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Journal of Sustainable Forestry

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/wjsf20

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To cite this article: Carlos Rodriguez Franco & Jennifer Conje (2022): The Evolution of the Dialogue and Perspectives on Sustainable Forest Management with Special Emphasis on the United States of America, Journal of Sustainable Forestry, DOI: 10.1080/10549811.2022.2059687

To link to this article: https://doi.org/10.1080/10549811.2022.2059687

Published online: 27 Apr 2022.

JOURNAL OF SUSTAINABLE FORESTRY
https://doi.org/10.1080/10549811.2022.2059687

The Evolution of the Dialogue and Perspectives on Sustainable Forest Management with Special Emphasis on the United States of America

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ABSTRACT

A review covering a synopsis of the history of forest sustainability concepts and how it has led to the social, economic, and legal frameworks, criteria and indicators, and key incentive programs, which promote and influence conservation and sustainable management of forests in the United States of America is presented in two parts. The main findings show that the United States of America is a world leader in sustainable forest management, demonstrated by the fact that since the beginning of the 20th Century, forest area has been relatively stable although the population has increased, and the country remains one of the top timber producers in the world. Sustainable forest management in the United States of America is achieved in the context of private and public ownership, stakeholder collaboration, a federalist system with overarching federal laws that give freedom to state and local jurisdictions to use regulatory and voluntary means to achieve those aims, and a variety of government incentive programs offering technical assistance, financial assistance, and tax relief for landowners who proactively practice responsible forest management. This framework is reinforced through consistent enforcement of laws, monitoring, and reporting of changing conditions, and an array of future modeling to inform management actions.

KEYWORDS

Sustainable forest management; sustainability; criteria and indicators; conservation; legal framework

PART ONE. The Evolution of Sustainable Forest Management Concepts, Tools, and Dialogue to Current Day

Introduction

Forests are one of the Earth's most important ecosystems because of the many environmental benefits and services they provide that preserve human existence. Forests are an important component in the global strategy of decreasing the impacts of climate change. They are one of the best ways to capture carbon at a large scale and low cost compared to other carbon sequestration options such as geologic sequestration. Forests account for 92 % of all terrestrial biomass globally, storing approximately 400 gt CO_2 (Janowiak et al., 2017). The sustainability of the world's forests is vital to ensuring the viability of future generations.

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From a holistic perspective, the long-term capacity of forests to be sustainable depends on their health, productivity, resilience, and adaptive capacity to the impacts of disturbances caused by climate change, human economic actions, and social preferences. Forest dynamics are affected by temporal and spatial variability in temperature and precipitation, insect and disease attacks, droughts, wildfires, catastrophic storms, and human activities (Oliver & Larson, 1996), as well as natural and man-made catastrophic and non-catastrophic disturbances. In this context, adaptive land management in a dynamic system considers cumulative effects across time and factors in risk, severity, scale, and likely outcomes of disturbances (Ashton & Kelty, 2018).

Forest sustainability is influenced by local, regional, national, and international perceptions and needs and the spatial and temporal scale at which it is assessed. The environmental, economic, social, and political conditions of their locations also play a role, thus making it difficult to assess sustainability as a static concept and to have one universal definition (Oliver & Deal, 2007).

Brief history of Western forest management sustainability: concepts and principles

Forests and people have been linked since the early stages of humans. People have always been dependent on the forest for sources of food, shelter, medicine, energy, and spiritual value (Tidwell, 2016). As humans increasingly transitioned to a non-nomadic lifestyle, their dependency on forests grew because of the increased need for wood for heat, cooking, building, and many other needs. Deforestation also increased because of the expansion of agricultural and pasture lands. Over time and in different places across the world, the pressure on natural resources became apparent, including soil erosion, flooding, and scarcity of products, causing the downfall of many settlements in the world (Farrell et al., 2000; Schelhaas et al., 2018; USGCRP, 2015). The lack of timely awareness of these pressures and the failure to adapt management and use is a key factor in unsustainability.

Forest overharvesting has been a concern since ancient times and for millennia human societies have protected natural areas for various cultural purposes (Heinen, 2012). These include the sacred forest of South Asia and parts of Africa, sacred burial grounds of some native American groups and traditional royal hunting reserves in parts of Europe, Asia and Africa. For example, in ancient Assyria forests were established for hunting and riding were set aside as early as 700 B.C. (Dixon & Sherman, 1990), in India reserves to protect elephants and battle equipment were established by the Mauryan state as early as 500 B.C. (Gadgil and Guha, 2012) and in Greece, laws existed in the 4th century B.C. prohibiting the removal even of twigs (Farrell et al., 2000). To avoid problems created by overharvesting forests, control measures for harvesting were promulgated in the 8th century in Irish Law that set penalties for cutting or damaging privately owned trees (Farrell et al., 2000). C. Oliver and Oliver (2018) mentioned that since 1346 in France, the commune of Brunoy's Waters and Forests Administration had issued the Brunoy executive order for foresters "to inspect all woods and ensure that they can perpetually sustain themselves in good condition." Chaney et al. (2000) indicated that in medieval times in Europe, forest laws were mainly directed to protecting game and defining rights and responsibilities. Hunting rights were entrusted to the feudal lord who owned the property and had the sole right to cut trees and sell timber. Peasants were permitted to gather fuel, timber, and litter for use on their properties and to pasture defined numbers of animals (Bathe, 2018). During medieval times degradation of

forests occurred because of economic development and rudimentary forestry techniques which caused a slow but steady deforestation of western Europe, Italy, and Spain as well as the Mediterranean islands (Europe Environmental Agency, 2016; McGrath et al., 2015; Wallerstein, 2011).

From a Western perspective, Chaney et al. (2000) attributed the notion of forest management as starting in the German States during the 16th century, where each forest property was divided into sections for timber harvesting and regeneration to ensure a sustainable yield of timber for the entire property. In 1713 the Director of Mines Hanns Carl von Carlowitz first presented the *concept of sustainability* in his "Sylvicultura Oeconomica oder Hauswirthliches Nachricht und Naturmässige Anweisung zur Wilden Baum – Zucht." He proposed continuous, permanent, and sustainable utilization as the rule for forestry (Schelhaas et al., 2018; Vehkamäki, 2005).

According to Bulkan et al. (2010), concern about forest sustainability in Europe beyond a relatively local scale was a result of the timber supply crisis 300 years ago. This crisis was triggered by overcutting for fuel (including smelting mineral ores and glassmaking), timber for construction and mine uses, livestock grazing which prevented regeneration, and forest loss during the Thirty Years' War. As a result, more formal forest management practices and knowledge were developed, including the concepts of *forest sustainability* and the *principle of sustained yield* (Wiersum, 1995). The *normal forest concept* was designed with the understanding of sustainable yield. This principle was based on the concept that forests should be capable of producing continuous, regular yields (Osmaston, 1968). It was implied that the forest must be constituted by trees or stands of differing ages, from youth to maturity, to provide an annual sequence of maturing timber.

The simplest conceptualization is to think about a set of forest even-aged stands covering a certain period of years, let us say from 1 to 100 years, each of them growing on an equal amount of land. Over a continuum of temporal and spatial dimensions, the accumulated increment of all forest stands younger than the last one (100 years) will be represented in the last age class, so when the oldest age class is harvested the next oldest one will take its place and the harvested stand will start a new cycle. In this manner, there would be a sustainable yield over an indefinite period. While this concept is helpful to understand the concept of sustainability, in real life it is much more complex because there are many environmental, economic, political, and social factors affecting how decisions are made relative to those stands.

The taxation of forests, including the need to know the amount of forests and how to value them, gave birth to forest inventory techniques with the aim of knowing three main aspects regarding the forests: the location of the resources, their condition, and their amount. Using inventories and the concept of normality, analytical tools were developed to predict the future yield per acre of the stands at different times of a forest with a specified character, growing on a specified soil class, and treated under a specified method of management. These analytical tools are known as *yield tables* (Chapman, 1921; Graves, 1906). *The normality concept* implies the evaluation of stand density and is also known as full stocking, normal growing stock, normal stocking, and normal density. All these analytical tools and concepts provide the foundation for modern forest management and have been incorporated in the development of simulation models that provide assessments of forest behavior under different forest management assumptions at different times.

Numerous advances have occurred during the last 250 to 300 years. The botanical classification of plants and the development of many other biological sciences have helped to increase the understanding of the different relationships between plants, the environment, and factors affecting growth. These factors include how growth and resiliency can be stimulated using physiological principles of the different biological relationships under specific growing conditions to keep a forest sustainable for the long term without losing productivity.

Maximization of economic return from timber production has been one of the main principles of forest management for many years. Currently, with changes in society's preferences toward conservation interests and more education about the impacts of climate change and biodiversity loss, the forest management objectives have moved towards maximizing or optimizing environmental and ecosystem services. This movement implies a *multi-resource approach* towards sustainable forest management that takes into consideration more protection for biodiversity, soil, water streams, wildlife, sacred sites, endangered species, other fragile ecosystems, wilderness areas, and esthetic places. Maximization of one dominant use as the main management objective is not possible anymore, and a combination of different uses should be optimized to respond to society's demands. The *concept of multiple use* has increased in importance as an objective for sustainable forest management in many parts of the world (Bulkan et al., 2010; Curtis et al., 2007; Kant, 2004 ; McArdle, 1960; Stevens & Montgomery, 2002; Wang & Wilson, 2007; Zhang, 2003).

