are also evident. These include trends in forest productivity and the availability of timber resources as well as the increasing public awareness of the value of forests and the connections between forests and water supplies, climate, biodiversity, and the spiritual, physical, and cultural well-being of communities.

PRODUCTIVE CAPACITY AND THE ABUNDANCE OF TIMBER

There have been substantial increases in the productive capacity and volume of timber on U.S. forests in recent decades, with particularly high productivity observed in the South (Criterion 2). Net increases in forest productive capacity and timber volume have occurred even as total timberland area has remained relatively stable. Average annual removals (e.g., from harvests, thinning, land clearing) of timber growing stock also have remained relatively stable in recent years (2011–2016) at 13 billion cubic feet, which is approximately 1 percent of total standing volume. Yet, recent removal rates are down from their peak in the late 1980s (e.g., more than 16 billion cubic feet in 1986). Overall, at the national scale, net annual wood growth on timberland is about twice total annual removals. However, where mortality rates are high owing to wildfire and other abiotic and biotic processes, such as in the Rocky Mountain Region, growth-to-removal ratios may be less than one, and they can be negative

when net growth is negative due to mortality. Overall, increasing standing wood volume nationally may allow for more flexibility in forest use and management, regionally or locally, including potentially concentrating timber production in places where it is most efficient.

JOBS AND THE RURAL ECONOMY

Forests continue to directly provide for livelihoods through the wood products industry. Between 2010 and 2020, the forest products industries employed roughly 800,000 people each year (U.S. Bureau of Labor Statistics 2021). Employment in the sector has significantly declined since the 1980s, driven by a consolidation in wood products production facilities, increasing mechanization of processing, and macroeconomic disruptions such as the Great Recession (Caprio, Jr. et al. 2014; Foster and Magdoff 2009) in the late 2000s. The COVID-19 pandemic also produced a global shock on the wood products sector, where after the initial lockdown phases of the pandemic, demand for softwood lumber and structural panel increased significantly as builders resumed a high rate of residential construction and homeowners invested in repairs and renovations. In response to pandemic-associated contractions in the overall labor market, forest sector wages rose (Prestemon and Guo 2022). These fluctuations in demand, in combination with pandemic-induced supply bottlenecks, resulted in abrupt changes in the price of lumber and related wood materials. For example, the softwood lumber price index rose from $400 per thousand board feet (mbf) in March of 2020 and a high of $1,500 per mbf in mid-2021 (Prestemon and Guo 2022).

In addition to wood products and associated incomes, forests continue to provide a valuable source of heating, food, and amenities for the U.S. public, particularly for people living near them. Forest lands managed by the U.S. Department of Agriculture, Forest Service—which make up nearly one-fifth of all U.S. forests—provide an affordable fuel source for households that depend on wood heating. In 2015 alone, 106 million cubic feet of commercial fuelwood were harvested from land managed by the Forest Service. While wood consumption for energy across the United States has decreased over the past decades, it still represents approximately 20 percent of renewable energy consumption by source, and can help to reduce emissions by replacing fossil fuel-based energy sources (Indicator 5.24).

Other forest products, such as mushrooms, berries, boughs, and plants, provide medicinal benefits, subsistence, and recreational activities (USDA Forest Service 2018a). The aggregate economic value of these nontimber forest products (NTFPs) is difficult to quantify given the wide spectrum of NTFP types and uses, imperfect or opaque markets for some NTFPs, as well as a lack of standard Federal reporting mechanisms for them. Nevertheless, an attempt to estimate the wholesale value of NTFPs harvested based only on Federal permits valued them at more than $1 billion in 2013 (Chamberlain et al. 2018b).

Outdoor recreation continues to be a major economic force: recreation visitors to Federal public lands spend more than $49 billion in the communities around those lands, supporting 826,000 jobs across the United States (Cline and Crowley 2018). Annually, more than 151 million people over the age of 5 engage in outdoor recreation activities in the United States and benefit from the health, cultural, and spiritual advantages of physically connecting with forested lands (Indicator 6.42). In addition to employment in the wood products and tourism sectors, forests provide outputs and amenities that, while difficult to measure, nonetheless underpin rural economies and lifestyles.

SOCIETY'S EVOLVING RELATIONSHIP WITH FORESTS

The U.S. population continues to become more urbanized, with nearly 80 percent of people living in urban areas (U.S. Census Bureau 2021). Urban lifestyles, in combination with industrialized food systems, the ubiquity of synthetic materials, and the transition to digital communication and entertainment, create a growing physical and cognitive distance between people and the natural systems upon which they ultimately rely. At the same time, the larger number of people recreating in forested ecosystems and a growing recognition of the many ways in which forests and trees benefit society, directly and indirectly, are changing the values and demands Americans have for forests. Underlying this is the continuing recognition of the important contributions of forests to sustainably providing crucial raw materials for building and other uses.

The past decade has seen increasing collaboration among public, private, and civil society sectors to advance forest sustainability, particularly by building local capacities and leveraging financial, technical, and human resources to work across ownership boundaries and geographic scales to address forest issues and management goals (Criterion 7; McGinley and Cubbage 2020). One notable trend is the increased mechanisms and investments to catalyze the restoration or maintenance of forests for the ecosystem services they provide. Most recently, the Repairing Existing Public Land by Adding Necessary Trees (REPLANT) Act was passed as part of the Infrastructure Investment & Jobs Act (Public Law 117–58), quadrupling investments to support reforestation projects on national forests, with an emphasis on reforesting burned areas. On private forests, in 2019 an estimated $3.6 billion was paid directly to private landowners for forest-provided ecosystem services through cost-sharing, rentals, offset and mitigation trading, leases, entrance fees, and easements (Indicator 6.27). This is an increase from the $2.1 to $2.3 billion per year in direct payments reported in the 2010 National Report on Sustainable Forests.

The role of voluntary and compliance transactions for ecosystem services has grown substantially in the last

decade. This has helped drive the evolution of market systems that seek to catalyze private investment in forest-based natural climate solutions and corresponding science and methodologies to quantify their climate impacts. The California Air Resources Board (CARB)-administered cap-and-trade program, launched in 2013, accounts for a large share of U.S. carbon market transactions. As of October 2021, more than 187 million offset credits had been issued to forestry projects that meet CARB-approved Compliance Offset Protocols.[9] These offsets are validated and sold by registries that serve both the CARB cap-and-trade program as well as corporate clients seeking to demonstrate progress toward voluntary carbon commitments. The CARB cap-and-trade program has also rendered benefits to Tribal communities, as roughly half of the credits issued to forest projects have gone to Tribal and Alaska Native corporation forestry projects (California Air Resources Board 2021). The higher levels of participation by these communities may be attributed to a confluence of factors that lower barriers for developing forest carbon offset projects, such as relatively large communal land holdings, existing timber inventories, and conservation-oriented objectives and land management practices.

Beyond California, the voluntary carbon market has been bolstered by international efforts to accelerate action toward climate change mitigation, including the 2015 Paris Agreement. Many corporate environmental and social sustainability targets at least partially rely on the purchase of offsets supplied through the voluntary carbon market. However, despite their significant expansion in recent years, the long-term capacity of these mechanisms to lower net atmospheric greenhouse gas emissions has been the subject of substantial academic, political, and public debate. Ethical questions about the premise of these markets and how they are regulated are contributing to an evolving public discourse, including the legitimacy of how additionality claims[10] are formulated, whether risks to buffer pools (intended to ensure against the unmitigable failures to forest carbon projects) are adequately managed (Badgley et al. 2022), and what the moral underpinnings for participation are for large corporations who are responsible for substantial greenhouse gas emissions.

Indicator assessments for Criteria 6 and 7 find sustained, and sometimes increasing, value placed by the public on forests for their cultural, spiritual, and health benefits. Indicator 6.44 (in preparation) draws from the 2018 National Woodland Owner Survey (NWOS), which identified "to enjoy beauty or scenery," "to protect or improve wildlife habitat," and "to protect nature or biological diversity" as the most common reasons that families own and maintain their private forest land. Given the focus of the 2018 NWOS was limited to family forest ownerships, this is not a comprehensive reflection of the public's perception of the value of forests, but it signals a recognition of the spiritual and cultural benefits offered by forests, separate from any economic benefits these private family forest ownerships may generate from their forests. Relatedly, Indicator 6.42 characterizes forest use for recreation and tourism, showing that the share of the population that has engaged in outdoor recreation has remained steady since 2010, but the total number has increased by about 13 million as a function of population growth. The pandemic also fueled a marked increase in visits to parks and natural areas. For example, during 2020, visits to national forests and grasslands increased by 25 percent (an increase of 25 million total site visits and 18 million national forest visits) as compared to 2019 (Avitt 2021).

THE FORESTS LEFT OUT

In accordance with the Montréal Process's focus on temperate and boreal forests, this report does not assess tropical forests occurring on U.S. tropical islands and affiliated jurisdictions in the Caribbean and south Pacific (Hawaii is included as a State). Also, within the conterminous United States, treed lands not meeting the standard Forest Service definition for forests[11] are omitted from Forest Inventory and Analysis (FIA) data collection. These omissions include trees and smaller forested plots of land in urban areas, as well as windbreaks and similar "linear forests" occurring on agricultural lands, and these trees and forested lands are likewise not included in the current analysis. In each case (tropical islands, agricultural forests, and urban forests), trees play an outsized role in providing benefits across ecological, economic, and social dimensions of sustainability, and are generally amenable to analysis using the Montréal Process C&I or similar C&I frameworks. As such, these "forests left out" crosscut the entire Montréal Process C&I framework. Significant progress documenting these forests has been made in recent years, particularly in terms of expanding forest inventory coverage, but comprehensive, broad-scale sustainability assessments have generally been lacking. In order to help fill this information gap, the Forest Service published several studies

9 An offset credit represents a reduction, avoidance, or sequestration of one metric ton of CO_2. These offset credits represent 187 MMT CO_2 Eq., roughly equivalent to the annual emissions released by 50 coal-fired powerplants, according to the U.S. Environmental Protection Agency's Greenhouse Gas Equivalencies Calculator.

10 Additionality claims provide the rationale for whether a carbon project creates a genuine benefit to the climate. It shapes the argument that the avoided emissions or increased sequestration rendered by the project would not have happened in the absence of the project.

11 Areas more than 120 feet (37 meters) wide and more than 1 acre (0.4 hectares) in total extent with at least 10-percent forest stocking.

in the last decade addressing U.S. tropical forests (McGinley et al. 2017) and urban and agricultural forests (Kellerman et al. 2019; Meneguzzo et al. 2013; Robertson and Mason 2016) and is currently leading an effort to inventory agroforestry systems across the United States in collaboration with other USDA agencies (Smith et al. 2022).

The following brief summaries are derived primarily from these publications.

TROPICAL FORESTS

Forests on U.S.-affiliated islands in the Caribbean and Pacific cover approximately 3 million acres, accounting for 45 percent of the total land area (as defined by the FIA and including Hawaii). Forest area throughout the islands is relatively stable, following several decades of forest recovery on abandoned agricultural lands on many of the inhabited islands, particularly in Puerto Rico where forest area increased substantially over the past 75 years and more recently has tapered off. Native biodiversity in the Pacific Islands is threatened by several factors, notably through the ongoing introduction of nonnative species (Moser et al. 2018). In the Caribbean, novel assemblages of native and nonnative tree species are maturing on lands once dominated by agriculture, indicating the dynamic nature and resilience of these tropical forest ecosystems (Lugo 2013). Although commercial timber production is relatively small in both regions, material and cultural linkages between people and forests are strong, including tourism and subsistence activities, and, in the Pacific, long established agroforestry practices. Investments in forest management are limited by fewer opportunities for economies of scale and constrained financial resources, but this is overcome to some extent through collaborative efforts at the regional level. Climate change poses major challenges to forest sustainability, for instance through increased flooding, drought, storm intensification, and salinization.

AGROFORESTRY AND FORESTS ON AGRICULTURAL LANDS

Unlike the tropical forests, many of the trees and forests occurring on agricultural lands in the United States do not fit standard forest definitions, are not inventoried at the national level, and comprehensive data describing them are not available in the form of nationwide aggregates. Across the United States, agricultural lands total slightly more than 1 billion acres divided between croplands (approximately 450 million acres) and grassland, pasture, and range (around 600 million acres). Even if the percent of tree cover on these lands is relatively small, these trees represent a significant forest resource, on the order of tens to perhaps 100 million acres or more (as compared to 765 million acres of inventoried forest land nationwide). For example, in just the Great Plains States of North Dakota, South Dakota, Nebraska, and Kansas, inventory efforts show more than 5 million acres of nonurban trees outside forests. This inventory effort was also used to identify over 400,000 acres of windbreaks in Nebraska and Kansas alone (Atchison et al. 2021).

Many of the trees occurring on agricultural lands were planted or expressly preserved and cultivated to support the production of nontimber forest products, food, and other agricultural products. In other cases, remnant forests along stream beds and between fields provide various and often similar benefits. In either case, benefits range from soil, water, and biodiversity conservation to direct economic benefits to producers through agroforestry applications. In the 2017 U.S. Census of Agriculture, 30,853 operations reported using agroforestry, representing 1.5 percent of all U.S. farms (Smith et al. 2022; USDA NASS 2019). Research exploring the extent of agroforestry use across the United States suggests that adoption is likely much higher (Smith et al. 2022). However, the size and scale of these systems is unknown, as no national inventory has been conducted exploring utilization by specific agroforestry practice or the associated acreage. Data from the 2022 National Agroforestry Survey will help fill this gap by providing national estimates for land area in agroforestry, as reported by producers using these integrated systems. The 2022 U.S. Census of Agriculture will also provide the first time series data for agroforestry use across the Nation. Looking to the future, expanded use of geospatial techniques and national producer surveys can help assess the extent and impact trees have across agricultural landscapes.

URBAN FORESTS

As urban centers face the challenges associated with the expanding urban population and footprint, air and noise pollution, and inequality, as well as rising temperatures and extreme weather events associated with climate change (Barona et al. 2020), the role of urban trees and forests to address these problems is increasingly coming into focus within academic, civil society, and policy spheres (Grilli and Sacchelli 2020; USDA Forest Service 2018b). Of note, while often difficult to quantify, the function of forests to support the emotional and physical well-being of human populations has become the subject of a growing field of academic research and policy focus over the past decade. The presence of trees and green spaces in urban communities has been shown to lower mortality and extend life expectancies, mitigate extreme heat (Janowiak et al. 2021; Kondo et al. 2020), lower stress, and generally improve quality of life (Wolf et al. 2020). Accordingly, Criterion 6 (social and economic benefits) figures prominently in discussions of urban forests, but other criteria also come into play.

The benefits from urban forests include energy conservation, carbon sequestration, air quality improvement, urban hydrology conservation, noise reduction, greater quality of life, community well-being, and local economic development (Robertson and Mason 2016). Despite their benefits, there is lack of data and studies to comprehensively evaluate urban and agricultural forests within the Montréal Process C&I framework (Robertson and Mason 2016). This lack

of data and studies traces primarily to challenges associated with defining, delineating, and measuring these forest types in the matrix of nonforest land uses. Since the publication of Robertson and Mason (2016), there has been significant growth in urban forestry techniques and applications, including the publication of extensive resources and guidance on urban forest stewardship (e.g., Vibrant Cities Lab, Field Guide for Urban Tree Monitoring). The FIA Program's Urban Inventory was deployed as a result of the 2014 Farm Bill and provides data to monitor and inform sustainable urban forest management. In addition, the i-Tree program and software suite, which includes a smartphone application that quantifies ecosystem services and provides decision support at various scales, offers the potential to empower municipalities, communities, and individuals in the stewardship of their urban forest resources.

Despite a growing body of literature demonstrating the benefits of urban forests, tree cover in urban areas of the United States is declining at a rate of about 175,000 acres per year. The estimated loss of benefits from trees in urban areas is conservatively valued at $96 million per year (Nowak and Greenfield 2018).

A freshly planted pine tree seedling. (USDA Forest Service photo)

A ponderosa pine seedling growing at the Placerville Nursery, one of six Forest Service nurseries that grow plants to reforests areas affected by drought, nonnative species, diseases, and wildfire. (USDA Forest Service photo by Andrew Avitt)

CHAPTER 4: CRITERION SUMMARIES

By providing criterion-level summaries for each of the seven Montréal Process criteria, this chapter further leverages the Montréal Process Criteria and Indicators (C&I) framework to organize information pertinent to the assessment of forest sustainability. The summary points listed here for each criterion were used to derive the overall key findings in chapter 2, while providing additional detail, including figures and quantitative data. For more in-depth information, see the individual indicator reports available on the U.S. Department of Agriculture, Forest Service Sustainability Reporting website (https://www.fs.usda.gov/research/inventory/sustainability).