The sustainability debate is mainly divided along two divergent points of view, the anthropogenic and the non-anthropogenic. The first one focuses on the economic objective to develop policies related to the environment, and the second focuses on the value per se of nature and rejects the point of view that nature has value only when it serves the human interests (Mather-Gratton et al., 2021; Seghezzo, 2009). Mather-Gratton et al. (2021) indicated that an anthropocentric approach will require more control over nature and acceptance of technological progress to sustain human societies because of the need for mitigating climate change and other environmental disturbances. The concepts and implementation of sustainable forest management and environmental sciences are central to their conversation and possibly to reconciling both points of view.

The dialogue and the internationalization of forests

During the second part of the 20th century, because of increasing concern over environmental degradation, sustainable development became a key policy topic on national and international agendas. The World Commission on Environment and Development (WCED (World Commission on Environment and Development), 1987) report, *Our Common Future*, defined sustainable development as "one that meets the needs of the present without compromising the ability of future generations to meet their own needs." The report established the three pillars of sustainability: economic, social, and environmental, all of which must be addressed to ensure sustainable development.

In 1992 the United Nations held the Conference on Environment and Development (UNCED), also known as the "Earth Summit," in Rio de Janeiro, Brazil. The conference hosted political leaders, diplomats, scientists, representatives of the media, and non-governmental organizations (NGOs) from 179 countries. The summit focus was the impact of human socio-economic activities on the environment. The conference's objective was to

produce a new blueprint, subsequently known as "Agenda 21," for international action on environmental and development issues that would help guide international cooperation and development policy in the twenty-first century.

One of the main results emerging from that process was a non-legally binding document, "The Forest Principles," which contained several recommendations for the sustainable management and conservation of forests. The text contains the following statement:

> Forest resources and forest lands should be sustainably managed to meet the social, economic, ecological, cultural, and spiritual needs of present and future generations. These needs are for forest products and services, such as wood and wood products, water, food, fodder, medicine, fuel, shelter, employment, recreation, habitats for wildlife, landscape diversity, carbon sinks, and reservoirs, and other forest products, Appropriate measures should be taken to protect forests against harmful effects of pollution, including air-borne pollution, fires, pests, and diseases, to maintain their full multiple values. (United Nations, 1992).

Many authors have pointed to this statement as a widely accepted aspirational statement regarding how the world should treat forests to achieve sustainability (Bastrup-Birk et al., 2016; Bulkan et al., 2010; Gillespie, 2017; Mcginley & Cubbage, 2017).

After the Earth Summit conference, the Ministerial Conference on the Protection of Forests in Europe held its conference in Helsinki in 1993. The Ministerial Conference is a Pan-European voluntary high-level political process for intergovernmental dialogue and cooperation on forest policies for its 45 country members and the European Union. It is currently known as Forest Europe and works on intergovernmental dialogue and cooperation on forest policies (Forest Europe, 2021). In Helsinki, they adopted the resolution for sustainable forest management. The resolution refers to the stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality, and potential to fulfill, now and in the future, relevant ecological, economic, and social functions at local, national, and global levels and that does not cause damage to other ecosystems (Forest Europe, 1993).

In October 2000, the Economic and Social Council of the United Nations established the United Nations Forum on Forests to promote "the management, conservation and sustainable development of all types of forests, and to strengthen long-term political commitment to this end." The Forum is formed by all Member States of the United Nations and specialized agencies (United Nations Economic and Social Council, 2000).

In December 2007, the UN adopted the Non-Legally Binding Instrument on All Types of Forests, later renamed in 2015 as the UN Forest Instrument. The United Nations forest instrument provides countries with a framework for promoting sustainable forest management. The instrument articulates a series of agreed-on policies and measures at the national and international levels to strengthen forest governance, technical and institutional capacity, policy and legal frameworks, forest sector investment, and stakeholder participation. Implementation of the UN Forest Instrument was enhanced in 2017 by the first-ever UN Strategic Plan for Forests 2017–2030. The Strategic Plan features a set of six Global Forest Goals and 26 associated targets to be reached by 2030 which are voluntary and universal.

Since Rio the dialogue on forests and their management and use has proliferated on local, regional, national, and international levels. Numerous forest management guidelines and best practices have been produced for all types of forests by international organizations such as the UN Food and Agriculture Committee on Forests (COFO), the UN Economic

Commission for Europe Committee on Forests and Forest Industry (COFFI), the International Tropical Timber Organization (ITTO), the International Union for the Conservation of Nature (IUCN), the International Union of Forest Research Organizations (IUFRO), the Center for International Forestry Research (CIFOR), the UN Development Programme (UNDP), the UN Environment Programme (UNEP), UN Forum on Forests (UNFF), the World Bank, the World Agroforestry Center, the Global Environment Facility (GEF) and the bodies of the UN convention(s) on biodiversity (CBD), climate (UNFCCC), desertification (UNCCCD), and international trade on endangered species fauna and flora (CITES). This consortium of forest-related organizations formed an innovative voluntary interagency partnership in 2001, named the Collaborative Partnership on Forests (CPF), to support the UN Forum on Forests and its member countries and to enhance cooperation and coordination on forest issues.

The use of criteria and indicators to assess progress toward sustainable forest management

From the 1990s, discussions about sustainable forest management flourished at different scientific conferences and international policy forums as interest grew among NGOs, the scientific community, and other interested parties on how to implement sustainable forest management and how to monitor, assess, and evaluate forest practices to benefit future generations. One of the key results of those discussions were proposals for criteria and indicators (C&I) that provided a common process and framework to assess progress towards sustainable forest management that could be applied at the national, regional, and international levels (Lanly, 1995).

The International Tropical Timber Organization (ITTO) pioneered the development of the first C&I process with a specific focus on tropical forests (Caswell et al., 2014). By 2000 several C&I processes had emerged that focused regionally or by forest type; for example the Lepaterique Process for Central America, C&I of the Tarapoto Process for Amazonian forests, Montreal Process for temperate and boreal forests, Helsinki Process, Pan-European Forest Process, African Timber Organization (in collaboration with ITTO), Dry Zone Africa Initiative, Near East Region Initiative, Asian Dry Forest Initiative, Association of Southeast Asian Nations, and Low Forest Cover Countries Process, also known as the Tehran Process (Bulkan et al., 2010; FAO, 2020; Garcia & Diez, 2012; Gillespie, 2017; Mcginley & Cubbage, 2017; Nunoo et al., 2016; Wolfslehner et al., 2016).

C&I sets helped promote agreement on key factors to assess and monitor progress toward sustainable forest management; helped identify information gaps; and served as a reference framework for policy and program designs. The Criteria and indicators sets were used as a starting point for the development of market-based forest certification standards, such as those of the Forest Stewardship Council, the Sustainable Forest Initiative, and the Programme for the Endorsement of Forest Certification (FAO, 2021). Mainly C&I indicators track conservation of biological diversity, productivity, health, carbon contribution, multiple socio-economic benefits, and legal, policy, and institutional framework. However, certification systems' criteria and indicators also cover the use of chain of custody tracking to follow forest products through the entire supply chain–from source to consumer–to assess the lifecycle aspects of sustainability. (Bastrup-Birk et al., 2016; Bulkan et al., 2010; Garcia & Diez, 2012; Gillespie, 2017; Mcginley & Cubbage, 2017)

According to Linser et al. (2018), since 1992, eleven intergovernmental, regional, and international processes for sustainable forest management focused on the use of C&I have been established with the participation of up to 171 countries. Those countries have recognized the value of forest inventory work by monitoring, assessing, and reporting progress in sustainable forest management at regional, national, and international scales. From the results of a brief review, it is noted that 116 countries have provided C&I country reports since 2000 (European Forest Institute, 2021); however, Linser et al. (2018) pointed out that C&I reporting is limited to existing information and data available and that many gaps remain. Though technology and the quality of available information have improved during the last 25 years and are quickly addressing some of those gaps, it is still difficult to assess the achievement of sustainable forest management because of differing country circumstances and the lack of appropriate interpretation of C&I's. They concluded that C&I's constitute a powerful policy tool for providing comprehensive information, evidence of the effectiveness of policy measures and management practices, and general trends of the resource base.

It is worth noting that one of the few quantitative studies proposing a methodology of assessing sustainable forest management at a country level was conducted by Nunoo (2010) on the high forest zone of Ghana with the application of the Use of the *Measure of Forest Resource-Use Sustainability Scale*, with the criteria and indicator prognosis. By identifying and assessing suitable criteria and indicators for forest resource use in Ghana, they completed a measure of the progress made toward sustainable forest management over the last two decades in the region. They used a quantitative approach where sustainable forest management is a function of increasing economic growth and development, increasing environmental vitality, and increasing societal well-being. They concluded that although sustainability had not been achieved in Ghana, good progress had been made in transitioning toward sustainability. Along with their conclusions, they pointed out limitations, barriers, and needs to have a more reliable assessment.

The main intent of all these tools, international agreements and processes, criteria and indicators, certification systems, best management practices (BMPs), and guidelines – while they may differ in approach but all work toward one common goal – is to evaluate the state of sustainability of forests with the objective of providing reliable information for decision-making in the conservation and sustainable use of forests.

PART TWO – Case study: sustainable forest management in the United States of America

Brief history of forests of United States of America

The early stages of forest history in the United States is similar to what occurred in Europe with intensive change of land use from forest and grassland to agriculture, along with increasing population centers. Long before the European settlers arrived in America, the Native Americans managed natural resources to cover their own needs, including clearing forests for agriculture. Shifting agriculture at 20-year rotation periods was the main agricultural approach. It is estimated that between 19.8 to 24.5 million acres (8.01 to 9.91 million ha) of forest were affected before European arrival (Wiersum, 1995). However, sustainability or overuse of the resource was not an issue. When the first

European immigrants arrived around the 1600′s, the total area of forest land was an estimated 1,045 million acres (422.91 million ha). This represented about 46 percent of the total land area (Smith et al., 2001). According to MacCleery (1992), when European settlement occurred, the predominant view in the early 1600′s was that the forest was both inexhaustible and an obstacle to agricultural use of the land. This point of view continued for almost three hundred years. The intent was to clear as much forest as possible, use the raw material for construction and firewood, and then pile and burn the excess wood as the clearings evolved (Harvard University, 1975).

By the time of the American Revolution, the identity and boundaries of the original 13 States had evolved spanning 150 years of British colonization and settlement. Under British rule, the colonial legislatures gradually achieved various degrees of autonomy and self-government. The system of individual States within a Federal union has its roots in the American colonial experience. The present Federal Union began in 1789 under the Constitution of the United States of America (USA). The original 13 States joined the United States by their act of ratification (Census Bureau, 2021). This construct is an important fundamental characteristic that still exists today in the forest governance context of the USA.

Land was cleared for tillage, pasturage, orchards, and construction sites, with around 70 % of the USA Eastern region under some kind of agricultural use. During this time the pressure for wood use was so high that a growing scarcity occurred; and as a result, coal was introduced for domestic and industrial uses to help to decrease the pressure on the forests of the region (Harvard University, 1975).

By the mid-1800′s, the degradation of the forests in the East became pronounced. George Perkins Marsh, a Congressman from Vermont, spoke at the Agricultural Society of Vermont calling attention to the destructive impact of human activity on the land, especially deforestation. He advocated for a conservationist approach to the management of forested lands highlighting “the injudicious destruction of the woods,” especially the effects on water and soil, and called for replacing “improvident waste” with “a better economy in the management of our forest lands” (The Library of The Congress, 2021). During the late 1800′s, the search for more land to develop saw a migration spread across the continent through the Great Plains to the West. The building of the Erie Canal, the railroads, the growth of industrial centers, the discovery of gold in California, and the Civil War were key factors in this shift. As people migrated west, the abandoned farmland in the East was gradually claimed by pine and hardwood forests (Harvard University, 1975; MacCleery, 1992; Wiersum, 1995).

The origins of the conservation movement in the USA

The conservation movement in the USA started gaining momentum in the late 1800s led by numerous philosophers and scholars, including Henry David Thoreau, Washington Irving, W.C. Bryant, Fenimore Cooper, Samuel H. Hammond, J. R. Lowell, Albert Bierstadt, and others. They called attention to the inherent spiritual, non-economic value of nature to mankind. Efforts of the early conservationists were influenced by the need to protect the environment from development and extraction that many had experienced or seen in the vast deforestation for development and industrialization that took place in the Eastern part of the US. Among this list was John Muir, founder of the Sierra Club and recognized head of

the Western conservation movement, who was instrumental in convincing the USA government to establish several national parks and monuments, including Yosemite National Park (1872) and the Sequoia National Park (1890). These set the pathway for the establishment of the National Park Service in 1916.

In 1864, the U.S. Congress approved the bill that granted Yosemite Valley to the State of California as a public park. This legislation was introduced at the request of a group of wealthy Californians. It established the nation's first public park created for the protection of scenic beauty, albeit by a grant to a state (The Library of The Congress, 2021). At the same time in 1870, with the increasing number of state-level measures for conserving supplies of fish and game, the U.S. Congress passed "An Act to prevent the Extermination of Fur-Bearing Animals in Alaska," the first of several Congressional and Presidential efforts in the future decades to protect the economically valuable Pacific fur seals by regulating their hunting (The Library of The Congress, 2021). In 1872, the U.S. Congress passed "An Act to set apart a certain Tract of Land lying near the Head-waters of the Yellowstone River as a public Park," consequently establishing Yellowstone National Park in Wyoming, the first in the history of the nation and of the world (The Library of The Congress, 2021).

The conservation movement in the USA was further advanced under Aldo Leopold's leadership when he wrote *A Sand County Almanac* (Leopold, 1949) in which he stated that "a system of conservation based solely on economic self-interest is hopelessly lopsided. It tends to ignore, and thus eventually to eliminate, many elements in the land community that lack commercial value, but that are (as far as we know) essential to its healthy functioning."

The origins and establishment of the US Forest Service

Between 1850 and 1910, forests were cleared in the amount of 13.5 square miles (3,496 ha) per day for agriculture – about 190 million acres (76.9 million ha) were cleared in this period. From the mid-1800s through the early 1900′s, timber was harvested in the north-eastern and north-central regions in huge amounts; and shortly after the end of the Civil War, a potential shortage of forest supplies raised concerns (LaBau et al., 2007). It was at this time that logging, and sawmill industries were large scale industrial operations in the USA; lumber production increased more than eight times from 5.4 billion to 44.5 billion board feet yr^{-1} (12.74 to 105 million m^3 yr^{-1}) (Fedkiw et al., 2002).

It was also during this period that the concept of sustainability came to the USA. through different sources. One of them was Bernhard Fernow, a German forester who settled in the USA and later became the chief of the Division of Forestry in the United States Department of Agriculture from 1886 to 1898. Mr. Fernow's work focused on establishing a national forest system, introducing science-based forest management, and protecting forested watersheds (Schmithüsen, 2013).

In 1873 under the influence of Marsh's *Man and Nature; or Physical Geography as Modified by Human Action*, Franklin B. Hough presented a paper at the annual meeting of the American Association for the Advancement of Science, in Portland, Maine, titled "On the Duty of Governments in the Preservation of Forests;" this inspired the Association to prepare and submit a Memorial on forest preservation to the U.S. Congress, which initiated Congressional interest in forest protection. That same year, the U.S. Congress passed "An Act to encourage the Growth of Timber on western Prairies," known as the Timber Culture

Act, granting settlers 160-acre (64.75 ha) plots if they have cultivated trees on one-fourth of the land for ten years. The act revealed the growing public concern with the conservation of forest resources, though it ultimately was unenforceable and was repealed in 1891 (The Library of The Congress, 2021).

In 1875 the organization American Forests was founded in Chicago, led by John A. Warder. Jr. (American Forests, 2021). In 1877 Carl Schurz was designated Secretary of the Interior; he took an active interest in conservation issues and advocated far-sighted conservation policies, promoting the creation of forest reserves and a federal forest service. In 1880 the American Forestry Association and the American Association for the Advancement of Science advocated the designation of Western timberlands as permanent public reserves (The Library of The Congress, 2021).

In 1881 the Division of Forestry was provisionally established in the Department of Agriculture, with Franklin B. Hough as its first chief; his role was to provide information and technical advice. In 1883, Charles Sprague Sargent (Director of Harvard University's Arnold Arboretum) published a Report on the Forests of North America (Exclusive of Mexico) as part of the Tenth Census. He highlighted in this influential work the need to reform destructive timber management policies (The Library of The Congress, 2021). The U.S. Government Congress in 1886 granted the Division of Forestry permanent status within the Department of Agriculture (The Library of The Congress, 2021). In 1888, the American Forestry Association organized the first American Forestry Congress in Cincinnati in conjunction with the first National Arbor Day tree planting (Bentley, 2022; American Forests, 2022).

During the 1890′s there was a growing interest in the potential benefits of scientific forestry; the forestry movement shifted its emphasis from saving trees to promoting scientific forest management. In 1891, the U.S. Congress passed "An act to repeal timber-culture laws, and for other purposes," known as the Forest Reserve Act repealed the Timber Culture Act of 1873 and empowered the President to create "forest reserves" (later known as national forests) by withdrawing land from the public domain; this act created the legislative foundation for what became the National Forest system. President Benjamin Harrison issued a Presidential Proclamation setting aside a tract of land in Wyoming as the nation's first forest reservation, the first unit in what eventually became the National Forest system (The Library of The Congress, 2021).

In 1897, the USA Government Congress passed the Forest Management Act, or Organic Act, making explicit the purpose of Forest Reserves (later National Forests) as resources for lumbering, mining, and grazing; it provided the blueprint for their management until the 1960′s; this act also placed federal forest administration under the jurisdiction of the General Land Office in the Department of the Interior. In 1898, Gifford Pinchot was appointed Chief of the Division of Forestry in the Department of Agriculture. He promoted public and forest industry support for scientific forest management (The Library of The Congress, 2021).

In 1900, the United States Congress (U.S. Congress) passed the first comprehensive federal legislation designed to protect wildlife: the Lacey Act. It was named in recognition of its chief sponsor, Rep. John F. Lacey; it outlawed the interstate shipment of any wild animals or birds killed in violation of state laws.

In 1901, President Theodore Roosevelt outlined in his First Annual Message his goals of forest conservation and preservation (including the use of forest reserves as wildlife preserves) (The Library of The Congress, 2021).

In 1905, the American Forestry Association held the second American Forest Congress to establish a broader understanding of the forest in its relation to the great industries depending upon it; to advance the conservative use of forest resources for both the present and future need of these industries; to stimulate and unite all efforts to perpetuate the forest as a permanent resource of the nation (American Forestry Association, 1905).