CRITERION 1: CONSERVATION OF BIOLOGICAL DIVERSITY

SUMMARY POINTS

- The area of forest on the U.S. land base is slightly higher today than it was 100 years ago (765 million acres now, 720 million acres then), despite a tripling of the U.S. population during this period.
- Stable to slightly increasing forest land area over the past several decades has tapered off in recent years as net increases in forest area in the South, North, and Alaska Regions have been offset by net decreases in forest land area in the Pacific Coast and Rocky Mountain Regions.
- Ongoing forest fragmentation resulting from forest disturbance and development is changing the structure of forests in many places across the country and remains a concern for forest sustainability at local and regional scales.
- The number and percent of known forest-associated species (i.e., vascular plants, vertebrates, and select invertebrates) presumed or possibly extinct increased between 2010 (77 species, slightly less than 1 percent of all species) and 2020 (111 species, about 1 percent of total). In addition, 31 percent of forest-associated species were designated as at risk of extinction in 2020 (up from 28 percent in 2010). These changes are attributed to a combination of actual changes in species numbers and in data gathering and accounting provisions.

WHAT IS THE CRITERION AND WHY IS IT IMPORTANT?

Forests support a large share of the world's biodiversity of flora and fauna. This biodiversity is critical to forests' maintenance of ecological processes, provision of ecosystem services, and response to disturbances. Human activities and natural processes can effect changes in the numbers or range of species through alterations or fragmentation of landscapes and habitats and introduction of nonnative species. Biodiversity is viewed as a fundamental value in its own right. Moreover, conserving biological diversity at ecosystem, species, and genetic levels contributes to forest function, production, service provision, and overall sustainability. Montréal Process Criterion 1 addresses the conservation of biological diversity of forest systems through nine indicators that address the extent, structure, composition, and protected status of forests, the number and status of forest-associated species and their genetic diversity, including species at risk of extinction, and related conservation efforts across forest types, species, and genetic diversity (box 4).

WHAT DOES THE CRITERION SHOW AND HOW HAS IT CHANGED?

FOREST AREA

According to Forest Inventory and Analysis (FIA) data, about one-third of the United States, or about 765 million acres, is classified as forest based on land use (box 5) (Indicator 1.01). Regionally, forest land use ranges from 18 percent of the land area in the Rocky Mountain Region to 46 percent in the South Region. Forest land in the United States is predominantly privately owned (58 percent), but forest ownership differs significantly by region, with 70 percent of forest area in the West (Alaska, Rocky Mountain, and Pacific Coast Regions) publicly

BOX 4. — Criterion 1 Indicators

Indicator 1.01: Area and percent of forest by forest ecosystem type, successional stage, age class, and forest ownership or tenure (Nelson 2022a)

Indicator 1.02: Area and percent of forest in protected areas by forest ecosystem type, and by age class or successional stage (Nelson 2022b)

Indicator 1.03: Fragmentation of forests (Riitters 2022)

Indicator 1.04: Number of native forest-associated species (Nelson and Knowles 2022a)

Indicator 1.04.1: Biodiversity of forest-associated fishes (Flitcroft et al. 2022)

Indicator 1.05: Number and status of native forest-associated species at risk, as determined by legislation or scientific assessment (Nelson and Knowles 2022b)

Indicator 1.06: Status of onsite and offsite efforts focused on conservation of species diversity (Nelson 2022c)

Indicator 1.07 [in preparation]: Number and geographic distribution of forest-associated species at risk of losing genetic variation and locally adapted genotypes

Indicator 1.08 [in preparation]: Population levels of selected representative forest-associated species to describe genetic diversity

Indicator 1.09: Status of onsite and offsite efforts focused on conservation of genetic diversity (Nelson 2022d)

owned and 81 percent of forest area in the East (North and South Regions) privately owned (see also Criterion 7). Most forest area is classified as naturally established and regenerated. Planted forest area ranges from 0.5 percent in the Rocky Mountain Region to 19.6 percent in the South Region. Conifer forests comprise 389 million acres in the United States (51 percent) and are found predominantly in the West (284 million acres) and South (77 million acres). Broadleaf forests comprise nearly 300 million acres (39 percent), mostly in the North and South Regions (255 million acres). Mixed forests are found mostly in the South and comprise primarily oak-pine (28 million acres) and oak-gum-cypress (25 million acres) forest types.

BOX 5. — Land Use Versus Land Cover Distinctions

Land use describes the social and economic intent for which land is used, whereas land cover describes the vegetation, exposed land surfaces, water, and artificial structures covering the land surface at a given time. Land use and land cover may differ in the perception of the actual or intended human use of the land base compared to its current biophysical cover. For example, forest stands recently disturbed and lacking enough trees of a large enough size to attain a minimum threshold of canopy cover may not be counted as forests when considering land cover. However, such areas are counted as forest land use by Forest Inventory and Analysis (FIA) and reported as such here because the land is expected to remain in forest use. Further, trees in pasture planted as part of silvopastoral systems or the trees in the median strips of interstate highways in rural areas are not counted as forest land use because those trees occur in nonforest land-use categories or occur in strips of insufficient width (i.e., agricultural, transportation/communications/utility corridors and rights-of-way). Forest area figures reported here are mostly derived from FIA data, which provide information based on a land-use perspective of forest land. Conversely, forest fragmentation assessments generally rely on spatially explicit data on land cover generated from remote sensing to monitor landscape patterns and dynamics. For instance, Indicator 1.03 relies on forest cover data from the National Land Cover Database, which defines forest land cover as areas dominated by trees generally greater than 5 meters tall, and greater than 20 percent of total vegetation cover (Nelson et al. 2020), when considering forest fragmentation.

Total forest area on the U.S. land base has increased slightly over the past 100 years (2017: 765.5 million acres, 1907: 720.4 million acres) despite the Nation's human population more than tripling during the same period. Some change in forest area is evident in shorter time periods, and larger relative changes in forest area are detectable at subnational scales. For instance, a slight increase in total forest area between 1997 and 2007 was reported in 2011 (+8 million acres; 0.1-percent average annual increase, mostly attributed to changes in classification of forest types). More recently, net decreases in forest area in the Pacific Coast and Rocky Mountain Regions offset net increases in forest area in the South, North, and Alaska Regions, essentially resulting in no net change in forest land area at the national level (e.g., 2012–2017: -0.02-percent average annual net change) (fig. 6). Changing land uses between forest and nonforest classes is attributed to a variety of factors in the United States, including suburban and exurban development, which typically are associated with permanent forest loss, and transitions to or from agricultural uses, which may be transient.

FOREST FRAGMENTATION

In general, forest is the dominant land cover where it occurs, but forest fragmentation associated with anthropogenic (e.g., urban development, expansion of road networks) and environmental (e.g., fire) processes continues to increase, with the area of forest land cover classified as interior forest continuing to decline, particularly in the West (fig. 7) (see also Criterion 3). Across the United States, as the lens of landscape size being considered increases, the percentage of forest cover that is relatively unfragmented decreases. Forest fragmentation can affect ecological processes, alter biological diversity, and may reduce forest resilience and capacity to provide a broad range of ecosystem services, particularly where fragmentation is permanent. Ultimately, all forests are associated with some degree of fragmentation from environmental processes at some spatial and temporal scales. Determining the effects of recent levels of and trends in forest fragmentation compared with historical fragmentation levels, in particular forest types or regions, remains uncertain.

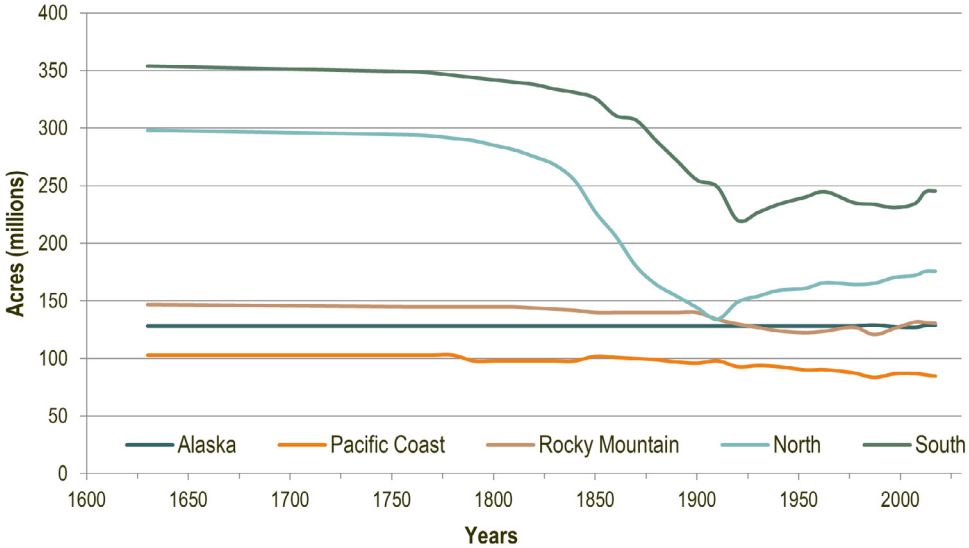


FIGURE 6. — Historical forest area in the United States by geographic region, 1630–2017. Source: Nelson (2022).

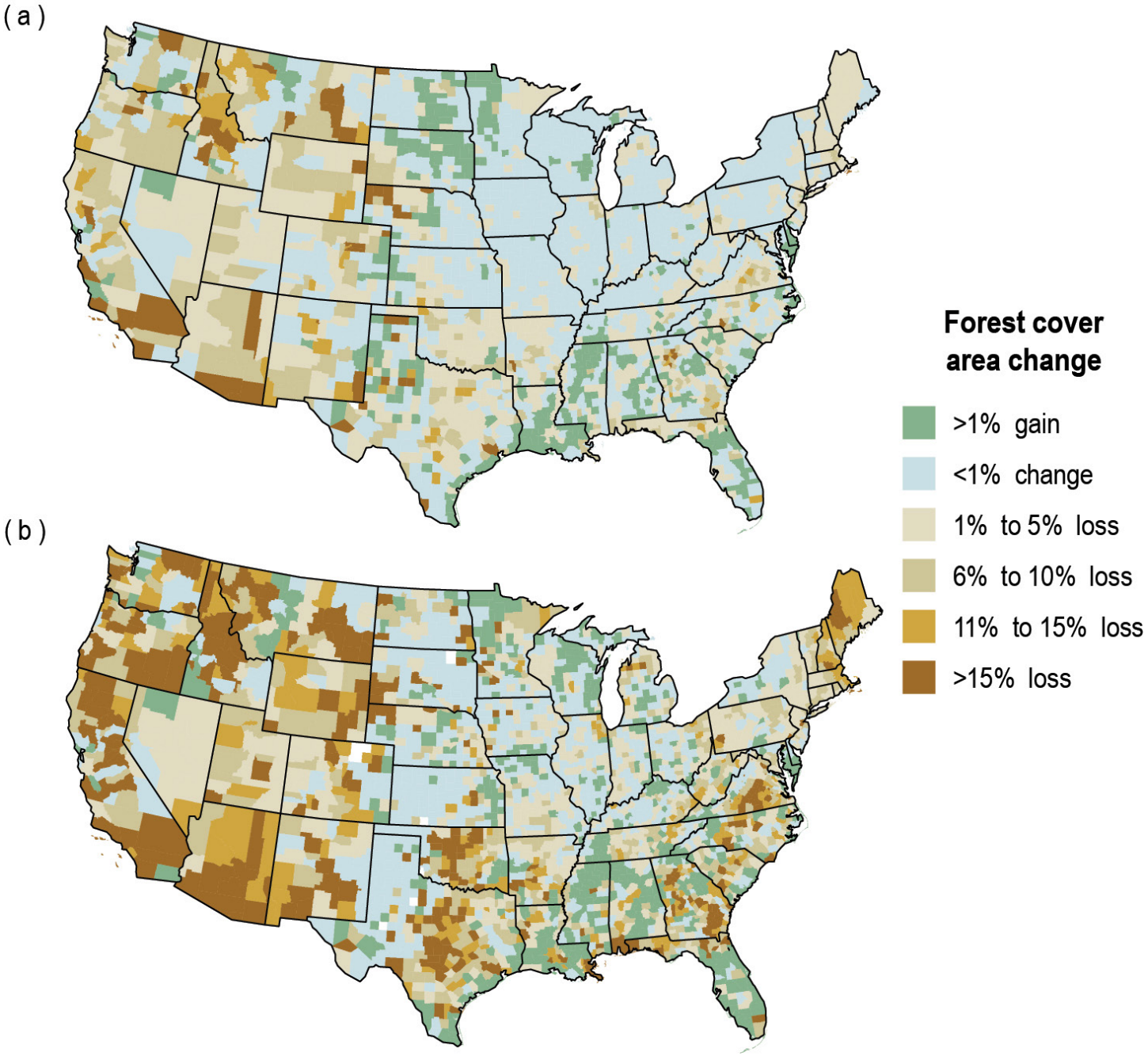


FIGURE 7. — (a) The net change in total forest land cover in a county from 2001 to 2016, expressed as a percentage of the total forest area in 2001 and (b) the net change in interior forest land cover in a county from 2001 to 2016, when analyzed with a 37.6-acre landscape size, expressed as a percentage of the total interior forest area in 2001. Because the same legend applies to both maps, it is possible to compare net percent changes in total forest area and interior forest area at the county level. Source: Adapted from Riitters and Robertson (2021).

FOREST SPECIES

U.S. forests harbor a rich diversity of plant and animal species, with more than 17,000 forest-associated native species currently identified, including 15,256 vascular plants; 1,194 vertebrate species, which include amphibians (216), birds (459), freshwater fish (60), mammals (233), and reptiles (226); and 1,014 invertebrates (an incompletely assessed group whose actual number of species is believed to be considerably higher). The number of native forest-associated species has increased significantly since the 2010 National Report on Sustainable Forests (NRSF) (+2,650), mainly due to revised accounting methods and improved data. However, some decreases in native forest-associated species at the ecoregional level (30 of 106 ecoregions of the conterminous United States) are detected when comparing past (1975–1999) with recent time periods (1999–2018). Forest-associated species that currently occupy a smaller portion of their former distribution also may signal a loss in genetic variation, which can reduce their capacity to adapt to environmental changes and increases their risk of extinction.

Among the documented forest-associated species of the United States (vascular plants, vertebrates, and selected invertebrates), 1 percent is presumed or possibly extinct and 31

percent is considered at risk of extinction (includes species assessed as critically imperiled, imperiled, or vulnerable to extinction) (fig. 8). The percent of at-risk species increased from 28 to 31 percent between 2010 and 2020. In relative terms, the 2020 percentage of at-risk species is 11 percent greater than what was observed in 2010. Furthermore, cumulative impacts of small changes within and across species over multiple decades can be substantial and trigger broader declines or shifts in the production of forest benefits. Changes in data gathering over time have also affected some measures and reported changes in at-risk species. Nevertheless, changes from forest to nonforest land uses, alteration of native habitats, introduction of nonnative species, and harvest have been shown to accelerate changes in forest-associated species distributions.