The second American Forest Congress was attended by Teddy Roosevelt, who addressed the participants indicating that the American Forest Congress was the most important meeting ever devoted to forestry in the U.S. and one of the most influential assemblies regarding the economics and conservation of forest in the country (American Forestry Association, 1905). Following one of the Forest Congress's principal recommendations, Gifford Pinchot succeeded getting oversight of national forest reserves transferred from the Department of Interior (General Land Office) to the Bureau of Forestry (formerly known as the Division of Forestry) in the Department of Agriculture. He also transformed the Bureau into the Forest Service through the U.S. Congress Transfer Act of 1905. This change also symbolized both a shift of emphasis from preservation to scientific forestry, and Pinchot's dominance in public conservation policy (The Library of The Congress, 2021). Under his direction, a practical interpretation of the Organic Act was issued, in which it is stated (Wilson, 1905; USDA Forest Service, 1978) "In the Administration of the forest reserves it must be clearly borne in mind that all and is to be devoted to its most productive use for the permanent good of the whole people and not for the temporary benefit of individuals and companies." This concept "*for the greatest good*" became a guiding principle of the United States Forest Service (U.S. Forest Service) in carrying out its work.

In 1911 the U.S. Congress passed legislation known as the Weeks Act, which (among other provisions) authorize interstate compacts for water and forest conservation and federal acquisition of land to protect watersheds; it also placed large amounts of Eastern forest land under federal jurisdiction for the first time and provided financial aid to efforts to protect timberlands at the heads of navigable streams from fire (The Library of The Congress, 2021).

According to Frederick and Sedjo (1991), up to the 1920′s 384 million acres (155.4 million ha) of the indigenous forest had been cleared, raising concerns about timber shortage and wildlife habitat at the end of the nineteenth century. After 1850, 270 million acres (109.2 million ha) were cleared; however, this trend decreased in the 1930′s after the development of the knowledge, machinery, and equipment for intensive agriculture and the resulting increase of crop productivity, thus requiring less clearing of forest lands.

The third American Forest Congress was held in 1946, followed by other four Congresses in 1953, 1963, 1975 and 1996 (Bentley, 2022). In 1996, the Seventh American Forest Congress was led by Yale University, which was a citizen meeting to discuss the common vision for America's forests and the principles toward that vision. This Congress was preceded by 51 regional and local round tables and 43 collaborative meetings in which an estimated 4,000 people participated (Guldin Forestry, 2022). Without any doubt, the seventh American Forest Congresses have had an outsize influence in shaping the dialog in USA sustainable forest management.

USA forests compared to other countries and regions

The USA land base area is nearly 2.3 billion acres (930.81 million ha) (USDA Economic Research Service, 2020), with 915 million acres (370.3 million ha) in agricultural use. Of this agriculture land, 45.4 percent is permanent pasture, 42.6 percent is cropland, and 8.4 percent is woodland. The remaining 3.6 percent is land in farmsteads, buildings, livestock facilities, and similar uses (USDA. National Agriculture Statistics Service, 2012). Oswalt and Smith (2014) indicated that since 1630 about 256 million acres (103.6 million ha) of forest land had been converted to other uses, but mostly agriculture. Nearly two-thirds of the net conversion to other uses occurred in the second half of the 19th century (Oswalt & Smith, 2014).

The U.S. is approximately one half the size of Russia, near three-tenths the size of Africa, close to one-half the size of South America, and about two and one-half times the size of Western Europe (Rosenberg, 2020). The USA has eight percent of the 4.06 billion ha of the world's forest area (C. Oliver & Oliver, 2018) and is fourth among the ten most forested countries in the world. These ten countries together account for 66 percent of the world's forest (FAO, 2020). The U.S. follows Russia, Brazil, and Canada in forest area. When China is added to this group of countries, the five countries account for 54 percent of the world's forests.

Since the beginning of the twentieth century, U.S. forest area has been relatively stable although the population has more than tripled since then. At present, the U.S. forests and woodlands comprise over one-third of the U.S. landscape. Forests and woodlands in the United States have stabilized at 822.5 million acres (332.87 million ha) after decades of expansion. Forest land area alone occupies 766 million acres (310 million ha), equivalent to 34 % of the U.S. land base (Oswalt & Smith, 2014). In comparison the forest of the world cover 4 billion ha of forest cover, which is equivalent to 31% of the terrestrial area (C. Oliver & Oliver, 2018).

According to Oswalt et al. (2014), currently the U.S. forests and woodlands occupy 332.87 million ha, with forests being 765.5 million acres (309.79 million ha) and woodlands being 57 million acres (23.07 million ha). Together, forests and woodlands cover 36 % of the U.S. land base. Since 1997 forest land has increased in all regions except the Pacific coast. The largest expansion in the last 20 years has been in the South, at 6 percent (Oswalt et al., 2014); Figure 1 shows the change in forest and woodland during the last 30 years.

During the last 30 years, 1.04 billion acres (420 million ha) have been lost by deforestation in the world (FAO, 2020). While the rate of deforestation has slowed in the last five years, deforestation still occurs at a rate of 25.2 million acres yr^{-1} (10.2 million ha yr^{-1}), with the majority occurring in the tropics (9.28 million ha yr^{-1}). The highest rate is in Africa (4.41 million ha yr^{-1}), followed by South America (2.96 million ha yr^{-1}) and Asia (2.24 million ha yr^{-1}) (FAO, 2020). By contrast, the U.S. has reforested 4.4. million acres (1.8 million ha) in the last 25 years (FAO, 2020a) at an average rate of close to 177.9 thousand acres yr^{-1} (72 thousand ha yr^{-1}). In the U.S. the amount of afforestation in the last five years reached 610.3 thousand acres (247 thousand ha) and a natural forest expansion of 69.2 thousand acres (28 thousand ha), with no net deforestation (FAO, 2020a).

FAO (2020) includes in its global assessments the category "other land with tree cover," which are areas in rural landscapes and urban environments that meet the thresholds for tree cover established by FAO's forest definition but for which the land use is not forest. This category of land is reported here because of its importance in the provision of goods and ecosystem services." This category includes trees in urban settings, tree orchards, palms, and

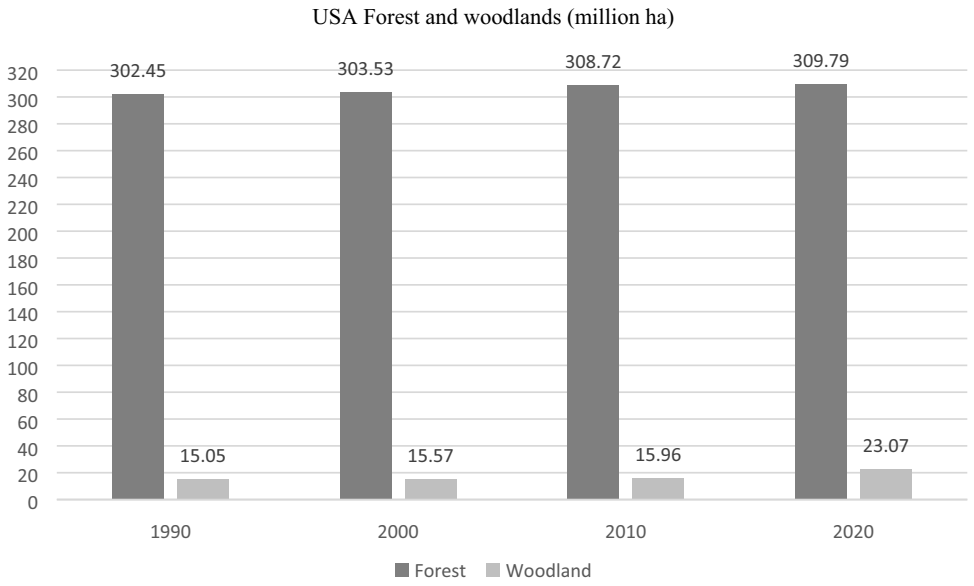

Figure 1. USA forest and woodlands in the last 30 years. (data source. global forest resource assessment 2020. Report USA).

agroforestry. The worldwide trend during the last 30 years is an increase in all subcategories: palm plantations doubled in area from 10.37 to 22.98 million acres (4.2. to 9.3 million ha), mostly in Asia; tree orchards increased 18.77 million acres (7.6 million ha) in that period mostly in China; agroforestry increased 4.21 million ha mainly in Asia, followed by Africa; and trees in urban settings increased by 18.4 million acres (7.45 million ha) with the U.S. having the largest increase followed by Central America. The U.S. increased in these subcategories by 15.22 million acres (6.16 million ha) during the last 30 years; the main increase was in urban settings with 15.32 million acres (6.2 million ha) during this period.

The FAO (2020) reported on naturally regenerated and planted forest subcategories. Naturally regenerated forests cover 93 percent, or 9.26 billion acres (3.75 billion ha), of the total world forest area. Europe has the largest area with 2.28 billion acres (928.8 million ha); South America, 2.03 billion acres (823.9 million ha); North and Central America, 1.74 billion acres (705.6 million ha); Africa, 1.54 billion acres (625.2 million ha); Asia 1.2 billion acres (487.1 million ha); and Oceania, 444.5 million acres (179.9 million ha). Current trends indicate that naturally regenerated forest area has decreased by 743.8 million acres (301 million ha) during the last 30 years, with decreases in all regions except Europe. The U.S. has decreased from 703 million acres (284.5 million ha) in 1990 to 692.3 million acres (280.2 million ha) in 2020 (FAO, 2020a).

Planted forests in the world have reached 7 percent of the forest area. The total area of planted forests globally is estimated at 726.48 million acres (294 million ha). Asia has the largest area of planted forest, at 333.5 million acres (135 million ha); Europe has 185.79 million acres (75.19 million ha). The lowest area of planted forest is in Africa, with 28.14 million acres (11.39 million ha); South America has 50 million acres (20.24 million ha). The U.S. in 1990 had 44.23 million acres (17.9 million ha) and 67.95 million acres (27.5 million ha) in 2020.

The area of planted forests with introduced species in the U.S. went from 761.08 thousand acres (308 thousand ha) in 1990 to 662.24 thousand acres (268 thousand ha) in 2020 (FAO, 2020a). During these 30 years, the area of planted forests worldwide has increased 303.93 million acres (123 million ha), and worldwide forest plantations with introduced species increased by 65.97 million acres (26.7 million ha) (FAO, 2020).

According to FAO (2020), primary forests are naturally regenerated forests composed of native tree species, with no visible indications of human activities; and ecological processes are not significantly disturbed. The estimated total area of primary forests worldwide is 2.74 billion acres (1.11 billion ha). Among the regions, North and Central America have the largest area of primary forest with 773.4 million acres (313 million ha), followed by South America with 738.84 million acres (299 million ha), and Europe with 640 million acres (259 million ha); excluding the Russian Federation, Europe would have only 10.32 million acres (4.18 million ha). Africa has an estimated 370.6 million acres (150 million ha); Asia, 213.4 million acres (86.4 million ha); and Oceania, 6.47 million acres (2.62 million ha). The U.S. has 199.1 million acres (80.6 million ha) of primary forests (Oswalt et al., 2014).

The total volume of living trees in a forest expressed as growing stock per unit area is an indicator of forest productivity; it is related to stand density and other stand characteristics such as basal area and height. Growing stock is used as the basis for estimating biomass and carbon stocks. Forest biomass, expressed in terms of dry weight of living vegetation, is an important indicator of a forest's capacity capture and store carbon. Globally forests are considered an important means of capturing carbon in large volumes at low costs in comparison with other carbon sequestration options, such as geologic sequestration. Forests account for 92% of all terrestrial biomass globally, storing approximately 400 gt C (Janowiak et al., 2017). Carbon dioxide is one of the most important greenhouse gases that contribute to the warming of our planet via the greenhouse gas effect. Carbon is emitted through the combustion of fossil fuels and the decay and combustion of organic material such as wood. In contrast, carbon can be sequestered through the growth of trees (Woodall et al., 2015).

FAO (2020) reported that the world's total forest growing stock is estimated at 557 billion m^3. Growing stock per unit area is highest in the tropics; and Brazil has the largest forest growing stock at 120 billion m^3almost 22 percent of the world's total growing stock. The Russian Federation, Canada, and the U.S. also have very large volumes of growing stock. The U.S. has increased from 33.2 billion m^3 in 1990 to 41.2 billion m^3 in 2020 (FAO, 2020a). The total living biomass in the world's forests amounts to almost 606 gigatons, or about 149 tons per ha. The highest biomass stock per ha was in tropical forests with values above 200 tons ha^{-1} in South America and Western and Central Africa. Deadwood in the world's forests is estimated at 14.5 tons ha^{-1}. The USA estimated living biomass stock is 94.6 tons ha^{-1}; and deadwood was estimated at 17.7 tons ha^{-1} in 2020 (FAO, 2020a).

FAO (2020) has estimated the total forest carbon stock (i.e. including all carbon pools) at 662 gt (163 tons ha^{-1}). Global trends indicated that forest carbon stocks decreased between 1990 and 2020 from 668 gt to 662 gt because of a decrease in forest area; however, the carbon stock in forest biomass increased in East Asia, Western and Central Asia, Europe, and North America because of forest area increases. They decreased considerably in South America and Western and Central Africa (FAO, 2020). Forest carbon in the USA increased from 192.33 tons ha^{-1} in 1990 to 201.21 in 2020 (FAO, 2020a). Carbon dioxide uptake by forests in the contiguous United States offsets about 12 to 19 percent of the USA's total carbon dioxide emissions each year (Ryan et al., 2010; Woodall et al., 2015). The USA forest

accounts for 714 million tons carbon dioxide equivalent sequestered annually. The biggest amount of carbon sequestration can be attributed to growth in live trees, accumulation of carbon in dead organic matter, and soils (Oswalt et al., 2014).

The area designated for multiple use was estimated at 1.85 billion acres (749 million ha) worldwide. The largest areas under forest management for multiple use are in North and Central America with 630.11 million acres (255 million ha), followed by South America with 560.9 million acres (227 million ha). Forest management for the protection of soil and water was estimated to be 983.47 million acres (398 million ha). Europe has 422.54 million acres (171 million ha,) followed by Asia with 326.17 million acres (132 million ha) (FAO, 2020). The U.S. has 453.19 million acres (183.4 million ha) under forest management soil and water protection (FAO, 2020a). The world area of forest designated primarily for biodiversity conservation was estimated at 1.05 billion acres (424 million ha). The largest area of forest designated for biodiversity conservation is in Africa, with 264.40 million acres (107 million ha) being the highest among all the reporting regions (FAO, 2020). The total world area of forest in legally protected areas is estimated at 1.79 billion acres (726 million ha). The proportion of forest in protected areas is more than 30 percent in South America, 11 percent in North and Central America, and 6 percent in Europe. There are in the world more than 4.94 billion acres (2 billion ha) of forest under management plans (FAO, 2020). The U.S. has 517.19 million acres (209.3 million) ha under forest management plans of which 78.33 million acres (31.7 million ha) are protected areas (FAO, 2020a). The world area of forest subject to management plans increased by 575.75 million acres (233 million ha) between 2000 and 2020. In the U.S. this area increased 33.8 million acres (13.7 million ha) in the same period.

Another important fact about U.S. forests is regarding ownership. In the U.S. 58 percent of forests and woodlands are privately owned by an estimated 10.6 million families, individuals, trusts, and estates (38 percent); and corporate ownerships are 20 percent of the forests and woodlands (Butler et al., 2016). The remaining forests and woodlands (42 percent) are publicly owned. The Federal Government controls 31 percent of forest lands. State agencies, in particular forest, wildlife, and recreation agencies, control 9 percent of the Nation's forests and woodlands; and local governments control an additional 2 percent. The remaining 2 percent of the forests and woodlands in the USA is within Native American Tribal reservation boundaries (Butler, 2019). In the world, public ownership is the dominant class with 71 % forest and woodland ownership. The regions with the largest shares of privately owned forests were Oceania, at 47 percent, and North and Central America, at 36 percent. (FAO, 2020).

In the USA 67 % of forest land is legally available for harvest activities; tree cutting, and removal occurs on less than 2 percent of forest lands annually (15.3 million acres yr^{-1}or 6.1 million ha yr^{-1}) in contrast with the nearly 3 percent (22.9 million acres or 9.2 million ha) disturbed annually by natural events such as insects, diseases, and fires (Oswalt et al., 2014). National Interagency Fire Center (2022) records show that during the last 21 years 155.02 million acres (62.7 million ha) have been affected by wildland fire. On average, wildland fire affects 7.38 million acres yr^{-1}(2.98 million ha yr^{-1}) in the USA. The net effect of fire in the U.S. was minimal at ~ 64.8 Tg C yr^{-1}. As long as the incidence and severity of wildfires remain constant, regrowth of burned areas offsets this release, which represents 9.08 % of the annual carbon sequestered by forests (U.S. Environmental Protection Agency, 2019).

According to Oswalt et al. (2019) forest industry in the U.S. represents 17 percent of global roundwood production. The U.S. has the highest consumption per capita of industrial roundwood. Removals of wood volume from timberland in the U.S. have declined by

17 percent, from 16 billion cubic feet (453.12 million m^3) in 2006 to 14 billion cubic feet (396.48 million m^3) in 2016. The decline in removals has occurred in every region but is particularly noticeable in the South, where total removals went down by 19 percent from 2006 to 2016, and 23 percent from 1996 to 2016. Non-wood forest products remain important to local economies and native peoples.

Sustainable forest management in the United States of America

The U.S. recognizes the importance of forests, both nationally and globally. The U.S. is party to and/or an observer to all major UN international environmental conventions. U.S.'s experts are actively involved in international forest-related forums and processes such as the Montreal Criteria and Indicator Process, the International Tropical Timber Organization, the UN Forum on Forests, the UN Convention on Combatting Climate Change, the International Union of Forest Research Organizations, and the Convention on International Trade and in Endangered Species of Wild Fauna and Flora. One main indicator of the sustainability of U.S. forests is demonstrated by the fact that during the last 110 years (since 1910) the forest area has remained relatively stable.

The USA is a world leader in sustainable forest management, which is pursued within a unique context of private and public ownership; stakeholder collaboration; a federalist system with overarching federal laws that also give freedom to state and local jurisdictions to use regulatory and voluntary means to achieve those aims; and a variety of government incentive programs offering technical assistance, financial assistance, and tax relief for landowners who proactively practice responsible forest management. Forest sustainability in the U.S. is also accomplished through consistent enforcement of laws, vigorous monitoring and reporting of changing forest conditions, and an array of future modeling to inform management actions.