BIODIVERSITY CONSERVATION EFFORTS

Policies and programs to protect forest area, species, and genetic diversity in the United States can promote conservation on public and private forest and nonforest lands. The Endangered Species Act (ESA) of 1973 protects listed threatened and endangered fauna on all lands, and listed flora on Federal lands, and many ownerships adhere to State and local legislation aimed at biodiversity conservation and other forest values (see also Criterion 7). Protected land-use designations that prohibit production of timber products and conversion to nonforest uses in perpetuity are found primarily on public lands, where about 81 million acres of forest (11 percent) are formally reserved or protected as such. The remaining 240 million acres of public forest land are not subject to strict preservation constraints (e.g., prohibiting the harvest of timber products), but are subject to public planning processes and management practices that consider biodiversity conservation in combination with other management goals such as timber production, recreation, and watershed protection. Millions of additional acres of forest area on private lands are protected for conservation values and from conversion to nonforest uses through conservation easements and fee-simple holdings of nongovernmental organizations (e.g., The Nature Conservancy, Trust for Public Land) and other private landowners (see also Criterion 6 and Criterion 7). While strictly protected forest area on public lands (i.e., with designations that prohibit timber products production and conversion to nonforest uses)

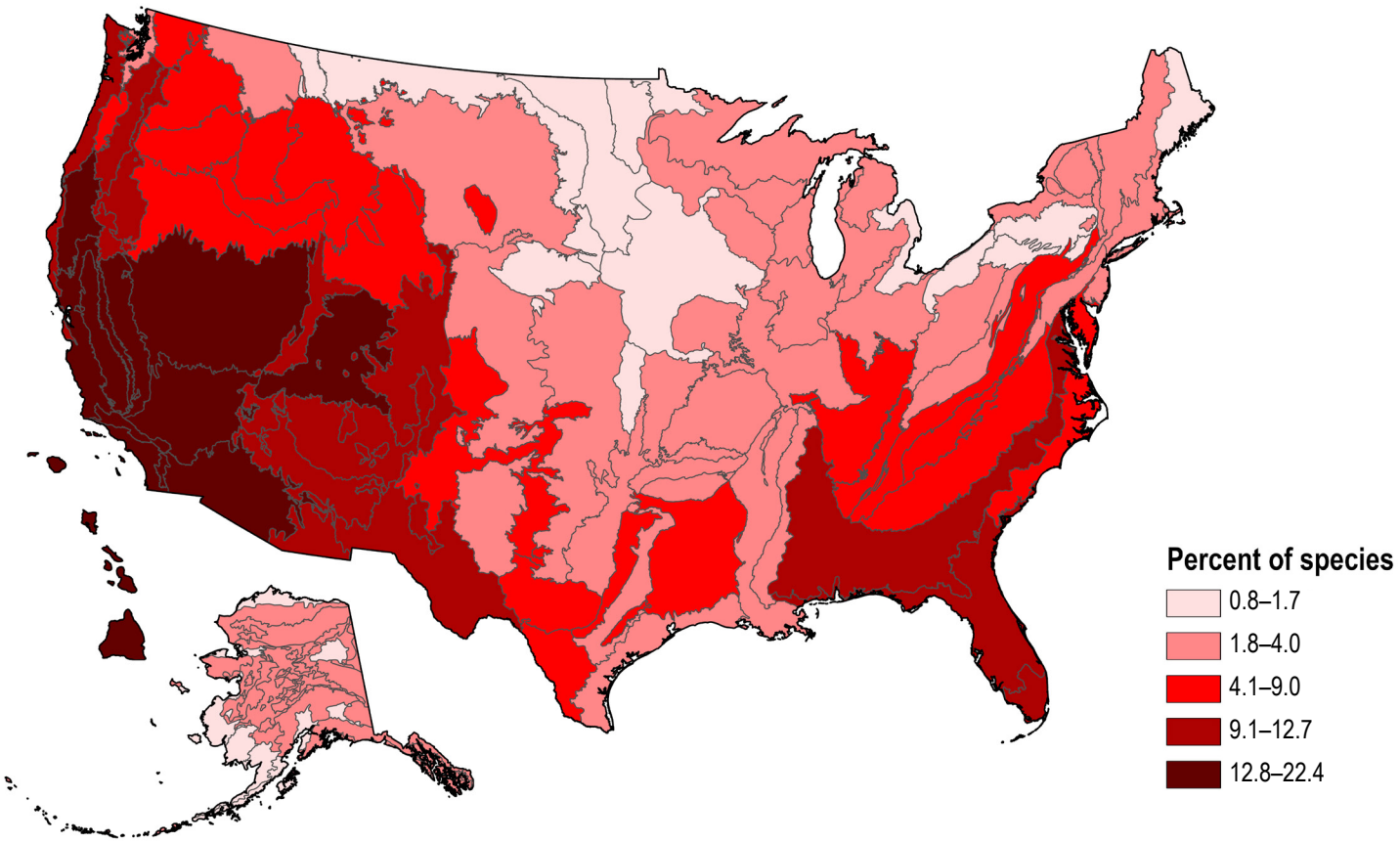


FIGURE 8. — The percentage of forest-associated species (vascular plants and vertebrates) occurring in each ecoregion determined to be at risk of extinction (does not include species classified as "possibly extinct"). Class upper thresholds represent 20, 60, 80, 90, and 100th percentiles. Source: Adapted from Nelson and Knowles (2022b).

has remained relatively unchanged since at least 2010, privately owned protected forest areas have increased in number and area. However, these are difficult to summarize and track over time owing to a diversity of efforts and definitions of "protected," as well as a lack of data at multiple scales. Measures to protect forest-associated species of concern and their genetic diversity through research, education, and management also occur across public and private lands and through offsite efforts, including zoos, arboretums, seed banks, and clonal archives. Related public expenditures are measurable and can be tracked over time, but determining whether and where related activities have increased or, more importantly, if they are effective in sustaining forest biodiversity, remains a challenge.

CRITERION 2: MAINTENANCE OF PRODUCTIVE CAPACITY OF FOREST ECOSYSTEMS

SUMMARY POINTS

- Total timberland area has remained fairly stable in recent decades, amounting to about 67 percent (514 million acres) of total forest area in 2017 and occurring primarily on private land (70 percent of total timberland).
- Timberland growing stock (985 billion cubic feet in 2017) continues to increase at the national scale even as total timberland area has remained relatively stable. Yet, at the regional level, the Rocky Mountain Region experienced a significant decline in growing stock between 2012 and 2017 due to high mortality rates attributed to forest impacts from insects and disease, wildfire, and drought.
- Net growth (i.e., growth minus mortality) of the Nation's timberland is about double annual removals.[12] This pattern has remained fairly stable over recent years. The Rocky Mountain Region is the only region where removals outpaced net growth in recent years. While wood harvest was considerably lower in comparison with other regions, it exceeded net growth due to high mortality rates associated with wildfire and other abiotic and biotic processes. Notably, recent annual removal rates are down from their peak in the late 1980s (e.g., 16 billion cubic feet harvested nationwide in 1986).
- Planted forest area (13 percent of total timberland area) in the United States, located primarily in the South (71 percent), increased from 66 million acres in 2012 to 68 million acres in 2017, spurred in part by recent increases in timber products demand. This increase follows several years of declines in planted area.
- Nontimber forest products (NTFPs) are highly valued for their ecological, economic, and social benefits and are widely collected and marketed. Yet, data on NTFP growth, yields, mortality, and removals across the range of products and lands remains incomplete.

WHAT IS THE CRITERION AND WHY IS IT IMPORTANT?

Many communities depend on forests, directly or indirectly, for a wide range of forest-based goods and services. If forest mortality rates exceed growth, or productive capacity is otherwise exceeded over the long term, there is risk of ecosystem decline. Forest sustainability requires an understanding of the levels at which forest goods and services may be extracted or used without compromising current and future ecosystem function. The nature of goods and services provided by forests changes over time with shifts in broader environmental processes, social and economic dynamics, and technological developments. Change in the productive capacity of forests may be a signal of ineffective forest management or other factors or processes affecting forest ecosystems. Criterion 2 considers the area, percent, and growing stock of natural and planted forest land available for wood production and the harvest rate of wood and nonwood forest products (box 6).

BOX 6. — Criterion 2 Indicators

Indicator 2.10: Area and percent of forest land and net area of forest land available for wood production (Oswalt 2021a)

Indicator 2.11: Total growing stock and annual increment of both merchantable and nonmerchantable tree species in forests available for wood production (Oswalt 2021b)

Indicator 2.12: Area, percent, and growing stock of plantations of native and exotic species (Oswalt 2021c)

Indicator 2.13: Annual harvest of wood products by volume and as a percentage of net growth or sustained yield (Oswalt 2021d)

Indicator 2.14 [in preparation]: Annual harvest of nonwood forest products

WHAT DOES THE CRITERION SHOW AND HOW HAS IT CHANGED?

About two-thirds (514 million acres) of the 765 million acres of forest land area in the United States is classified as timberland (i.e., forest land not reserved (withdrawn from wood extraction by law or statute) and capable of producing at least 20 cubic feet per acre per year of industrial wood). Much of the Nation's timberland is located on privately owned land (70 percent)—a large percentage (81 percent) of which is classified as timberland. About 30 percent of timberland is located on public forest land, of which 48 percent is classified as timberland (fig. 9). The area of forest available for timber

12 Annual removals include the net volume of growing stock trees removed from the inventory during a specified year by harvesting, cultural operations such as timber stand improvement, or land clearing.

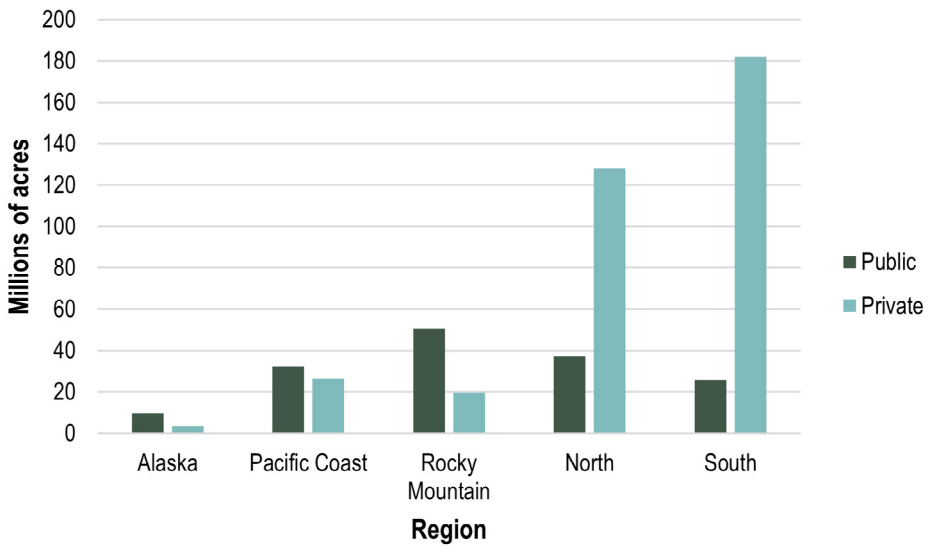


FIGURE 9. — Area of U.S. timberland by ownership and region, 2017. Source: Oswalt et al. (2019).

production generally reflects land ownership patterns in the United States, with much of the privately owned timberland concentrated in the East and publicly owned timberland occupying more area in the West and Alaska (Indicator 2.10).

About 13 percent of the Nation's timberland acreage originates from planted stock, including intensively managed plantations (e.g., loblolly pine (*Pinus taeda*) trees grown in rows), augmented planting of naturally regenerating stands (e.g., interplanting oak (*Quercus* spp.) trees under existing forest canopy), and areas planted for the purposes of forest restoration and where at least 40 percent of stand composition is planted trees. In 2017, there were 68 million acres of planted forest in the United States, about half of which comprised intensively managed plantations. The area of planted forest increased slightly between 2012 (66 million acres) and 2017 (68 million acres) driven in part by increasing demand for forest products following several years of declining demand associated with the 2007–2009 Great Recession and subsequent decreases in construction and manufacturing (Indicator 2.12; Hartsell 2019).

Planted forests are located predominantly in the South (71 percent of total planted area), followed by Pacific Coast (19 percent), North (9 percent), and Rocky Mountain Regions (1 percent). Intensively managed plantations are more prominent in the East, and augmented or interplanted naturally regenerating forests are more prominent in the West. The percent of total timberland classified as planted is highest in the South (22 percent of total timberland) and Pacific Coast (20 percent) Regions. The North and Rocky Mountain Regions have relatively low rates of planted timberland (fig. 10) (Indicator 2.12; Hartsell 2019).

Total timberland growing stock in the United States was estimated at 985 billion cubic feet in 2017, nearly evenly distributed between hardwood and softwood species (Indicator 2.13). The vast majority of growing stock is found in natural forests (90 percent; 885 billion cubic feet). About 10 percent (102 billion cubic feet) of total growing stock is attributed to planted forests (including augmented forests) (Indicator 2.11). Although total timberland area in the United States has remained relatively stable since at least 2012, total growing stock volume has continued to increase (e.g., 2012: 1,865 cubic feet per acre; 2017: 1,915 cubic feet per acre (48 percent higher than 1963)) (fig. 11). The increase in growing stock reflects maturing natural forests where harvests have decreased or shifted to planted forests, enhancements in tree planting and management technologies, and shifts in wood product outputs (Wear and Bartuska 2021). At the regional level, per-acre timber volume increased in most regions between 2012 and 2017, except the Rocky Mountain Region, which demonstrated a significant decline in growing stock because of high mortality rates attributed to a combination of impacts from insects and disease, drought-induced mortality, and wildfires (see also Criterion 3).

In 2016, average annual timberland net growth (i.e., accounting for mortality) across the United States was 25 billion cubic feet—about twice average annual removals in that year (13 billion cubic feet or about 1 percent of total standing volume) (Indicator 2.13). Average annual removals of growing stock in the United States have remained relatively stable since at least the mid-2000s. In the North Region, net growth outpaced removals 2.4 to 1, followed by the Pacific Coast (2 to 1) and South (1.8 to 1) Regions. In the Rocky Mountain Region, removals outpaced net growth due to high mortality rates, specifically in the States of Colorado, Utah, and Wyoming. Despite high tree mortality in these States, nationwide mortality declined from 11 million cubic feet in 2011 to 10 million cubic feet in 2016.

Average annual net forest growth and removals on a per-acre basis are highest on private land (e.g., 57 cubic feet per acre and 32 cubic feet per acre, respectively, in 2016) (fig. 12). Private lands provide most wood products harvested annually in the United States (89 percent), with private lands in the South providing 58 percent of timber harvested annually, followed by private lands in the North (15 percent) and Pacific Coast (14 percent) Regions (Butler 2019). Conversely, net growth and removals were lowest on lands managed by the Forest Service (e.g., 20 cubic feet per acre and 5 cubic feet per acre, respectively, in 2016); these lands also had the highest tree mortality among the major ownership categories. Growth and mortality are influenced by a number of factors including site productivity, species characteristics, biotic and abiotic processes, and

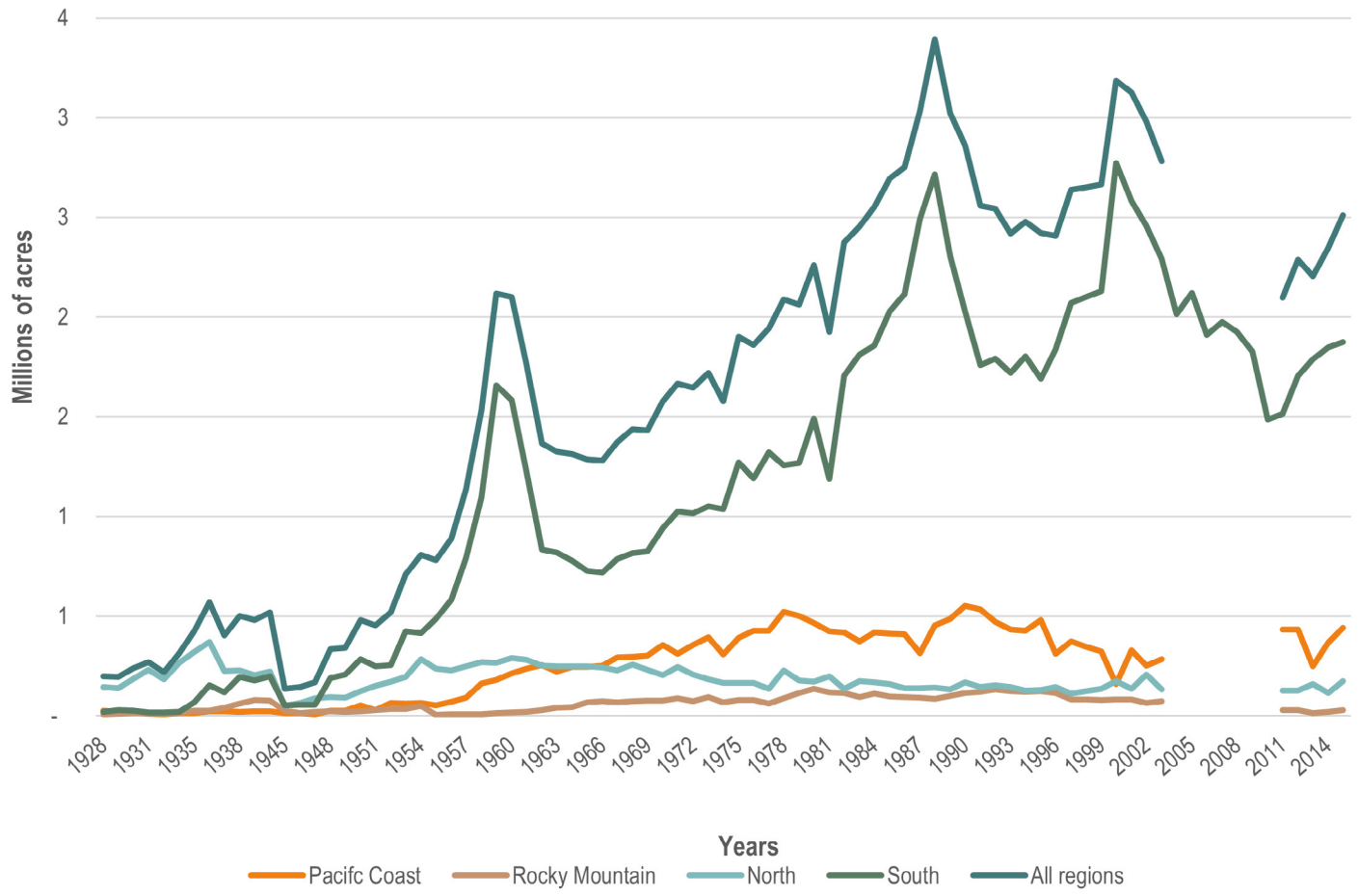


FIGURE 10. — Average annual planted timberland acres in the United States by region and year, 1928 to 2015. Source: Oswalt et al. (2019).

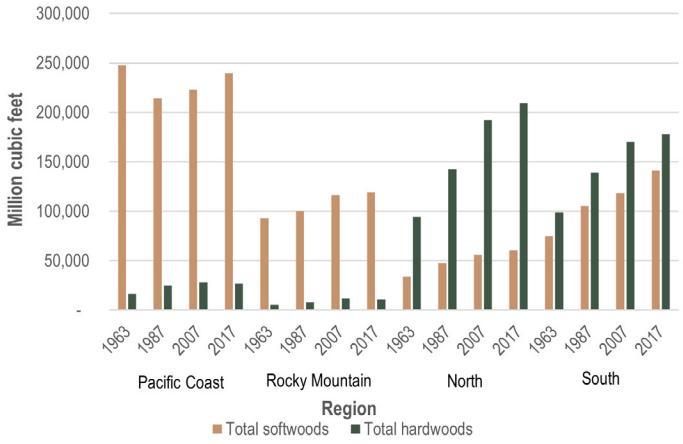


FIGURE 11. — Growing stock volume on timberland by region and major species group, 1963, 1987, 2007, and 2017. Source: Oswalt et al. (2019).

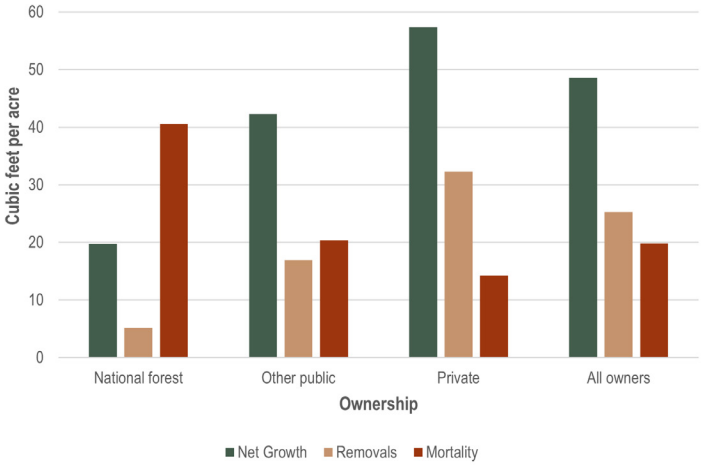


FIGURE 12. — Average annual net growth (gross growth minus mortality), average annual net removals, and average annual mortality on timberland by ownership group, 2016. Source: Oswalt et al. (2019).

management objectives and approaches. There is some evidence that less intensively managed forests may have higher susceptibility to fire and disease and pest outbreaks as they mature compared to those under more active forest management (Wear and Bartuska 2021).

The Nation's forests also produce a diverse set of nontimber forest products (NTFPs), which are associated with important ecological, economic, and social values. People harvest and use NTFPs for food, medicine, arts and crafts, and religious and cultural rituals. They also harvest, trade, and sell NTFPs in local to global markets. Some NTFPs are managed, monitored, or tracked on some lands or in specific links of the supply chain, but they are not fully incorporated into management, monitoring, policies, or resource valuation at national or subnational levels. The best available data on NTFPs in the United States, albeit with challenges to quality and quantity, are captured in harvest permits associated with Federal lands and some industry association surveys. In 2013, the Forest Service and the U.S. Department of the Interior's Bureau of Land Management (BLM)—two Federal agencies managing the greatest areas of Federal forest that also allow for harvest of NTFPs—issued permits for the harvest of 5.646 million pounds of arts, crafts, and floral products; 670,726 pounds of edible fruits, nuts, berries, mushrooms, and sap; and 42,650 pounds of medicinals (table 2). Permitted harvest volumes, as reported by the Forest Service and BLM, do not include private lands or unpermitted collections and can include some products from nonforested areas. These data are not compiled regularly, so harvest trends are difficult to assess. Ultimately, information to determine growth, yields, mortality, and removals of NTFPs from public and private lands to estimate their optimal production and sustainable management in the United States remains incomplete.

TABLE 2. — Permitted harvest volumes of nontimber forest products (NTFPs) from Forest Service and U.S. Department of the Interior, Bureau of Land Management by product category, unit of measure, and region, 2013. Source: Chamberlain et al. (2018a).

Product category	Unit	Alaska	North	Rocky Mountain	South	Pacific Coast	Total
Arts, crafts, and floral	Bunches	0	0	100	0	0	100
	Bushels	0	40	590	100	71,093	71,823
	Cords	0	0	5	0	93	98
	Cubic feet	0	0	295	348	22	665
	Number	0	0	1,000	0	0	1,000
	Pounds	150	5,630	116,743	201,506	5,321,503	5,645,532
	Tons	0	651	293	65	6,716	7,725
Christmas trees	Each/number	0	2,678	133,577	249	76,240	212,744
	Linear feet	0	0	1,566	0	175	1,741
Edible fruits, nuts, berries, and sap	Gallons	0	0	890	0	302,858	303,748
	Pounds	200	400	226,868	30	443,228	670,726
	Taps	0	18,430	0	0	0	18,430
Grass and forage	Pounds	0	104	10	0	4,120,869	4,120,983
	Tons	0	295	3	8	830	1,136
Fuelwood	CCF	244	21,431	351,664	18,397	219,759	611,495
Medicinal	Pounds	0	856	12,148	14,936	14,710	42,650
Nonconvertible	Acres	0	0	0	28	0	28
	Bushels	0	0	6	100	0	106
	Cubic feet	0	0	500	750	450	1,700
	Each/piece	0	3,604	250	2,469	6,129	12,452
	Pounds	3,000	0	0	4,320	56,776	64,096
	Tons	0	0	43	0	1	44
Nursery and landscape	Each/number	600	204	9,827	24,942	10,926	46,499
	Tons	0	0	1	0	0	1
Posts and poles	CCF	0	7,538	11,399	97	16,369	35,403
	Linear feet	0	0	0	0	2,140	2,140
	Number	0	100	22,253	0	6,547	28,900
Regeneration and silviculture	Bushels	0	10	2,193	0	3,513	5,716
	Pounds	0	0	316,744	0	17,037	333,781

CCF = 100 cubic feet.

CRITERION 3: MAINTENANCE OF ECOSYSTEM HEALTH AND VITALITY

SUMMARY POINTS

- Forest disturbance agents pose threats to forest sustainability at regional levels and potentially at the national level. Concerns and uncertainty are greatest in places where multiple disturbance agents, such as pest outbreaks, drought, and wildfires, are present.
- Many disturbance agents are directly or indirectly linked to climate change. For example, the increased prevalence of multiyear droughts and higher average temperatures can reduce snowpack depth and water content (notably in the Rocky Mountain and Pacific Coast Regions) and contribute to accelerating incidence of severe wildfires.
- Analyses of the effects of different disturbance agents are influenced by many factors across space and time, and clear trends seen regionally and locally are not necessarily apparent at the national level. Likewise, reference values for comparison are confounded by past management practices and limited historical data.
- Insect-induced mortality is lower relative to the spikes in bark beetle mortality in the West in the 2000s, but annual mortality totals from the last 3 years of available data (2015–2017) may indicate the start of an increasing trend in insect-induced mortality in the North, South, Pacific Coast, and Alaska Regions.
- Wildfire extent and severity continue at the elevated levels experienced over the last two decades. Major wildfire events in the last few years have highlighted the potential severity of wildfire under extreme climate conditions, especially where they occur in areas recently affected by other disturbances.

WHAT IS THE CRITERION AND WHY IS IT IMPORTANT?

Over millennia, flora and fauna evolve to function within their biophysical conditions. Forests are among the most dynamic ecosystems, responding to the ebb and flow of seasons and disturbance events. Endemic disturbance agents are often integral to healthy forest ecosystems, influencing the evolution and current composition of the systems. For example, lodgepole pine (*P. contorta*) and mixed conifer forests rely on fire to open the canopy and fertilize soil for new generations of trees, other vegetation, and animals to begin a new cycle. However, where degradation exceeds a critical threshold, forest ecosystem health and vitality may be significantly altered, inhibiting the ability to recover from disturbance and affecting the long-term trajectory of ecosystem composition and development (Hessburg et al. 2019).

The expansion of human populations across landscapes has played a role in changing disturbance patterns and environmental conditions. Expanding infrastructure, settlement, and agriculture; wildfire exclusion and suppression; and the manipulation of hydrologic systems have modified biophysical conditions over a timeframe inconsistent with the evolutionary capabilities of many species and ecosystems. More broadly, climate change is also affecting forest ecosystems and driving, or compounding, the effects of biotic and abiotic stressors (see chapter 3 for a discussion on disturbance agents and drivers and how they interact with findings from indicators in other criteria).

The increasing extent and severity of disturbance events, notably those associated with wildfires, have emerged as major concerns for forest management in the last few decades, and therefore, the need to monitor these processes has increased. Climate change will affect disturbance agents in complex and sometimes unanticipated ways, increasing the need for monitoring and assessment (box 7).

BOX 7. — Criterion 3 Indicators

Indicator 3.15: Area and percent of forest affected by biotic agents (e.g., insects, disease, invasive alien species) beyond reference conditions (Koch and Potter 2020)

Indicator 3.16: Area and percent of forest affected by abiotic agents (e.g., fire, storm, land clearance) beyond reference conditions (Koch and Ellenwood 2020)

WHAT DOES THE CRITERION SHOW AND HOW HAS IT CHANGED?

In the United States, insects constitute the largest biotic cause of tree mortality, with the most significant impacts occurring in the Pacific Coast and Rocky Mountain Regions. From 2002 to 2017, total forest area[13] subject to insect-induced tree mortality exceeded 5 million acres annually, or 0.5 percent of total U.S. forest area every year. Within the 1997–2017 time period evaluated, mortality peaked in 2009, when nearly 12 million forest acres experienced mortality from biotic agents, including 8.4 million forest acres in just the Rocky Mountain Region attributed to the native mountain pine beetle (*Dendroctonus ponderosae*). Another significant year was 2016, when 5.7 million forest acres suffered from mortality in the Pacific Coast Region, driven by a more mixed set of agents including the fir engraver (*Scolytus ventralis*), mountain pine beetle, and the western pine beetle (*D. brevicomis*).

Between 1998 and 2002, the southern pine beetle (*Dendroctonus frontalis*) accounted for 99.9 percent of all mortality in the South Region from biotic agents. The sharp drop in mortality from the southern pine

[13] Total acres evaluated via the Insect and Disease Survey (IDS) data may omit some islands and territories outside the conterminous United States because Hawaii, Puerto Rico, and other U.S. territories have not been surveyed consistently.

beetle (*D. frontalis*) after that time period may be explained by better management practices that emerged from research during the last previous major southern pine beetle outbreak in the 1980s and the resulting and improved conditions (e.g., less overstocking) in the region's pine forests.

Relative to other regions, the North Region experienced low rates of mortality induced by biotic agents, though the nonnative emerald ash borer (*Agrilus planipennis*) was responsible for two-thirds of all forest mortality from biotic agents in the region since 1997. The nonnative hemlock woolly adelgid (*Adelges tsugae*) is another significant driver of mortality in the North Region. Since its introduction in the 1950s, it has spread extensively through New England to the Southern Appalachians, driving a significant decline in hemlocks (*Tsuga* spp.) across the region, potentially threatening the species altogether (Letheren et al. 2017).

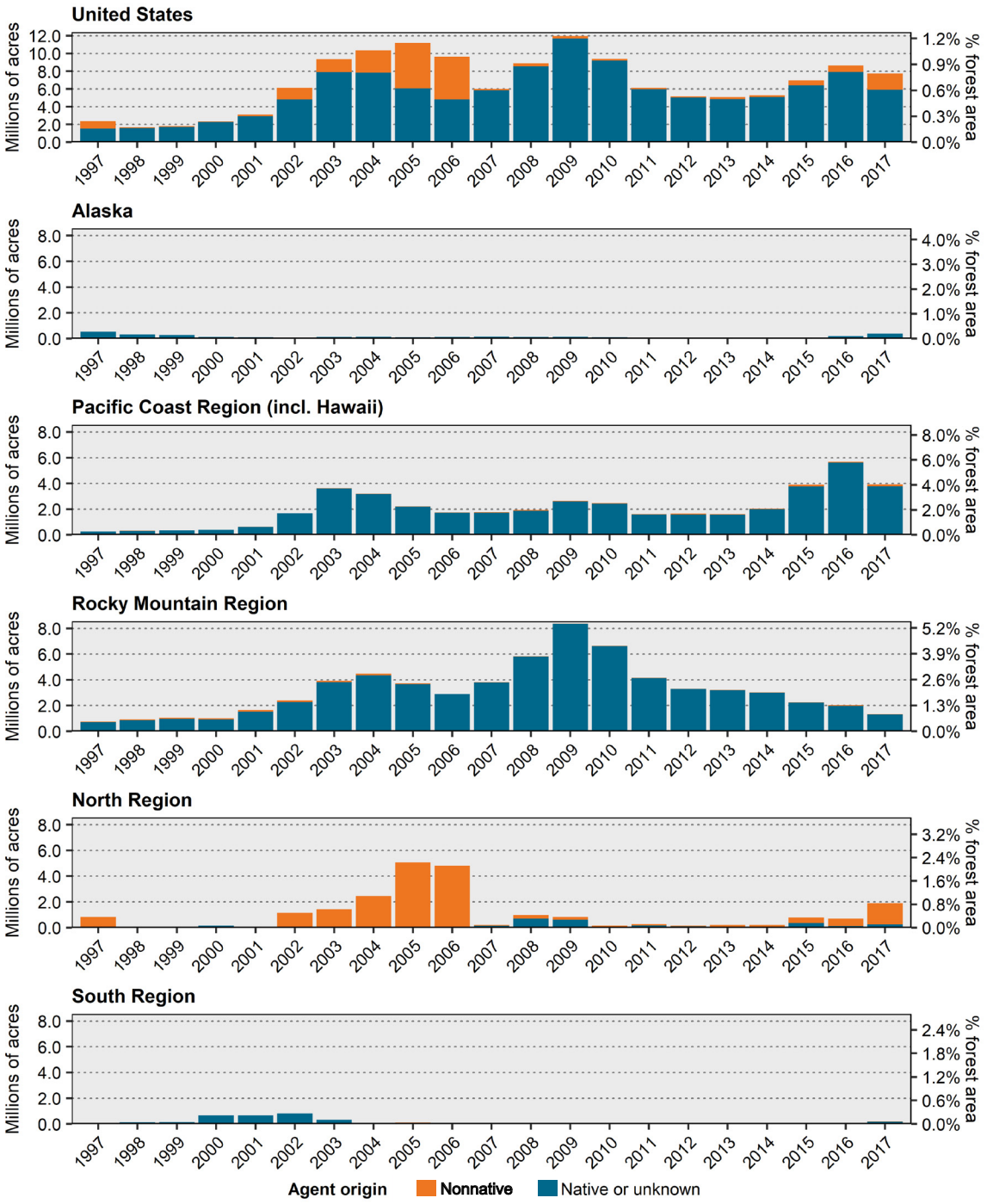


FIGURE 13. — Forest acres with mortality caused by biotic agents, summarized annually from 1997 to 2017 by agent category (nonnative versus native/noninvasive). Hawaii is included in the totals for the Pacific Coast Region for years when data were reported (2013 and 2015–2017). Forest area defined using National Land Cover Database 2011 percent tree canopy data (conterminous United States and Hawaii) and classified land cover data (Alaska). Source: Koch and Potter (2020).