In addition to the regulatory, legal, and institutional frameworks described below, some U.S. private landowners also choose to utilize the following three main market-based certification systems to assess and verify sustainable forest management on their land: The Forest Stewardship Council, the Sustainable Forest Initiative (Programme for the Endorsement of Forest Certification recognition), and the American Tree Farm System.

The remainder of this document presents the main mechanisms and tools used to pursue and to assess progress towards sustainable forest management in the U.S.

Sustainable forest management legal, policy, and institutional framework

The U.S. possesses an array of laws, regulations, policy instruments, best practice guidance, and voluntary incentive programs addressing sustainable forest management applied at the federal, state, and local levels. The diversity of these approaches and their democratic underpinnings are a fundamental characteristic of forest policy and management in the U.S. There is no single law governing all aspects of forest management and harvesting in the U.S. Instead, legality is determined by complying with a combination of laws governing different aspects of forest harvesting (water and soil quality, property rights, harvesting practices, protection of biodiversity and ecosystem services, duties/taxes, and others). Land ownership type (public, private, tribal) and location (state) mainly determine the combination of laws that apply to a specific harvest.

There are some major national (federal) laws relevant to harvesting that must be complied with regardless of the land ownership type. These include: the USA Lacey Act; the Clean Water Act (CWA); the Clean Air Act (CAA); the Endangered Species Act (ESA); the Plant Protection Act (PPA); the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA); and the Coastal Zone Management Act (CZMA).

Additionally, for federal public lands, the National Environmental Policy Act (U.S. Government, 2017 edition) outlines specific planning procedures, stakeholder consultations, and environmental assessment processes. Each federal agency that holds U.S. Forests in public trust has laws and regulations governing its management. For example, the U.S. Forest Service has the National Forest Management Act (U.S. Government, 1976) along with an array of other regulations that dictate U.S. Forest Service activities to ensure lands are managed in the interests of the American people.

The interplay of laws at different governance levels (federal, state, local, and tribal) work in combination to address the major components of sustainable forest management. Each stipulates thresholds and management actions to be taken if those thresholds are violated.

The majority of forest land in the United States is privately owned. Butler et al. (2021) indicated that an estimated 10 million families, individuals, trusts, and estates own 39 % of the forestland in the U.S., excluding interior Alaska. The USA legal system provides strong protections for personal property, and U.S. citizens and enterprises highly value their property rights. Landowners of all types have readily available administrative and judicial options to resolve disputes arising over use and access to their lands and title to timber assets; however, they also must follow state laws and regulations.

All 50 states and U.S. territories have legislation governing the management of their state public forest lands. In addition, the vast majority of states have forestry and/or environmental laws that govern private forest lands (Ellefson et al., 2004; Ma et al., 2009a; Ma et al., 2009b). State governments also have statutes and codes governing state and private forest lands that address a variety of forest values and the forest practices used to enhance and protect such values. Only a few States' Forest Practices Acts have set stricter thresholds than outlined by federal law. State governments have the authority to implement these statutes/codes in a variety of programmatic ways. In addition to environmental laws, each state has laws regarding the ownership of timberland titles, which have provisions for prosecution if violated. The U.S. is considered low risk in terms of illegal logging.

The sum of laws, regulations, required practices, and voluntary guidelines governing private forest lands vary by region and resource. Most states use a variety of technical assistance, financial incentives, and educational policies and programs to promote sustainable forest management on private forest lands. All 50 states have developed BMPs. Initially, BMP's were developed in response to federal laws that require implementable and enforceable programs focused on the water quality impacts of forest practices, although most now address a variety of forest management and harvesting issues such as wildlife protection and reforestation (Ellefson et al., 2005). Depending on the state, BMP's can be mandatory or voluntary. A recent study placed compliance rates with BMP's at 92% (National Association of State Foresters, 2019). A short description of all laws referenced in this document and other main federal laws relevant to forest management in the U.S. is presented in Table 1.

Table 1. Main federal laws relevant to forest management in the U.S.

Law	Summarized Description	Source
Bankhead-Jones Farm Tena1937nt Act (1937)	The Secretary is authorized and directed to develop a program of land conservation and land utilization, in order thereby to correct maladjustments in land use, and thus assist in controlling soil erosion, reforestation, preserving natural resources, protecting fish and wildlife, developing and protecting recreational facilities, mitigating floods, preventing impairment of dams and reservoirs, developing energy resources, conserving surface and surface moisture, protecting the watersheds of navigable streams, and protecting the public lands, health, safety, and welfare, but not to build industrial parks or establish private industrial or commercial enterprises.	https://www.agriculture.senate.gov/imo/media/doc/Bankhead-jones%20Farm%20Tenant%20Act.pdf
Clean Air Act (CAA) (1963)	A part of Environmental Law, the CAA is part of legislation from the 1970s that promulgates uniform national standards for a wide range of air pollutants and sources, through a handful of systems. The CAA regulates air quality levels and regulates sources of pollution.	https://www.congress.gov/bill/101st-congress/senate-bill/1630/text
Clean Water Act (1972)	Provides the foundation for regulation of discharges of pollutants into US waters. Sections 301 and 303 addresses point and non-point source pollution wherein individual states are directed to establish state water quality standards and implement plans. The Federal and private agencies within states are required to meet state established standards, which requires measuring water parameters.	https://www.fws.gov/laws/lawsdigest/FWATRPO.HTML
Coastal Zone Management Act (1972)	This law works to preserve, protect, develop, and where possible, to restore or enhance, the resources of the Nation's coastal zone for this and succeeding generations; (2) to encourage and assist the states to exercise effectively their responsibilities in the coastal zone through the development and implementation of management programs to achieve wise use of the land and water resources of the coastal zone, giving full consideration to ecological, cultural, historic, and esthetic values as well as the needs for compatible economic development, which programs should at least provide for – (A) the protection of natural resources, including wetlands, floodplains, estuaries, beaches, dunes, barrier islands, coral reefs, and fish and wildlife and their habitat, within the coastal zone, among other national policies.	https://coast.noaa.gov/data/czm/media/CZMA_10_11_06.pdf
Cooperative Forestry Assistance Act (1978)	Revised the authority of the United States Forest Service under the earlier Clarke–McNary Act of 1924 and other statutes) for to provide financial and technical assistance to states and private landowners on a variety of forestry issues, including forest management and stewardship, fire protection, insect and disease control, reforestation and stand improvement, and urban forestry.	https://www.fs.fed.us/spf/coop/library/SPF-CF%20handbook.pdf

(*Continued*)

Table 1. (Continued).

Law	Summarized Description	Source
Endangered Species Act (1973)	The 1973 Act implemented the Convention on International Trade in Endangered Species of Wild Fauna and Flora (T.I.A.S. 8249), signed by the United States on March 3, 1973, and the Convention on Nature Protection and Wildlife Preservation in the Western Hemisphere (50 Stat. 1354), signed by the United States on October 12, 1940.	https://www.fws.gov/laws/lawsdigest/ESACT.html
Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) (1910, revised 1972, 1996)	It regulates chemical use in forest stands, whether for insect control or for vegetation management. It also indicates that the state shall have primary enforcement responsibility for pesticide use violations during any period for which the Administrator determines that such state – (1) has adopted adequate pesticide use laws and regulations, except that the Administrator may not require a state to have pesticide use laws that are more stringent than this Act; (2) has adopted and is implementing adequate procedures for the enforcement of such state laws and regulations; and (3) will keep such records and make such reports showing compliance with paragraphs (1) and (2) of this subsection as the Administrator may require by regulation.	https://www.epa.gov/sites/production/files/documents/fifra.pdf
Forest and Rangeland Renewable Resources Planning Act of 1974	This Act provides for the Forest Service, Department of Agriculture, to protect, develop, and enhance the productivity and other values of certain of the Nation's lands and resources, and for another purpose.	https://www.fs.fed.us/emc/nfma/includes/range74.pdf
Knutson-Vandenberg (K-V) Act of 1930	The Secretary of Agriculture is hereby authorized to establish forest tree nurseries and do all other things needful in preparation for planting on national forests on the scale possible under the appropriations authorized by this Act.	https://www.agriculture.senate.gov/imo/media/doc/Act%20Of%20June%209,%201,930-(Knutson-vandenberg%20Act).pdf
US Lacey Act (1900, Amended in 2008 to include plant and plant products)	This law makes it unlawful to import, export, sell, acquire, or purchase fish, wildlife, or plants that are taken, possessed, transported, or sold: 1) in violation of U.S. or Indian law, or 2) in interstate or foreign commerce involving any fish, wildlife, or plants taken possessed or sold in violation of State or foreign law.	https://www.fws.gov/le/pdffiles/Lacey.pdf
McSweeney- McNary Act of 1928,	Congress finds that scientific discoveries and technological advances must be made and applied to support the protection, management, and utilization of the Nation's renewable resources. It is the purpose of this Act to authorize the Secretary of Agriculture (hereinafter in this Act referred to as the "Secretary") to implement a comprehensive program of forest and rangeland renewable resources research and dissemination of the findings of such research.	https://uscode.house.gov/statutes/pl/95/307.pdf

(*Continued*)

Table 1. (Continued).

Law	Summarized Description	Source
Multiple Yield Act (1960)	Authorizes and directs that the national forests be managed under principles of multiple use and to produce a sustained yield of products and services, and for another purpose. It establishes the national forests and indicates that they shall be administered for outdoor recreation, range, timber, watershed, and wildlife and fish purposes.	https://www.govinfo.gov/content/pkg/STATUTE-74/pdf/STATUTE-74-Pg215.pdf
National Environmental Policy Act (NEPA) (1970)	NEPA establishes the broad national framework for protecting the environment. NEPA's basic policy is to assure that all branches of government give proper consideration to the environment before undertaking any major federal action that significantly affects the environment.	https://www.govinfo.gov/content/pkg/USCODE-2017-title42/html/USCODE-2017-title42-chap55.htm
National Forest Management Act of 1976 (NFMA)	An Act to amend the Forest and Rangeland Renewable Resources Planning Act of 1974, and for other purposes, and recognizes that the management of the Nation's renewable resources is highly complex and the uses, demand for, and supply of the various resources are subject to change over time.	https://www.agriculture.senate.gov/imo/media/doc/National%20Forest%20Management%20Act%20Of%201,976.pdf
Organic Administration Act of 1897, as amended (16 U.S.C. 473–478, 479–482, 551).	Section 24, which established the National Forests, included provisions for the inventory and management of these lands.	https://www.publiclandsforthepeople.org/wp-content/uploads/2015/05/ORGANIC-ACT-OF-1897.pdf
Organic Act of 1916	An act to establish a national park service, and for other purposes.	https://www.nps.gov/foun/learn/management/upload/1916%20ACT%20TO%20ESTABLISH%20A%20NATIONAL%20PARK%20SERVICE-5.pdf
The Planning Rule (2012)	The planning rule establishes the requirements for developing, amending, and revising land management plans for units of the National Forest System, as required by the Forest and Rangeland Renewable Resources Planning Act of 1974, as amended by the National Forest Management Act of 1976.	https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd583096.pdf
Plant Protection Act (2000)	It prevents the introduction of forest and plant pests into the United States or the dissemination of forest and plant pests within the United States.	https://www.aphis.usda.gov/plant_health/plant_pest_info/weeds/downloads/PPAText.pdf
Resource Conservation and Recovery Act of 1976	This Act provides technical and financial assistance for the development of management plans and facilities for the recovery of energy and other resources from discarded materials and for the safe disposal of discarded materials, and to regulate the management of hazardous waste.	https://www.govinfo.gov/content/pkg/STATUTE-90/pdf/STATUTE-90-Pg2795.pdf

(*Continued*)

Table 1. (Continued).

Law	Summarized Description	Source
Title 16: United States Code, Titled Conservation covers a wide range of laws governing how the Forest Service and other agencies manage public lands.	Chapter 2: National Forests Chapter 3: Restoration management Chapter 4: Protection of Timber Chapter 3: Forests, Forest Service, Restoration, Management Chapter 36: Forest and Rangeland Renewable Resources Planning Chapter 41: Cooperative Forestry Assistance Chapter 65: International Forestry Cooperation Chapter 81: User Fees Under Forest System Recreation Residence Program Chapter 81A: National Forest Organizational Camp Fee Improvement Chapter 84: Healthy Forest Restoration Chapter 86: Southwest Florida Health and Wildfire Prevention Chapter 92: Forest Landscape Restoration	https://uscode.house.gov/browse/prelim@title16/chapter3&edition = prelim
The Weeks Act of 1911	Permitted the federal government to purchase private land to protect the headwaters of rivers and watersheds in the eastern US and called for fire protection efforts through federal, state, and private cooperation. It is considered one of the most successful pieces of conservation legislation in US history.	https://www.tandfonline.com/doi/abs/10.1080/02646811.2012.11435298
Wilderness Act of 1974	It establishes the wilderness system to assure that an increasing population, accompanied by expanding settlement and growing mechanization, does not occupy and modify all areas within the United States and its possessions, leaving no lands designated for preservation and protection in their natural condition. It is to secure for the American people of present and future generations the benefits of an enduring resource of wilderness.	https://wilderness.net/learn-about-wilderness/key-laws/wilderness-act/default.php

Conservation of the productive capacity of forest ecosystems

In the U.S. regeneration of forest ecosystems is achieved through applying silvicultural systems according to the shade tolerance, species composition, and growing conditions of the forests stands for natural regeneration. When natural regeneration fails or rapid establishment of a target species or changes in species or genetic composition of the forest are desired, artificial regeneration and plantation systems are utilized. Plantation systems are used after the final cutting is done to speed up the regeneration process, especially on commercially managed lands. On public lands, the Organic Administration Act of 1897 provides for reforestation work to secure favorable conditions of water flows and to furnish a continuous supply of timber. The Weeks Law of 1911 provided for the acquisition of forested, cutover, or denuded lands within watersheds to regulate the flow of navigable streams or for the production of timber, enabling the Secretary to conduct reforestation work on the acquired lands. The Knutson-Vandenberg (K-V) Act of 1930 explicitly provides for the establishment of forest tree nurseries and also authorizes the Secretary to require timber sale purchasers to make financial deposits that cover the cost of reforestation and related work within timber sale boundaries.

States have reforestation programs and annually invest on average $30 million producing 123 million seedlings for annual reforestation programs used in their BMP's to fulfill the Clean Water Act and the Coastal Zone Management Act requirements (National State Foresters Association, 2020).

The U.S. was an instrumental partner in the birth of the Global Partnership of Forest Landscape Restoration (GPFLR) established in 2003. The U.S. understands the global importance of restoring forest landscapes so they can continue to provide a broad range of ecosystem services (The Global Partnership on Forest Landscape Restoration, 2021). Under the Bonn Challenge of 2011, the U.S. set an ambitious target of restoring 15 million ha of U.S. forest land by 2020. By the beginning of 2019, the U.S. succeeded in placing over 17 million ha under restoration, surpassing its goal (Dave et al., 2019).

Conservation of biological diversity

The National Park System Organic Act (1916), the Wilderness Act (1974), the National Wildlife Refuge System Administration Act (1966), the Endangered Species Act (1973), the Lacey Act (1900), the Clean Water Act (1972), and the Weeks Act (1911) are just some of the main foundational laws that set aside protected areas and areas specifically targeted for the conservation of biodiversity, wetlands, and watersheds.

The U.S. has 36,283 protected areas under the categories recognized by the International Union for Conservation of Nature (IUCN) classification system. The Federal Government holds about 640 million acres (259 million ha) in trust. This is about 30 percent of the country's total land area. Federally owned and managed public lands include national parks, national forests, national wildlife refuges, and other Federal agency ownerships. The primary land-management agencies include the Bureau of Land Management, the Bureau of Reclamation, the US Forest Service, the US Fish and Wildlife Service, the National Park Service, the US Army Corps of Engineers, and the Tennessee Valley Authority. Additional Information about the protected lands of the U.S. is provided in Table 2.

Table 2. Additional information about protected lands in the US.

Agency	Protected land	source
National Park Service	Designations include parks, monuments, battlefields, military parks, historical parks, historic sites, lakeshores, seashores, recreation areas, scenic rivers, and trails.	https://www.nps.gov/index.htm
The National Wildlife Refuge System	According to the US Fish and Wildlife Service, national wildlife refuges generally are "... special places where the US Fish and Wildlife Service and its partners restore, protect, and manage habitat for America's wildlife." By September 2008, the refuge system totaled 94.5 million acres in 530 national wildlife refuges and 206 waterfowl production areas. In January 2009, 50 million acres were added to the National Wildlife Refuge System by creating three island refuges in the Pacific Ocean for protection under the Antiquities Act. About 20.7 million acres (22 percent of the National Wildlife Refuge System) are protected as Federal designated wilderness.	https://www.fws.gov/refuges/
Forest Service Experimental Forests and Natural Research Areas (USDA FS, 2014)	The Forest Service maintains a network of 82 experimental forests and rangelands that extends from St. Croix in the US Virgin Islands, up to Alaska, all the way over to Hawaii, and down to the Deep South. These living laboratories support a diverse portfolio of applied and basic studies with short- and long-term planning horizons. In addition, the Forest Service has designated Research Natural Areas (RNAs) that are to be permanently protected and maintained in natural conditions. These protected natural areas include unique ecosystems or ecological features; rare or sensitive species of plants and animals and their habitat; and/or high-quality examples of widespread ecosystems. RNAs play an important role in maintaining biological diversity on National Forest System lands by conserving unique natural ecosystems and representative ecosystems. There are more than 500 RNAs established nationally. The network of RNAs helps protect biological diversity at the genetic, species, ecosystem, and landscape scales.	https://www.fs.fed.us/research/efr/ https://www.srs.fs.usda.gov/rna/

The National Park Service was established to manage national parks and monuments to conserve the nation's natural and cultural heritage for the benefit of current and future generations. It manages 419 individual units covering more than 85 million acres (34.4 million ha) in all 50 states, the District of Columbia, and U.S. territories.

The National Wildlife Refuge System covers more than 850 million acres (343.9 million ha) of land and water and includes 568 national wildlife refuges from Alaska to the Caribbean and Maine to the south Pacific. There is at least one national wildlife refuge in each state. The Refuge System also includes five marine national monuments and 38 wetland management districts (Fish and Wildlife Service, 2021).

The National Wilderness Preservation System consists of specially designated Federal lands identified by an act of the U.S. Congress to protect wild character as outlined in the Wilderness Act of 1964. The National Wilderness Preservation System represents the most pristine and protected of federal natural lands and includes over 109 million acres (44.11 million ha). State level wilderness area programs include 74 areas covering 2.7 million acres (1.09 million ha). The state wilderness preservation programs complement federal efforts in the National Wilderness Preservation System (Dawson & Thorndike, 2002). In addition, in the USA, The Nature Conservancy (2022) currently holds preservation easements on 3.1 million acres (1.25 million ha) of lands in 49 states.