With the exception of the North Region, the most consequential mortality-causing agents are native bark beetle species (fig. 13), which have a history of periodic outbreaks, influenced by predisposing factors such as persistent drought. Analysis and monitoring of these predisposing factors will become increasingly critical as changing climatic conditions lead to altered dynamics of drought and other forest disturbances, both within and between regions.

The most significant abiotic drivers of losses in forest cover and forest mortality in the United States are land-cover change, wildfire, and drought. Between 2001 and 2015, the United States experienced a net overall loss in forest cover of 15.5 million acres, or 2.6 percent. Regionally, the Pacific Coast and Rocky Mountain Regions experienced the largest net forest cover losses between 2001 and 2016, whereas the South Region saw more variability with forest cover losses but also the largest gains. This variation can be attributed to

the active forest management in the region, with its large share of industrial plantations (Chen et al. 2017). The North Region lost 577,000 acres of forest to development (10.2 percent of the gross forest cover loss), whereas the South Region lost 1.3 million acres of forest to development (6.8 percent of the gross loss). Forest cover patterns are reviewed in more detail in Indicator 1.03, which considers forest fragmentation. While both land-cover change and land-use change can result in losses, their distinction is important within the context of forest sustainability because land-use change reflects a more permanent disturbance to the forest ecosystem. Therefore, the discussions around land-cover change observations offered in this criterion attempt to contextualize within broader regional land-use dynamics. See box 5 for a more in-depth discussion of the distinctions between the terms land cover and land use.

Fire is a dominant abiotic agent of forest mortality, yet it is a vital part of many forested ecosystems. Burned forest area (including areas burned in prescribed fire) exceeded 10 million acres in recent years (2015 and 2017). Although extensive, that area remains far below the totals recorded in the first half of the 20th century, before expanded wildfire suppression activities were initiated in the 1950s. Nationally in the past 20 years, there has been a general trend toward a greater burned area extent and higher severity fires (see fig. 3). This trend is only somewhat apparent at the regional scale, primarily because burned area extent can vary widely from year to year. Regions in the West (Pacific Coast, Rocky Mountain, and Alaska) drive the national burned area figures. However, the South Region has experienced relatively large burned areas in some recent years. In that region, most of these fires are low severity and many are planned forest management actions, especially in longleaf pine (*P. palustris*) ecosystems where fire is used as part of fuels management and ecosystem recovery activities. The North Region had very little burned area on forested lands.

Drought can cause considerable stress to trees, especially when it coincides with periods of abnormally high temperatures. Drought stress makes trees vulnerable to a variety of biotic and abiotic agents, compounding mortality and inhibiting forest health and productivity. The percentage of U.S. forests experiencing at least a mild moisture deficit has remained above 20 percent since 2000. The geographic concentration of exceptional drought conditions (fig. 14) between the 2008 and 2017 periods has shifted slightly toward greater concentrations in the West. The increasing incidence of extreme drought events is believed to be exacerbated by climate change and linked to widespread forest mortality. Climate change is expected to drive increased concentrations of drought conditions at regional scales, which

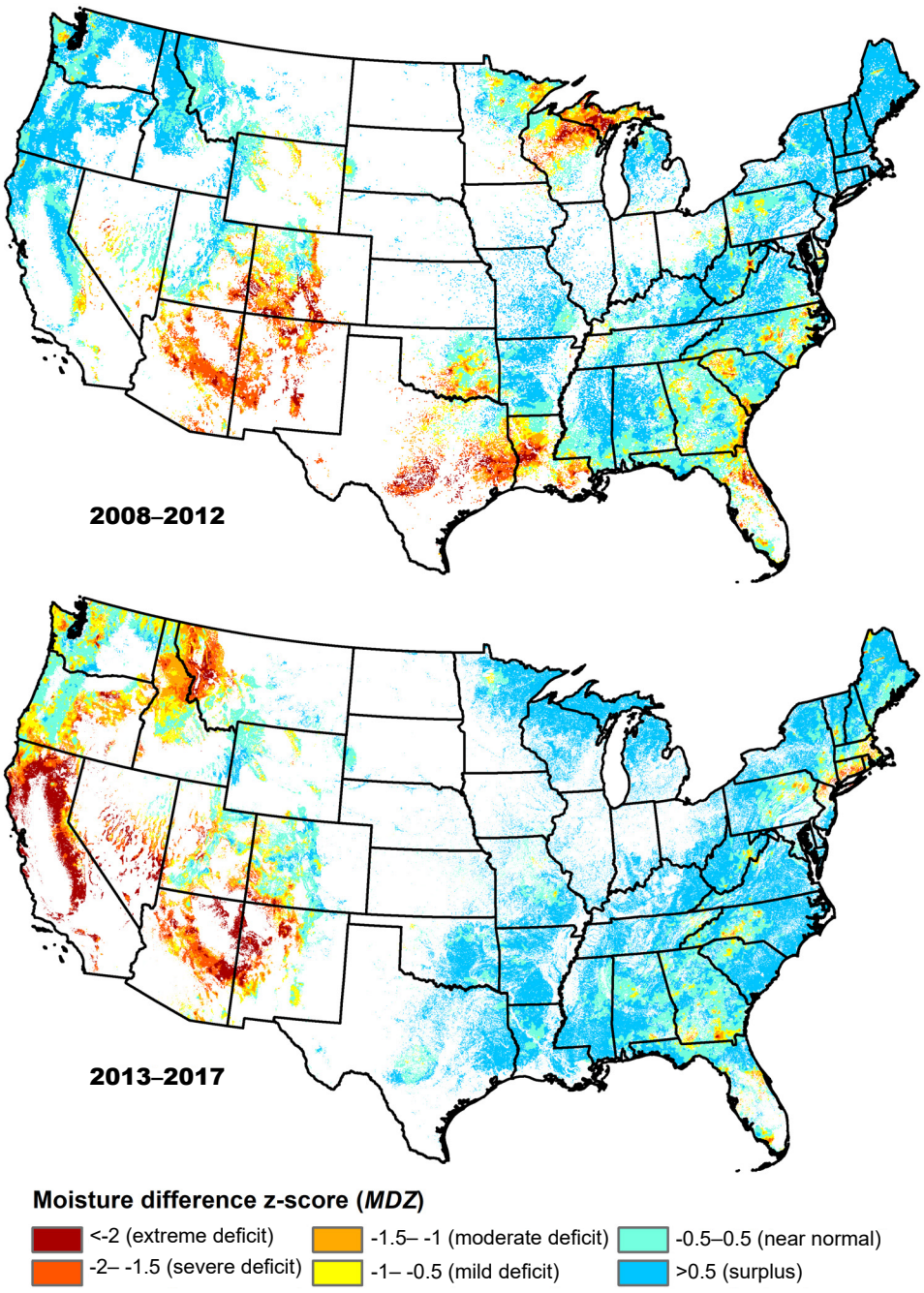


FIGURE 14. — Five-year moisture difference z-score (*MDZ*) maps for the conterminous United States, 2008–2012 and 2013–2017. In each map, the *MDZ* values depict the degree of departure during that 5-year period from long-term (100-year) average moisture conditions. Nonforest areas have been masked from both maps. Source: Koch and Ellenwood (2020).

may exacerbate other disturbance agents as drought-stressed trees are more susceptible to insects and wildfire.

CRITERION 4: CONSERVATION AND MAINTENANCE OF SOIL AND WATER RESOURCES

SUMMARY POINTS

- Nationwide assessments of water bodies paint an overall picture of poor condition, though there is evidence that best forest management practices and other protections put in place to safeguard public water supplies are effective.
- The percentage of forested soils with high levels of acidification has continued to decrease. Still, 21 percent of forested soils are likely experiencing terrestrial acidification impacts, particularly in the North and South Regions.
- Overall, silvicultural activities are not shown to be major sources of pollution for water bodies, potentially attributable to widespread implementation of best management practices and other standards and practices nationwide.

WHAT IS THE CRITERION AND WHY IS IT IMPORTANT?

Water and soil are fundamental building blocks for terrestrial ecosystems. The health of soils and water resources set the productive capacity of ecosystems, driving the availability of food, habitat, and resources that all living things need. Soil and water health are also tightly connected in that healthy soils promote water filtration, reduce wind and water erosion, enhance plant and soil biodiversity, contribute to clean and abundant water supplies, and can enhance drought resilience through soil water retention. This criterion evaluates the condition of soil and water resources and the extent of formal management practices in place to sustain the capacity of ecosystems to sustain forests, forest economies, and forest-dependent societies.

Soil and water resource conservation in the United States is shaped by the Clean Water Act (CWA) of 1972, enacted by Congress to maintain and restore the chemical, physical, and biological integrity of the Nation's waters. The CWA shapes how water quality is managed and monitored across the Nation, and associated CWA reporting is central for reporting on Criterion 4 indicators (box 8).

BOX 8. — Criterion 4 Indicators

Indicator 4.17: Area and percent of forest whose designation or land management focus is the protection of soil and water resources (Amacher et al. 2020a)

Indicator 4.18: Proportion of forest management activities that meet best management practices or other relevant legislation to protect soil resources (Amacher et al. 2020b)

Indicator 4.19: Area and percent of forest land with significant soil degradation (Amacher et al. 2020c)

Indicator 4.20: Proportion of forest management activities that meet best management practices, or other relevant legislation, to protect water related resources such as riparian zones, water quality, quantity and flow regulation (Amacher et al. 2020d)

Indicator 4.21: Area and percent of water bodies or stream length in forest areas with significant change in physical, chemical, or biological properties from reference conditions (Amacher et al. 2020e)

WHAT DOES THE CRITERION SHOW AND HOW HAS IT CHANGED?

STANDARDS AND BEST MANAGEMENT PRACTICES

Forestry standards and best management practices (BMPs) are designed to protect soil and water resources through preventive measures that control or reduce movement of sediment, nutrients, pesticides, or other pollutants from soils to receiving water bodies. State-level regulatory and voluntary BMPs have been developed in all 50 States in accordance with the CWA. Additionally, the Forest Service has BMPs for the agency to meet CWA mandates and corresponding State laws to protect water quality from land and resource management activities.

The National Association of State Foresters (NASF) conducts periodic surveys of State nonpoint source pollution control programs for silviculture, including the implementation of BMPs. In the 2013 survey, 32 States reported forestry BMP monitoring statistics. The average overall use of silvicultural BMPs by responding States was 91 percent and covered activities such as prescribed burns, forest roads, log landings, stream crossings, chemical site preparation, pesticide use, and wetlands protection. The 2019 survey showed a slight increase to 92 percent of BMP use. The Forest Service National BMP Monitoring Summary Report for fiscal years 2013–2014 (Carlson et al. 2015) documented that 84.5 percent of the monitored sites/projects implemented BMPs to varying degrees (38 percent were fully implemented). The report also documented that 78.4 percent of BMPs were at least marginally effective at protecting water quality.

WATER CONDITION

Across the United States, 288,780 miles of rivers and streams (8.2 percent of total) and 7,146,581 acres of lakes, ponds, and reservoirs (17.2 percent of total) have been designated as public water supplies. Public water supplies generally receive some governmental protections to conserve water quality. These protections can include mandatory or voluntary forest BMPs or the requirements to maintain forest buffers around river corridors or waterbody shorelines. About 53 percent of all U.S. rivers and streams and about 71 percent of U.S. lakes/ponds/reservoirs were found in poor overall condition in 2012. Those serving as public water supplies, and thus receiving protection, are 1.6 times more likely to be classified as being in good condition. About 25 percent of public water supply rivers/streams

and 20 percent of public water supply lakes/ponds/reservoirs designated were found to be in poor overall condition.

Approximately 34.1 million acres, or 6.2 percent, of U.S. forests are within 100 feet of water bodies, and therefore function as a protective forest to help prevent water quality impairment. The top sources of water quality impairment in rivers and streams are unknown sources, agriculture pollutants, and hydromodification. In contrast, for lakes/ponds/reservoirs, atmospheric deposition, unknown sources, and unspecified nonpoint source pollution are the top sources of water quality impairment.

SOIL CONDITION

Data on soil health and degradation across U.S. forests are available from the FIA Soil Quality Indicator, which assesses the condition and trend of soil quality on all U.S. forest lands, including incidence of bare soils (which have heightened potential for erosion) and visual evidence of compaction. Most FIA plots surveyed were found to have at least some bare soil and some compaction but constituted relatively small areas of the plots in all regions, with a few exceptions. Plots in the Interior West had a greater incidence of bare soil and plots in the South had more observations of soil compaction. However, soil compaction is not a large areal extent problem on forested lands and is largely confined to trails and forest harvest operations.

The most serious soils-related forest condition threat is increasing soil acidity and associated decreasing soil calcium reserves, along with increasing—and potentially toxic—levels of exchangeable aluminum. This soil condition is related in part to atmospheric acid deposition (Driscoll et al. 2001). Based on an analysis of critical loads of these elements for terrestrial acidification, 21 percent of forested soils are likely experiencing terrestrial acidification impacts, primarily concentrated in the Appalachia area of the North and South Regions, putting sensitive tree species at risk. However, the percentage of forested soils exceeding their critical load for terrestrial acidification has decreased by 1.3 percent since 2010, and 7 percent since 2005, indicating that overall soil quality may be improving.

CRITERION 5: MAINTENANCE OF FOREST CONTRIBUTION TO GLOBAL CARBON CYCLES

SUMMARY POINTS

- Forests in the United States sequestered a net 547.6 million metric tons of carbon dioxide equivalent (MMT CO_2 Eq.) in 2018, equivalent to approximately 10 percent of national economy-wide emissions that year. This is consistent with findings in Criteria 1 and 2 that forest area is stable and the amount of wood in these forests is increasing as they continue to grow.
- Forests in the Rocky Mountain Region are producing net emissions of carbon owing to forest disturbance processes such as wildfire and insect-induced tree mortality.
- Substantial carbon is transferred from the forest to harvested wood products (HWPs) each year and accounts for 99 MMT CO_2 Eq. in long-lived wood products annually.
- Wood energy currently accounts for approximately 20 percent of renewable energy consumption in the Nation, ranking behind hydroelectric and wind. This share is shrinking as use of other energy sources increases and wood energy production remains relatively stable.

WHAT IS THE CRITERION AND WHY IS IT IMPORTANT?

Forest ecosystems are the largest terrestrial carbon sink on Earth, helping to reduce atmospheric carbon globally and thus partially mitigate the deleterious effect of increasing atmospheric carbon concentrations that are a driving force in climate change. Wood products and wood energy can further contribute to reductions in atmospheric carbon. The three indicators in Criterion 5 track carbon pools and fluxes in forests and in harvested wood products, as well as avoided fossil fuel emissions resulting from the use of wood for energy (box 9).

BOX 9. — Criterion 5 Indicators

Indicator 5.22: Total forest ecosystem carbon pools and fluxes (Domke and Murray 2021a)

Indicator 5.23: Total forest product carbon pools and fluxes (Domke et al. 2021)

Indicator 5.24: Avoided fossil fuel carbon emissions by using forest biomass for energy (Domke and Murray 2021b)

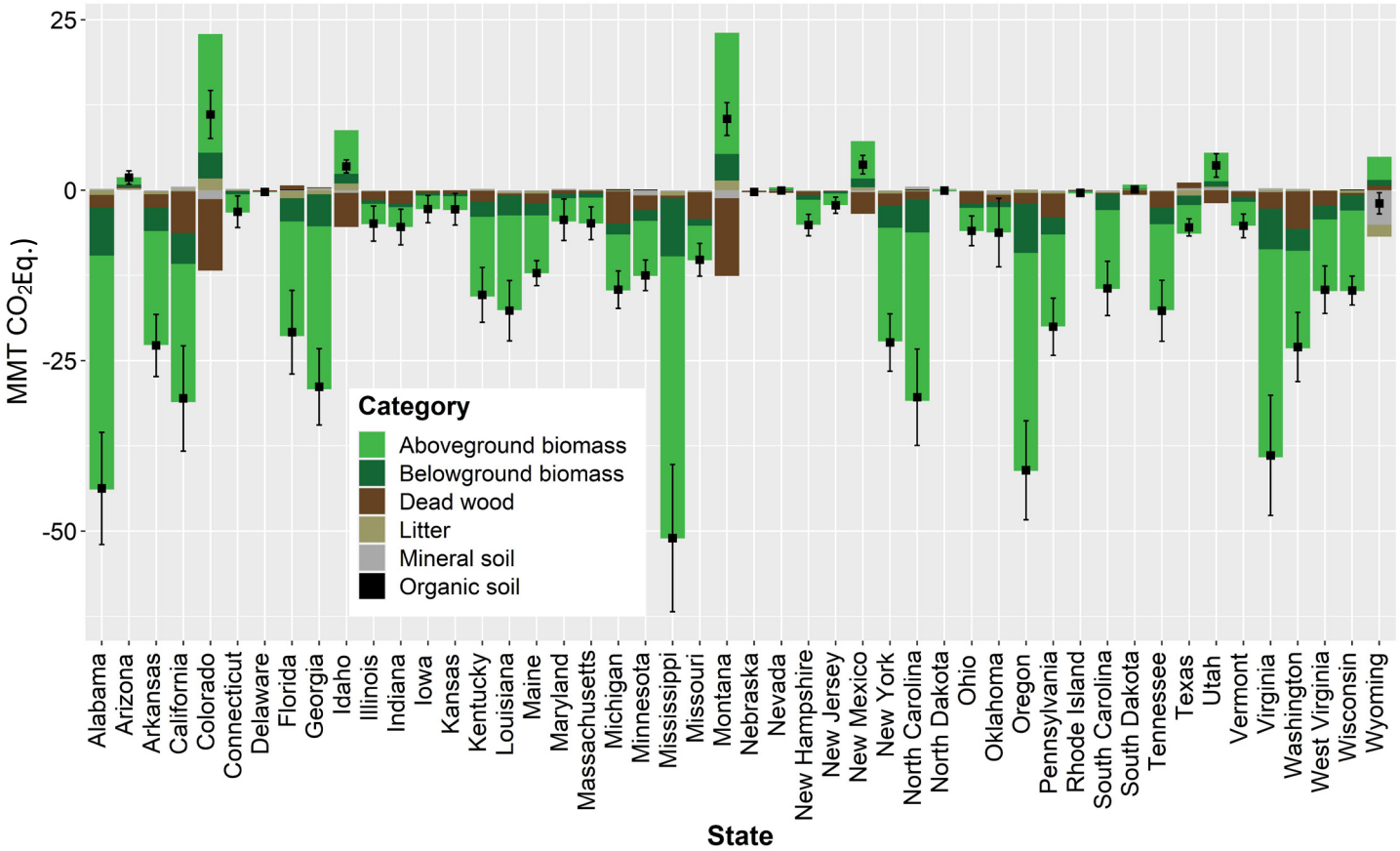
WHAT DOES THE CRITERION SHOW AND HOW HAS IT CHANGED?

CARBON POOLS AND FLUXES IN FORESTS

Forests in the United States are a significant carbon sink. In 2018, the net total of forest carbon uptake was an estimated 547.6 million metric tons of carbon dioxide equivalent (MMT CO_2 Eq.), an amount which is equivalent to approximately 10 percent of the total economy-wide CO_2 Eq. emissions that year. This estimate represents the balance of emissions from forests and forest lands converted to other land-use categories (127.4 MMT CO_2 Eq.) and sequestration through growth and storage of carbon in forest ecosystems (675.1 MMT CO_2 Eq.).

Overall, forests in the conterminous United States remain carbon sinks, though several Intermountain West States are now net sources of carbon (fig. 15). This is due to the frequency and severity of often interconnected natural disturbances, including wildfire, drought, insects, and diseases (see Criterion 3), which have increased in recent decades. While the growth of live trees drives the year-to-year carbon sequestration capacity of U.S. forests, soils account for the majority of long-term carbon storage, making up more than 56 percent of the total carbon stocks.

FIGURE 15. — Estimated emissions and removals from forest land remaining forest land by carbon pool for each U.S. State in 2018, in million metric tons of carbon dioxide equivalent (MMT CO_2 Eq.). Note that points and confidence intervals (95 percent) reflect net flux for all carbon pools in each State. Individual State estimates do not sum to national total estimates due to independent rounding. Negative estimates indicate net carbon uptake (i.e., a net removal of carbon from the atmosphere). Source: Domke and Murray (2021a).



CARBON IN HARVESTED WOOD PRODUCTS

Harvested wood products (HWP) are an important carbon pool, representing the carbon transferred to wood products after timber harvesting. The carbon stored in HWPs may remain in place for just a few years in the case of paper products, to over 100 years for solid wood used in building construction. After their useful life, HWPs may also be discarded in solid waste disposal sites (i.e., dumps or landfills) where they decay over time and/or are stored indefinitely. Storage of carbon in HWPs in use and in solid waste disposal sites delays or reduces carbon emissions.

In 2018, the net HWP contribution from forest products in use and in landfills was 99 MMT CO_2 Eq., or about 15 percent of the total annual carbon flux (i.e., uptake from the atmosphere or transfer from one carbon pool to another) from forest ecosystems and HWPs combined. The annual HWP contribution decreased about 56 percent between 1990 and the Great Recession (2007–2009), although it has rebounded in recent years resulting in an overall drop of 20 percent from 1990 to 2018. This long-term trend is primarily the result of decreasing harvests of U.S. timber as well as partial replacement of domestically harvested products with imports.

WOOD ENERGY AND SUBSTITUTION FOR MORE CARBON-INTENSIVE MATERIALS

If sustainably managed, wood represents a renewable source of energy and building material. The use of HWPs can reduce emissions from other sources by substituting for more emissions-intensive products, such as cement in construction or fossil fuels for energy production. While this "substitution" impact is not reported under Criterion 5, Indicator 5.24 does explore the magnitude of avoided fossil fuel carbon emissions potentially resulting from the use of forest biomass for energy via a discussion on the use of wood fuels within the growing renewable energy sector. Burning wood for energy does emit carbon, but in sustainably managed forests, these emissions may be reabsorbed over time as forests grow. Moreover, a significant amount of wood energy is produced from wood residues generated in timber harvest and mill processing. Those residues have the potential to quickly release their carbon to the atmosphere if not otherwise used.

Wood in the form of fuelwood logs, mill residues, wood chips, pellets, spent pulping liquor, and other derivatives was used to produce nearly 2,300 trillion British thermal units [Btu] of renewable energy in the United States in 2018. This accounted for approximately 20 percent of total U.S. renewable energy consumption by source, third only to hydroelectric power and wind. Between 1990 and 2018, there has been a 90-percent

increase in overall renewable energy consumption. Wood energy consumption, a significant proportion of which is generated in the wood products sector, has remained relatively stable over that time period, resulting in declines in the overall contribution of wood energy relative to total renewables. Nevertheless, wood energy continues to play a major role in forested regions of the United States and has consistently comprised approximately 2 percent of total energy consumption nationally (fig. 16).

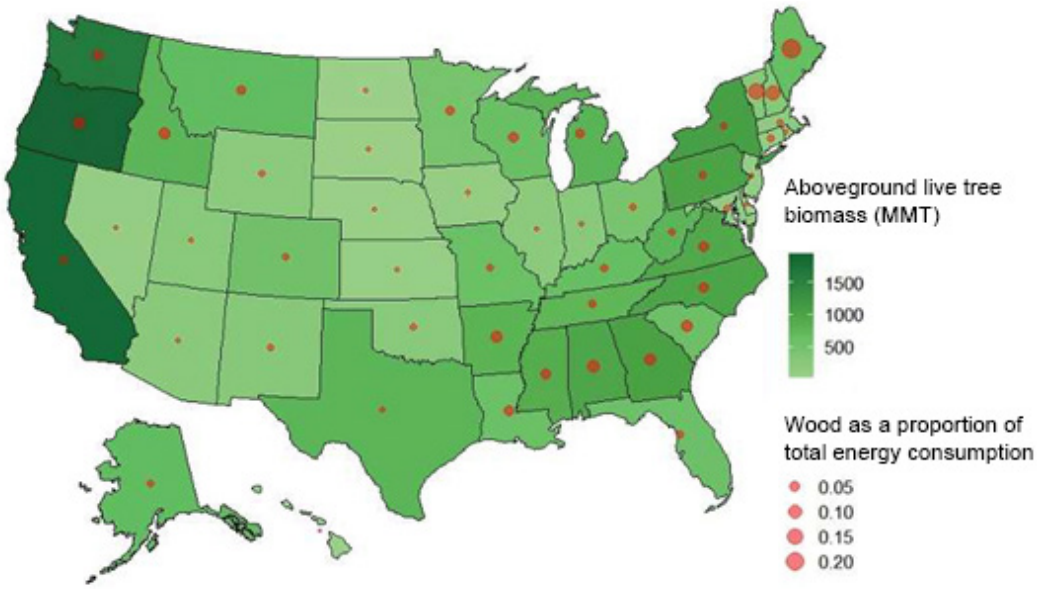


FIGURE 16. — Estimated total aboveground live tree biomass (2.54-cm diameter at breast height) and wood energy as a percent of total energy consumption in the United States for 2018. Estimates for Alaska only represent the coastal southeast and south-central forest land. Source: Domke and Murray (2021b).
MMT = million metric tons.

CRITERION 6: MAINTENANCE AND ENHANCEMENT OF LONG-TERM MULTIPLE SOCIOECONOMIC BENEFITS TO MEET THE NEEDS OF SOCIETIES

SUMMARY POINTS

- Wood production (industrial roundwood and fuelwood) rebounded in the last decade in conjunction with the recovery in the broader economy. However, at approximately 16 billion cubic feet, current annual production levels are still well below their peak of around 19 billion cubic feet in the late 1980s. Per capita consumption of wood and paper products fell by 21 percent over the past decade.
- Revenues from forest-based ecosystem services continued to increase to approximately $3.6 billion in 2019. Nontimber forest products (NTFPs) are an important forest output, but data on their production and consumption is incomplete.
- Investments in the wood products and paper sectors ($4.2 billion and $8.9 billion, respectively, in 2020) increased significantly over the past decade, reflecting the period of economic growth following the 2007–2009 Great Recession. However, these investments remain below peak levels of the late 1990s.
- Employment in forestry, logging, wood products, and paper products declined by 39 percent (508,000 jobs) between 1990 and 2020. Recreation and tourism-based employment directly associated with forests, as well as less tangible forest contributions to local amenities and lifestyles, are important but more difficult to measure.
- Forest recreation, in all its forms, is a principal forest output. As recreation activity on public lands (notably wilderness areas and national and State parks) continues to increase, crowding is increasingly evident in some places (Indicator 6.42). This was especially true in 2020 and 2021 when visitation rates increased at the start of the COVID-19 pandemic. Meanwhile, physical access to forested recreation lands may be declining because road, trail, and facility maintenance is increasingly backlogged, particularly on public lands (e.g., the National Forest System) and where forest disturbances, notably wildfire, have resulted in the temporary closure of some public and private forests to recreation.
- There are 322 million acres of public forest land in the United States (42 percent of total forest land). Public lands are subject to various designations and management activities supporting cultural, social, and spiritual values. Tribal trust lands are particularly important in this regard, supporting Indigenous traditions and lifestyles. They encompass 18 million acres of forest across 305 U.S. Indian Reservations.

WHAT IS THE CRITERION AND WHY IS IT IMPORTANT?

The indicators in Criterion 6 assess the socioeconomic status of forest systems. The Montréal Process includes 20 indicators in this criterion organized by 5 subcriteria:

1. Production and consumption (9 indicators)
2. Investment in the forest sector (2 indicators)
3. Employment and community needs (5 indicators)

4. Recreation and tourism (2 indicators)
5. Cultural, social, and spiritual needs and values (2 indicators)

The depth and breadth of coverage in Criterion 6 point to the many benefits forests provide to society, and they highlight the many linkages between human systems and forested ecosystems (often referred to as "coupled human-natural systems"). While these benefits and linkages are also outlined in the other criteria, often in the form of biophysical outputs or policy provisions, Criterion 6 focuses on socioeconomic variables. Of these, traditional measures of production, consumption, and employment in the wood products sector are the most developed as they rely on longstanding national reporting conventions applied at the national and State level and across different economic sectors. Many of the other indicators in Criterion 6 are challenged by less-developed data owing to an absence of national-level reporting infrastructure or conceptual difficulties related to definition and measurement.

One result of the data challenges and overall depth and breadth of Criterion 6 is that updates for a majority of these indicators have not yet been completed for this round of reporting (box 10). Finalized reports for Indicators 6.27 (revenues from ecosystem services), 6.38 (resilience of forest communities), 6.41 (forests available for recreation), and 6.42 (forest recreation visits) have been released. A number of other indicator reports, particularly those related to wood products production, are in preparation. Given this lack of published indicator reports, the summary provided here relies on completed indicators, but it also draws upon external information to address other Criterion 6 indicators summarized in accordance with the five subcriteria noted above. Ultimately, the application of C&I frameworks requires flexibility when confronting information gaps, particularly when addressing indicators with substantial data issues (e.g., nonwood forest products) or challenges in conceptual framing (e.g., social value and the importance of forests to people).

WHAT DOES THE CRITERION SHOW AND HOW HAS IT CHANGED?

SUBCRITERION 1: PRODUCTION AND CONSUMPTION

The indicators in this subcriterion cover production, consumption, and trade for wood products and NTFPs. The subcriterion also includes indicators addressing recycling of wood products and revenues from forest-based environmental services. The physical productivity of timber and NTFPs for forest lands in the United States is also considered in Criterion 2.

WOOD PRODUCTS

Wood products constitute a major industrial sector in the United States, providing building materials, furniture, paper products, and a variety of other products. The most fundamental measure of production activity in the wood products sector is total production of industrial roundwood and fuelwood, the raw

BOX 10. — Criterion 6 Indicators

Indicator 6.25 [in preparation]: Value and volume of wood and wood products production

Indicator 6.26 [in preparation]: Value of nonwood forest products produced or collected

Indicator 6.27: Revenue from forest-based environmental services (Frey et al. 2021a)

Indicator 6.28 [in preparation]: Total and per capita consumption of wood and wood products

Indicator 6.29 [in preparation]: Total and per capita consumption of nonwood forest products

Indicator 6.30 [in preparation]: Value and volume in exports and imports of wood products

Indicator 6.31 [in preparation]: Value of exports and imports of nonwood products

Indicator 6.32 [in preparation]: Exports and imports as a share of wood and wood products production and consumption

Indicator 6.33 [in preparation]: Recovery or recycling of forest products

Indicator 6.34 [in preparation]: Capital investment in forest management, forest-based industries

Indicator 6.35 [in preparation]: Annual expenditure in forest-related research, extension, and education

Indicator 6.36 [in preparation]: Employment in forest products sector

Indicator 6.37 [in preparation]: Average wage and injury rates in major forest employment categories

Indicator 6.38: Resilience of forest-dependent communities (Frey et al. 2021b)

Indicator 6.39 [in preparation]: Area and percent of forests used for subsistence purposes

Indicator 6.40 [in preparation]: Distribution of revenues derived from forest management

Indicator 6.41: Area and percent of forests available and managed for public recreation and tourism (White 2021a)

Indicator 6.42: Number, type, and geographic distribution of visits attributed to recreation and tourism and related to facilities available (White 2021b)

Indicator 6.43 [in preparation]: Area of forest managed primarily to protect cultural, social, and spiritual needs and values

Indicator 6.44 [in preparation]: The importance of forests to people

materials from which finished wood products are derived (fig. 17 and Indicator 5.23). After relatively steady increases through the 1960s and 1970s and peaking at around 19 billion cubic feet in the late 1980s, wood production in the United States experienced steady declines, culminating in a fall to around 12 billion cubic feet by 2009—a result of the 2007–2009 Great Recession, which affected the wood products sector particularly hard owing to strong linkages with the construction sector. Production levels subsequently increased through the last decade in conjunction with the recovery in the broader economy. However, at approximately 16 billion cubic feet, current production levels are still well below their peak in the late 1980s. The declining trend is due in large part to steady declines in the pulp and paper sector driven in part by competition from digital communication technology. An approximate value for this material was estimated at around $40 billion in 2015, and the total value of finished products produced from it would be much higher (Johnston et al. 2023).

During approximately the same period (1965 to 2020), U.S. population almost doubled and real gross domestic product (GDP) increased by a factor of five. Conversely, per capita consumption of wood and paper products fell by 21 percent. This is ostensibly a good sign for forest sustainability because, on a per capita basis, the wood products industry is continuing to support increasing population and economic activity but using less wood inputs. However, this view does not consider substitution, where wood products are being replaced by nonrenewable or otherwise less sustainable materials. This particularly applies in the area of atmospheric carbon balances and global climate change where increased wood product use may provide positive benefits through carbon sequestration and storage in long-lived wood products and the substitution of wood for more carbon intensive materials (see Criterion 5).

NONTIMBER FOREST PRODUCTS

Nontimber forest products (NTFPs), alternately referred to as "nonwood forest products," constitute a diverse set of forest products including foods, medicines, decoratives, and ornamentals. Products are harvested for commercial and personal use and traded in formal and informal markets. Unlike wood products, there are no comprehensive statistics for NTFP production or other economic variables reported through standard Federal reporting activities. Therefore, it is not currently possible to report precise measures of production volumes and values aggregated across the many different product markets. Nonetheless, the value associated with these products is substantial. Chamberlain et al. (2018b), in a comprehensive survey based on Federal harvest permits augmented by industry sources, estimate that the total wholesale value of NTFPs harvested in 2013 was more than $1 billion. This value mostly excludes harvests from private lands and assumes commercial use of NTFPs. A proportion of NTFP harvest is known to be for personal use, and the associated recreational, cultural, and subsistence values are significant. Ultimately, the challenges involved in estimating the total value of NTFP harvest in the United States is immense, but the framework for doing so is improving.

ECOSYSTEM SERVICES

Revenues from forest-based ecosystem services are another indication of the value society places on forest outputs. Identified revenues in this category were around $3.6 billion per year in 2019 as compared to approximately $2.3 billion in 2010 (Indicator 6.27). Hunting leases and private entrance fees constitute the single largest category of revenue: about $1.3 billion per year. These revenue figures are likely incomplete as many revenue streams remain unmeasured. In addition, revenues (money exchanged in the marketplace) do not fully reflect the societal value of ecosystem services—the total value of these services is certainly much higher.

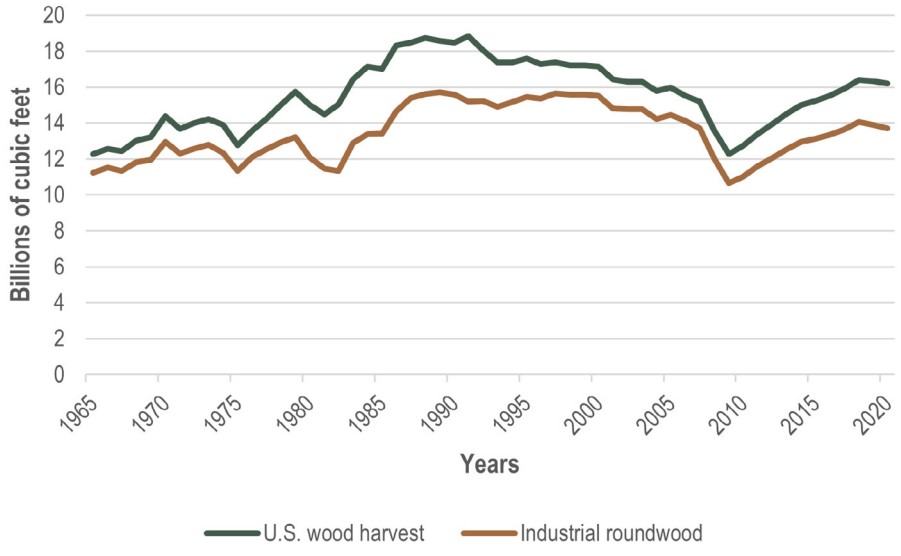


FIGURE 17. — Volume of U.S. industrial roundwood and total wood production (roundwood + fuelwood), 1965–2020. Source: Brandeis (2022) and Howard and Liang (2019).

SUBCRITERION 2: INVESTMENT IN THE FOREST SECTOR

The two indicators in this subcriterion cover investments in forestry and forest industries, and investments in forest research and education. The U.S. Census Bureau's Annual Capital Expenditure Survey reports that in 2020 the wood products sector invested $4.2 billion in structures and equipment. The paper sector invested $8.9 billion (fig. 18). This represents an approximate increase of 70 percent in both sectors since 2010, but significant declines (34 and 42 percent, respectively) relative to levels prevailing in the late 1990s. Near-term

FIGURE 18. — Capital expenditures in the wood products and paper sectors (1997 to 2020). Source: U.S. Census Bureau Annual Capital Expenditures Survey (ACES) (https://www.census.gov/programs-surveys/aces.html).

gains likely result from recovering economic prospects in the sector following the 2007–2009 Great Recession, but whether these gains signal a reversal in long-term declining trends is unclear.

SUBCRITERION 3: EMPLOYMENT AND COMMUNITY NEEDS

Forests supply various and often crucial benefits to communities, particularly small, rural communities in forested regions. In addition to employment in the forest products and tourism sectors, forests provide outputs and amenities that, while difficult to measure, nonetheless underpin rural economies and lifestyles. Employment in the forest products sector (fig. 19) remains a primary focus for considering the contribution of forests to local economies and livelihoods. Between 1990 and 2020, employment in forestry, logging, forest products, and paper products declined by 39 percent, a drop of 508,000 jobs. In comparison, the total number of full-time jobs in the United States increased by 16 percent. Since 2012, forest sector employment has posted modest gains in tandem with a recovery in the construction sector following the economic downturn in the late 2000s, but the generally downward trend persists in the forest management and paper industries. While these trends may be partially explained by macroeconomic fluctuations associated with the business cycle, the long-term trend of declining employment across the sector is clearly evident. This trend is the result of stable to declining harvest and forest products production since the 1990s (see subcriterion 1) and of increasing mechanization in the forest products sector resulting in long-term increases in labor productivity—fewer workers are needed to produce the same amount of goods (Parajuli et al. 2020). The impacts of declining employment are concentrated in specific locales; overall, communities associated with higher forest cover, forest employment, and Indigenous populations have lower average levels of employment, income, and infrastructure investments (see Indicator 6.38). Not all forest-dependent communities have experienced losses equally, however, and comparisons between forest-dependent and nonforest-dependent counties for other types of measures of community resilience show more mixed results, indicating perhaps some areas of strength in terms of human and social capital.

Employment in tourism and recreation services is substantial but difficult to measure across all geographic scales and for all ownerships. Nationally, outdoor recreation (on both forest

and nonforest land) generates about $453 billion in economic activity (1.9 percent of GDP) (U.S. Bureau of Economic Analysis 2022). More closely connected to forest land, spending by recreation visitors in communities around national forests generates about $13.5 billion in economic activity nationally and supports more than 161,000 jobs (USDA Forest Service 2021). The Forest Service figures are the most complete estimate of economic activity from forest-based recreation but account for only that single ownership. Substantial employment and related economic activity are generated by recreation on other Federal lands (notably the National Park Service and BLM) (Cline and Crowley 2018) and on State lands, but only a portion of those effects trace to forest land. The lack of consistent data notwithstanding, it is clear that forest recreation is a major source of jobs and incomes in forest communities and elsewhere.

SUBCRITERION 4: RECREATION AND TOURISM

Forest recreation opportunity is a principal forest output and a source of significant value to the public. Access to forest recreation is generally related to ownership, with mostly open access to public lands such as those managed by the Forest Service, BLM, or State and local entities. Public recreation access to private lands is generally more limited but many forest corporations and nongovernmental organizations allow and manage for recreation (Indicator 6.41). Over recent decades, forest area across these different ownership categories has been relatively stable, and the level of jurisdictional access for recreation activities can be assumed likewise to be stable. However, changing ownership patterns within the private forest holdings category have the potential to change the accessibility of private forests to public recreation as new owners make new decisions about allowing recreation access.

At the same time, U.S. population has increased significantly over the years, recreation activity on public lands (notably wilderness areas and national parks) has increased, and crowding is increasingly evident in some places (Indicator 6.42). Though comprehensive measures are not available, physical access to forested recreation lands may be declining. The Forest Service, a major provider of forest recreation opportunities, is reporting increasing backlogs in road, trail, and facility maintenance, compromising user access and experiences. Additionally, increasing forest disturbance activity (Criterion 3), particularly wildfires, have resulted in at least temporary closure of recreation areas for safety.

SUBCRITERION 5: CULTURAL, SOCIAL, AND SPIRITUAL NEEDS AND VALUES

The two indicators in this subcriterion address (1) the area of forests managed for cultural, social, and spiritual values; and (2) the importance of forests to

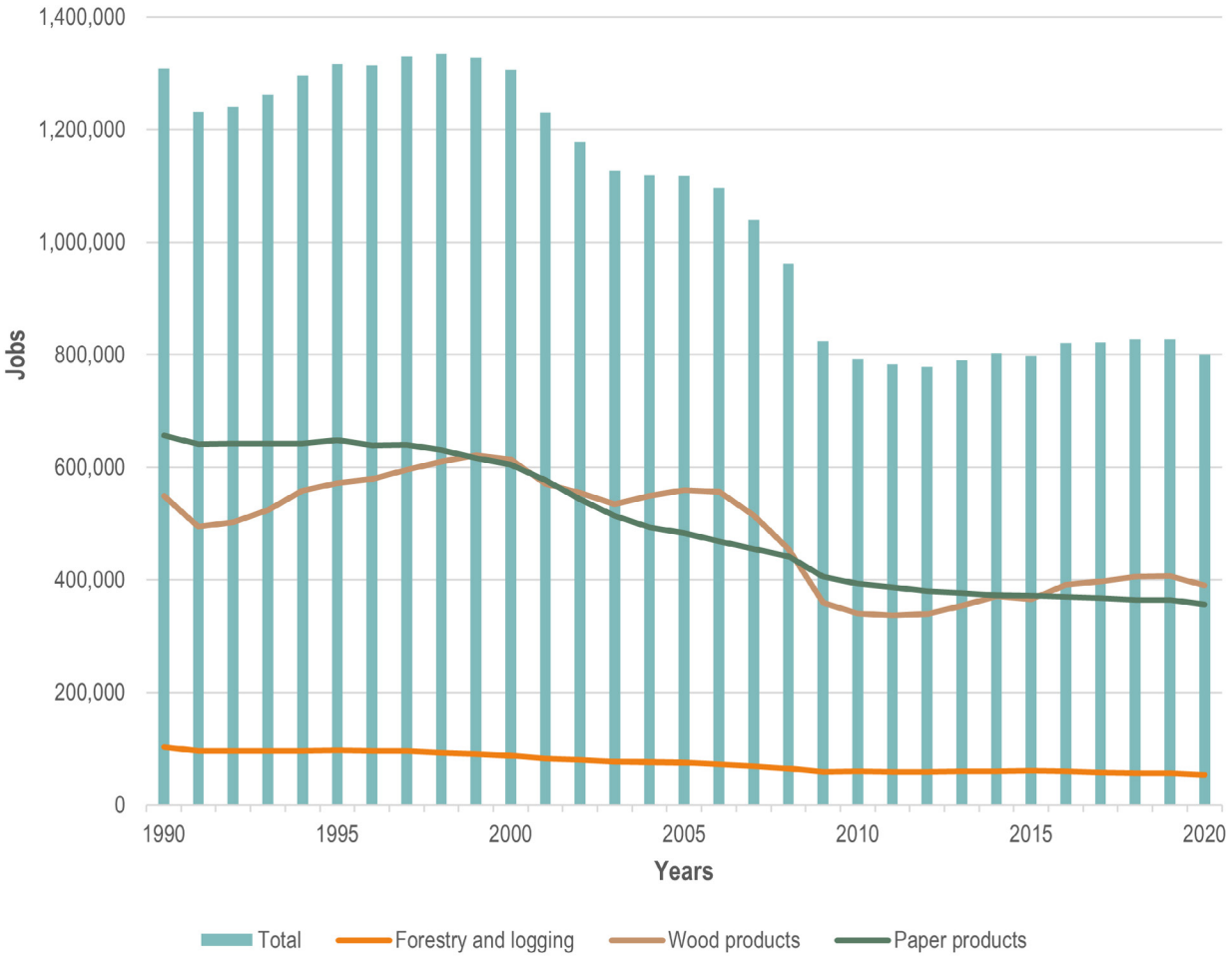


FIGURE 19. — Employment in the forest products sector, 1990 to 2020. Source: U.S. Bureau of Labor Statistics (2021).

people. Conceptual development is lacking for this subcriterion and neither indicator includes precise definitions. Concise, replicable data for these indicators are generally not available, especially at the national scale. These issues notwithstanding, the subcriterion and its indicators highlight the diverse benefits forests provide.

There are 322 million acres of public forest land in the United States (42 percent of total forest land, Indicators 1.01 and 1.02). These forest lands include various designations, ranging from congressionally designated wilderness to managed resource areas. Although not explicitly designated as such, all these lands are subject to varying levels of management associated with cultural, social, and spiritual values, either through explicit conservation designations applying to wilderness areas, national monuments, parks, and nature reserves, or through stipulations incorporated in resource area management plans. The area of public forest land has been stable in recent decades and the level of management dedicated to cultural, social, and spiritual values is assumed to be stable as well, although there is limited data to confirm this finding.

Tribal trust lands encompass 18 million acres of forest across 305 reservations (White 2013), and they represent a critical cultural, social, and spiritual resource for native peoples. Native Americans have long-established cultural and spiritual connections to these forest lands and those throughout their historical range outside their reservation lands. Ancient and sacred sites across forests serve as spiritual links between living people and their ancestors, and they are fundamental to the long-term cultural survival of the Tribes (Flores and Russell 2020).

The many criteria and indicators considered in this report outline the different ways that forests benefit or are otherwise important to people. These range from the provision of economic livelihoods and recreational opportunities to the conservation of local aesthetics and biological diversity. In the years since the last NRSF, new areas of benefit have been recognized, including psychological and health benefits from trees and forested parks in urban areas. The COVID-19 pandemic has further highlighted these benefits as people flock to urban forests and more remote natural areas (Derks et al. 2020; Weinbrenner et al. 2021). Likewise, the potential role of forests and wood products to sequester and store carbon and thus help ameliorate global climate change has come to the fore. At the same time, increased forest disturbances, notably wildfires, have highlighted the benefits of healthy forests and the risks associated with forests and their management, notably in areas where forests and human settlement intersect.

WHY CAN'T THE ENTIRE CRITERION BE REPORTED AT THIS TIME?

Criterion 6 contains 20 indicators covering a broad range of socioeconomic measures. A lack of consistent data regularly reported at national scale limits reporting on a number of these indicators. In some cases, this is simply the result of not having the statistical reporting processes in place. In others, the conceptual nature of the indicator is not amenable to quantitative measurement. Regardless of data scarcity, these indicators are important in the C&I framework applied in this NRSF, even if they cannot adequately be reported on now or in the future.

Generally speaking, sufficient data are available for production, consumption, and trade volumes of wood products, for wood products sector employment and related labor statistics, and for capital investment in the sector. Certain other indicators benefited from focused research attention in this reporting cycle, notably those for recreation, revenues from ecosystem services, and community resilience, but replication and the future development of consistent time series for these categories will be expensive and difficult. Reporting on NTFPs and cultural, social, and spiritual values is lacking in terms of consistent, comprehensive data replicated at national scale.

CRITERION 7: LEGAL, INSTITUTIONAL, AND ECONOMIC FRAMEWORK FOR FOREST CONSERVATION AND SUSTAINABLE MANAGEMENT

SUMMARY POINTS

- Sustainable forest management is pursued in the United States through a broad range of legal, economic, and institutional approaches developed and applied at multiple scales across public and private lands. Together, these approaches address forest sustainability across ecological, economic, and social dimensions.
- Institutional capacity for traditional forest management activities has declined in some areas, notably forestry research, and many land management agencies are devoting an increasing portion of their budgets to wildfire response.
- Forest-related collaboration and partnerships have increased across forest ownerships and at multiple scales, with an increasing focus on forest restoration, wildfire risk reduction, providing multiple uses, and preserving or promoting local forest-based livelihoods.

WHAT IS THE CRITERION AND WHY IS IT IMPORTANT?

Criterion 7 considers the legal, institutional, and economic frameworks that shape forest use and sustainability at national and subnational scales. The criterion includes 10 indicators that focus on forest policy and law; property rights, ownership, and tenure; law enforcement; incentives and taxation; programs and services; research and technology; monitoring and reporting; public participation; conflict resolution; partnerships; and cross-sectoral coordination (box 11). Together, these indicators provide the governance context for examining the biophysical and socioeconomic conditions and trends measured through Montréal Process Criteria 1 to 6.

BOX 11. — Criterion 7 Indicators

Indicator 7.45: Legislation and policies supporting the sustainable management of forests (Cubbage et al. 2018a)

Indicator 7.46: Cross-sectoral policy and program coordination (McGinley and Cubbage 2018a)

Indicator 7.47: Taxation and other economic strategies that affect the sustainable management of forests (Cubbage et al. 2018b)

Indicator 7.48: Clarity and security of land and resource tenure and property rights (Cubbage and McGinley 2018a)

Indicator 7.49: Enforcement of laws related to forests (McGinley and Cubbage 2018b)

Indicator 7.50: Programs, services, and other resources supporting the sustainable management of forests (Cubbage and McGinley 2018b)

Indicator 7.51: Development and application of research and technologies for the sustainable management of forests (Cubbage and McGinley 2018c)

Indicator 7.52: Partnerships to support the sustainable management of forests (McGinley and Cubbage 2018c)

Indicator 7.53: Public participation and conflict resolution in forest-related decision making (McGinley and Cubbage 2018d)

Indicator 7.54: Monitoring, assessment, and reporting on progress towards sustainable management of forests (McGinley et al. 2022)

WHAT DOES THE CRITERION SHOW AND HOW HAS IT CHANGED SINCE 2010?

LEGAL FRAMEWORK

A number of national-level policies and laws apply to all forest lands in the United States, including the Clean Air Act (CAA) of 1970, the Clean Water Act (CWA) of 1972, and the Endangered Species Act (ESA) of 1973. However, there is no single, overarching national forest policy or law governing all forests or even all Federal forest lands. In fact, there are thousands of Federal, State, and local laws concerning forests, their protection, and their production (Indicator 7.45). Ultimately, forest management and conservation are governed by a broad spectrum of legal, institutional, and economic measures involving public, private, and civil society sectors at all scales that reflect the Nation's diversity of forest ecosystems, ownerships, values, and uses.

Members of the Montana Conservation Corps clear trails near Wade Lake in the Beaverhead-Deerlodge National Forest, MT. (USDA photo by Preston Keres)

Most forests—58 percent—are privately owned (family: 34 percent, corporate: 20 percent, Tribal: 2 percent, other private: 2 percent) (fig. 20). Private property rights largely afford private landowners' full discretion to determine the uses and objectives for the forests on their land, but these rights generally are bound by legal limits on negative externalities (e.g., water, soil, air pollution), including those regulated by CAA, CWA, and ESA. Timber harvesting and other forest management operations on private land are regulated mostly by State governments through State forestry and environmental laws that require or support best practices to protect water quality, soil resources, and other public goods (Indicator 7.48).

All 50 States have developed BMPs to limit or mitigate potential impacts to waterways and water bodies from forest operations on private land in support of State water quality programs and are consistent with CWA (NASF 2021; Indicator 7.45). These forestry BMPs vary across States and are implemented through a range of voluntary (40 percent of States), regulatory (22 percent), and quasi-regulatory (38 percent; i.e., recommended practices to meet requisite water quality standards) approaches. Across these varied approaches, implementation of forestry BMPs on private land nationwide is high (92-percent implementation overall in 2019 (NASF 2021)) (see also Criterion 4). Technical and financial assistance for forest management and conservation on private lands, including education and incentives for BMP implementation, are provided through various State forestry and environmental law provisions, many of which are supported by Federal policies and programs (Indicator 7.49).

Public forests account for 42 percent of the total forest area in the United States (Federal: 31 percent, State: 9 percent, local government: 2 percent). Public forests are typically managed for multiple uses (e.g., production, recreation, conservation) and are regulated by an expansive legal framework that determines their protections, management approaches, permitted uses, planning procedures, and public involvement in forest planning and management. Most Federal forest land is overseen by Federal land management agencies in accordance with their mission and other guiding principles and objectives (box 12). State governments also have laws and regulations governing the management of State forest lands, as do most local governments for their public forests.

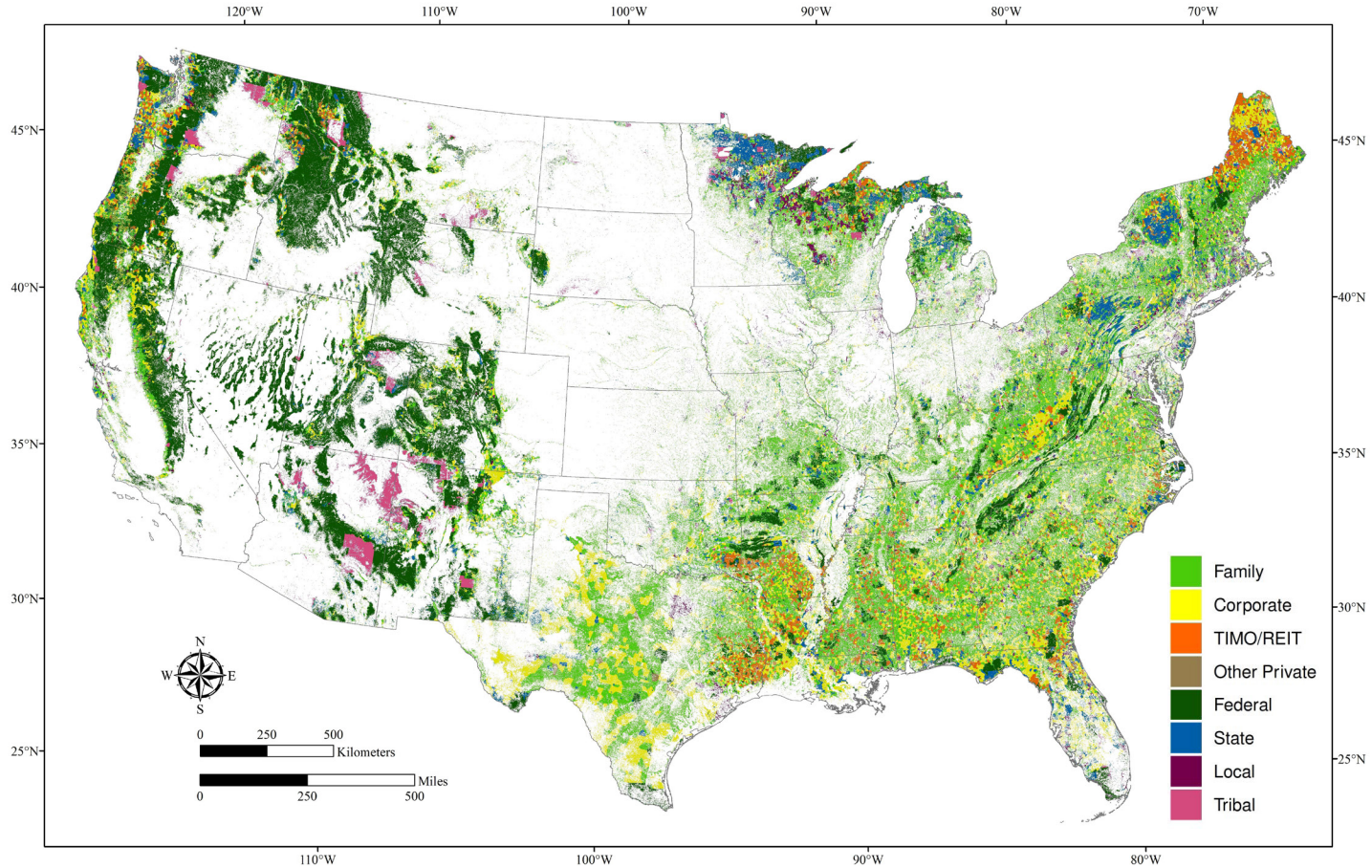


FIGURE 20. — Forest ownership across the conterminous United States, 2017. Source: Sass et al. (2020). TIMO = timber investment management organization; REIT = real estate investment trust.

BOX 12. — Major Federal Land Management Agencies in the United States, Total Land Area Administered, Estimates of Total Forest and Woodlands Area,* and Agency Mission Statements

- Bureau of Land Management: 245 million acres. "Sustain the health, diversity, and productivity of the public lands for the use and enjoyment of present and future generations."
- Fish and Wildlife Service: 150 million acres (3 million acres of forest and woodlands). "Working with others to conserve, protect, and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the American people."
- Forest Service: 193 million acres (145 million acres of forest and woodlands). "Sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations."
- National Park Service: 84 million acres (9 million acres of forest and woodlands). "Conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations."

* Estimates of forest and woodlands are based on statistically valid sample estimates from the Forest Service Forest Inventory and Analysis Program, but will not match the absolute area recorded by each land management agency for their own properties. Estimates for the total forest and woodlands area for the Bureau of Land Management and the Forest Service are published in Oswalt et al. 2019. Fish and Wildlife Service and National Park Service estimates do not include forest and woodlands in interior Alaska.

The major laws governing forest management and conservation in the United States have remained largely static since their establishment, mostly in the 1960s and 1970s. Changes in their implementation through new or modified policies, rules, regulations, and budgetary allocations are more significant than changes in the laws themselves. While some of these changes in implementation have been made by land management agencies under their own authorities, others have been made by regulatory agencies who do not own land, but whose authorities apply broadly to all landowners or land managers.

The legal framework governing Federal forest land use has increasingly incorporated requirements and support for public involvement, partnership opportunities, and collaboration within and across Federal boundaries and particularly on National Forest System (NFS) lands (Indicators 7.45, 7.46, 7.52). As wildfires, insect and disease outbreaks, and recreational and other public demands on forests have increased, so too have policies and programs aimed at forest and watershed restoration and wildfire risk reduction at Federal, State, and local levels. For instance, the Collaborative Forest Landscape Restoration Program (CFLRP) was established by Congress in 2009 through the Omnibus Public Land Management Act (Public Law 111–11) to support forest restoration, wildfire risk reduction, and rural economies through cross-boundary, collaborative landscape-scale restoration projects that leverage local, private, and Federal resources for work on NFS lands. As of 2022, the number of funded CFLRP projects totals 35 and the total area supported by the program is approximately 17 million acres.

Since the last NRSF, Congress has further expanded Federal land management agencies' authorities to collaborate and partner with States, local governments, and Tribes to improve forest conditions across jurisdictions and beyond Federal land boundaries. For example, the Good Neighbor Authority (GNA) (Public Law 113–79, §8206, enacted in 2014), grants authority to the Forest Service and BLM to partner with States on forest restoration activities in mixed ownership settings. These authorities were further expanded in 2018 to include partnerships with local governments and Tribes. As of 2020, 32 States have entered GNA agreements with the Forest Service and BLM across 132 projects (NASF 2021).

Other legislative and regulatory developments since the last report include (1) the 2012 Planning Rule for the NFS (77 Fed. Reg. 21162), which revised the Forest Service land management planning process to include increased Tribal consultation, State and local government coordination, and public involvement and collaboration throughout all stages of the planning process; (2) the Forest Service publication of national BMP standards for water quality management on NFS lands in 2012; and (3) the Great American Outdoors Act of 2020, which authorized permanent funding for the Land and Water Conservation Fund and provides support for the maintenance of critical facilities and infrastructure on Federal lands and in American Indian schools through revenues from energy development. Several States also have updated or amended their forestry BMPs (e.g., Georgia, North Carolina, Oregon) and at least 30 States have adopted forest biomass harvesting guidelines as of 2020. Local government forest policies and ordinances likely have expanded or otherwise changed as well but are more difficult to track.

ECONOMIC INSTRUMENTS

A broad range of economic policies and instruments have been developed in the United States to promote forest conservation and sustainable management and encourage forest regulatory compliance (Indicator 7.47). This economic framework includes financial payments, tax benefits, and other fiscal measures designed to favor long-term forest resource investments, provide consistent market-based incentives, and provide some payments for the provision of ecosystem services and values associated with forests. Examples include direct conservation incentive payments established through the Federal Farm Bill and by Federal agencies, State programs, and private sources; incentives and subsidies in the form of Federal and State income tax benefits; favorable

treatment of timber and wildlife habitat in State and local property taxes; and deductions for donating land or its development rights in perpetual conservation easements. Most of these measures are coupled with technical assistance programs devised and implemented mostly by State and Federal agencies.

Federal timber taxation provides various operating costs and carrying charge deductions for forest landowners. Most States have some type of favorable use value property tax treatment, including exemptions, rebates, yield taxes, modified assessment rates, or modified assessment property tax laws. These property tax reductions may help to protect forests from conversion to more developed uses by offsetting otherwise high annual property taxes. Most States also have forestry incentive programs that focus on timber production, with some conservation programs for forests (Indicator 7.47).

Many newer, non-State, market-based instruments that support forest conservation and sustainable management have continued to expand throughout the United States, including wetland banks, payments for ecosystem services, conservation easements, and forest certification (also see Criterion 6). Forest certification is a non-State, market-based instrument to measure, monitor, and market sustainably managed forests and their products through a voluntary process that involves the independent evaluation of the environmental, economic, and social aspects of forest management and production according to agreed standards of sustainability. Certified forest products generally carry a label that can be differentiated in the marketplace and may garner increased prices or enhanced market access (Indicators 7.45 and 7.47; McGinley and Cubbage 2020).

The number and area of certified forests in the United States increased through the late 2000s, but growth has slowed since about 2010. As of 2020, approximately 95 million acres of forest were certified under the three active systems in the United States (the total accounts for dual certified areas; Sustainable Forestry Initiative: 66 million acres, American Tree Farm System: 18 million acres, Forest Stewardship Council: 35 million acres). Although debate about the market and nonmarket benefits of forest certification persists, most certified operations in the United States have maintained and renewed their certification over time and many primary and secondary forest products manufacturers, wholesalers, and retailers highlight their use of certified wood products as part of their brand image. Additionally, forest certification has been shown to enhance State-level forestry BMP acceptance, adoption, and compliance (Indicator 7.49; Schilling et al. 2021).

INSTITUTIONAL RESOURCES

Human and institutional capacity dedicated to forest conservation and management in the United States is substantial but has declined slightly in recent decades, particularly in terms of the public sector workforce and expenditures (Indicators 7.50, 7.51). For example, permanent Forest Service personnel numbers have decreased about 35 percent since the early 1990s; annual budgets have decreased slightly when accounting for inflation, despite increasing in real terms. Forest research capacity in terms of funding and scientists also has declined. Forest research in the United States is conducted primarily by university faculty in forestry and forest-related sciences, Forest Service research scientists, and forest industry researchers. The total number of researchers across all three categories decreased approximately 15 percent between 2002 and 2016 (i.e., number of faculty, scientists, and researchers with forestry and forest- related research programs in these institutions decreased from 2,103 in 2012 to 1,786 in 2016) (McGinley et al. 2019a; Indicator 7.51).

Public and private resources dedicated to forests have been increasingly directed to the management of biotic (e.g., pests, disease) and abiotic (e.g., wildfire) forest disturbance processes in recent decades. Most public forestry agencies have responded to increasing or intensifying disturbances by shifting existing human and financial resources toward firefighting and fire prevention, often at the expense of nonfire-related personnel and programs. For example, since the 1990s, an increasing percentage of Forest Service funding has gone to firefighting (e.g., 17 percent in 1995 and 50 percent in 2015), often leading to borrowing from nonfire forest-related programs and priorities when firefighting costs exceeded their allocated funding thresholds. In the 2018 Consolidated Appropriations Act (Public Law 115–141, also known as the omnibus spending package), Congress authorized a new budgetary mechanism, similar to a disaster fund, that the Forest Service and the U.S. Department of the Interior could utilize to pay for wildfire suppression costs exceeding their annual appropriations. This "wildfire funding fix" is intended to ensure that land management agencies can continue to fight wildfires without borrowing from or depleting other parts of their budgets. Having become available in fiscal year 2020, it remains to be seen if the change is sufficient to reestablish the budgetary balance and restore capacity in nonfire programs to levels in past decades, especially if increasing trends in wildfire continue.

Ultimately, resources for forest management, production, protection, and research have continued to be constrained by increasing forest stresses and by declining budgets and personnel levels since the last report. In response, forest-related public, private, and civil society sector collaborations and partnerships have increased and expanded at local to international scales to build capacity; leverage financial, technical, and human resources; enhance political commitment; and strengthen public support to advance forest sustainability in the United States (Indicator 7.52). Moreover, as the value of forests is increasingly recognized across different sectors and scales, new perspectives and resources are being added to the effort to sustain forests, but these remain difficult to track and account for outside of traditional forestry and forest-related institutions.

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METRIC EQUIVALENTS

When you know:	Multiply by:	To find:
Feet (ft)	.305	Meters (m)
Miles (mi)	1.609	Kilometers (km)
Acres (ac)	.405	Hectares (ha)
Cubic feet (ft^3)	.0283	Cubic meters (m^3)
Pounds (lb)	.454	Kilograms (kg)
Tons (ton)	.907	Tonnes or megagrams (t or Mg)
Cubic feet per acre (ft^3/ac)	.07	Cubic meters per hectare (m^3/ha)
British thermal units (Btu)	1.050	Joules (J)

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