Each state has both a State Forest Action Plan (SFAP) as well as an associated Wildlife Action Plan (WAP), which are updated regularly to direct and prioritize natural resources work and investments within each state. These documents provide an analysis of forest conditions and trends and delineate priority forest landscape areas. They offer practical, long-term plans for investing state, federal, and other resources where they can be most effective in achieving national conservation goals. Links to each of these state-level plans as well as more information on the national sustainability picture they present are housed at the website of the (National Association of State Foresters, 2020) (https://www.stateforesters.org/timber-assurance/sustainabiilty/state-programs-and-policies/).

One way that the U.S. monitors biodiversity is through the work of the US Geological Survey (USGS) Gap Analysis Project (GAP), which produces national and regional assessments and species richness maps of vertebrate species and plant communities in the U.S. In addition, since these models are logically linked to mapped data layers that constitute habitat suitability, this suite of data provides an intuitive data system for further exploration of biodiversity and implications for change at ecosystem and landscape scales (Gergely et al., 2019).

The past decade has seen a plethora of innovative market-based mechanisms such as wetland banks, biodiversity offsets, payments for environmental services, and conservation easements programs implemented and run by non-governmental organizations in partnership with private sector and local communities and municipalities.

Conservation of soil and water resources

Soil surveys started in the U.S. under the authorization of the Agricultural Appropriation Act of 1896. This act authorized the "investigation of the relation of soils to climate and organic life" and "of the texture and composition of soils in field and laboratory" by the Division of Agricultural Soils. This act led to the first soil survey field operations during the summer of 1899. Subsequent appropriation acts continued that authorization until 1966, when the Public Law-560, Soil Surveys for Resource Planning and Development, further clarified the legal authority for the soil survey program of the US Department of Agriculture by specifying:

- Soil surveys are needed by

States and other public agencies in connection with community planning and resource development for protecting and improving the quality of the environment, meeting recreational needs, conserving land and water resources, providing for multiple uses of such resources, and controlling and reducing pollution from sediment and other pollutants in areas of rapidly changing uses (Public Law 89-560, 1966).

- The Secretary of Agriculture

. . .shall make a reasonable effort to assure that the contributions of any State or other public agency under any cooperative agreement which may be entered into between the Secretary and such State or other public agency with respect to a soil survey shall be a substantial portion of the cost of such soil survey (Public Law 89-560, 1966).

- Technical and other assistance needed for use of soil surveys be provided

This law emphasized that soil surveys are needed by States and other public agencies to support community planning and resource development to protect and improve the quality of the environment, meet recreational needs, conserve land and water resources, and control and reduce pollution from sediment and other pollutants in areas of rapidly changing uses.

Many soil surveys have been initiated, completed, and published cooperatively by the U.S. Department of Agriculture, state agencies, and other federal agencies. The total effort is the National Cooperative Soil Survey (NCSS), which is a nationwide partnership of federal, regional, state, and local agencies and private entities and institutions working cooperatively to investigate, inventory, document, classify, interpret, disseminate, and publish information about soils of the United States and its trust territories and commonwealths (USDA-Natural Resources Conservation Service, Soil Science Division Staff et al., 2017).

In the United States, considerable data document the state of soil resources. The primary source for soil information is the Soil Survey Geographic (SSURGO) database. This database is maintained by Natural Resource Conservation Service and contains hundreds of estimated properties for soil landscapes and components that cover over 90 percent of the continental United States mapped at a 1:24,000 spatial scale. The State Soil Geographic (STATSGO) database, also distributed through Web Soil Survey (http://websoilsurvey.nrcs.usda.gov/), provides a smaller set of estimated properties for the entire country at a 1:250,000 scale (USDA Natural Resources Conservation Service, 2020a).

The National Cooperative Soil Survey (NCSS) Soil Characterization database contains measured data on over 1,000 soil properties obtained from over 63,000 sites throughout the United States and the world (USDA Natural Resource Conservation Service, 2020b).

Ensuring the conservation and maintenance of soil and water resources and ensuring that the negative impacts to soil quality and biodiversity during harvesting are part of the Clean Water Act (CWA). Individual states are directed to establish state water quality standards and implement plans, including measuring water parameters that address point and non-point source pollution. Section 404 of the CWA regulates the placement of dredged or fill material into wetlands, lakes, streams rivers, estuaries, and certain other types of waters. The goal of Section 404 is to avoid and minimize losses to wetlands and other waters and to compensate for unavoidable losses through mitigation and restoration.

In addition to the CWA, there are several other laws and regulations that address soil and water quality. They include the Organic Administration Act (1897), Bankhead-Jones Farm Tenant Act of July 22, 1937, Multiple Use-Sustained Yield (1960), National Environmental Policy Act of 1969, the Cooperative Forestry Assistance Act (1978), and the National Forest Management Act (1978).

Currently, every state has published BMP Guidelines for agencies, industry, and family forest owners to use and/or reference. BMP's ensure that the equipment used in timber harvests and silvicultural activities such as forest thinnings do not inadvertently push sediment or brush into nearby waterways or promote erosion of stream banks. Some examples of BMP's include correctly planning and constructing forest roads (on the appropriate slopes, etc.), log landings, stream buffers, and stream crossings.

The US Forest Service also tracks soil productivity and soil indexes using the Drainage Index (DI), which is a measure of long-term soil wetness. DI was intended to reflect the amount of water that a soil supplies to plants under natural conditions over long timescales in general. DI varies from 0 for the driest soils (e.g., those shallow to bedrock in a desert) to 99 (open water). It is primarily derived from a soil's taxonomic subgroup classification, which is a reflection of its long-term wetness. DI assumes that soils in drier climates and with deeper water tables have less plant-useable water; taxonomic indicators such as soil moisture regime and natural drainage class figure prominently in its formulation. Other factors are quantified in its value determination because they can impact soil water content, quality, and/or availability (e.g., texture). These data aid in the identification of areas at risk to various forest insects and diseases because they help identify regions of potential tree stress (Schaetzl et al., 2009). Additionally, every state also has regulations governing prescribed forest fires and the prevention and control of human and naturally caused wildfires on all forest lands (Yoder et al., 2004).

Incentive programs promoting sustainable forest management of USA forest ecosystems

All of the laws and programs mentioned within this document work together to include provisions aimed at the long-term productive capacity of U.S. forests and the caring for all ecosystem values provided by them. They address the major components of sustainable forest management; e.g. water quality, air quality, soil quality, threatened and endangered species, and reducing the risk of invasive forest pests. As mentioned in the above subsection "Sustainable Forest Management Legal, Policy and Institutional Framework," the implementation of these laws occur through regulatory and non-regulatory mechanisms. Federal programs administered in collaboration with states are a large part of implementation, especially when it comes to private lands.

The US Forest Service administers several programs that incentivize private landowners to undertake sustainable management practices on their forest lands. Most notable of these is the Forest Stewardship Program, which assists owners of forest land where good stewardship, including agroforestry practices, will enhance and sustain multiple forest resources and contribute to healthy and resilient landscapes. The program also helps create jobs in rural communities by sustaining local markets for forest products and increasing demand for qualified private forestry consultants and state field foresters (USDA Forest Service, 2021a). Table 3 provides descriptions and links to the numerous federal assistance programs that work toward nature protection and sustainable forest management in the U.S.

In addition to these federal incentive programs, regional and species-specific partnerships and programs exist among the public and private sector, non-governmental organizations, and individual landowners. For example:

1) America's Longleaf Restoration Initiative (ALRI) is a collaboration of multiple public and private partners that support range-wide efforts to restore and conserve longleaf pine ecosystems. ALRI's vision is to have functional, viable longleaf pine ecosystems with a full spectrum of ecological, economic, and social values inspired through the voluntary involvement of motivated organizations and individuals (ALRI-America's Longleaf Restoration Initiative, 2020).

Table 3. Programs contributing to nature protection and sustainable forest management in the US.

Program	description	source
Forest Legacy Program	The Forest Legacy Program provides grants to states through their forestry agencies for the purchase of conservation easements and fee simple purchase of sensitive or threatened forest lands. The Forest Legacy Program provides an alternative to selling forest land for other land uses by allowing voluntary conservation to private owners. In FY2010, Forest Legacy Program funding was projected to grow by 60 percent to nearly $80 million. As of November 2010, the program passed the milestone of 2 million acres protected	http://www.fs.fed.us/spf/coop/programs/loa/flp.shtml
Conservation Reserve Program/Conservation Enhancement Reserve Program	The program assists farmers, ranchers, and forest owners with to comply with federal, state, and other environmental laws and provides technical and financial assistance for environmental protection. The Conservation Reserve Program is administered by the Farm Service Agency. The Conservation Reserve Program is aimed at addressing soil erosion, managing land for food and fiber production, reducing sedimentation in streams and lakes, improving water quality, assuring habitat for wildlife, and protecting forest and wetland resources. As of February 2010, the program enrollment was at 31.2 million acres.	https://www.fsa.usda.gov/programs-and-services/conservation-programs/conservation-reserve-program/index
The Environmental Quality Incentives Program (EQIP)	A voluntary program authorized under the Agricultural Act of 2014 (2014 Farm Bill) that helps producers install measures to protect soil, water, plant, wildlife, and other natural resources while ensuring sustainable production on their farms, ranches, and working forest lands. This program helps producers meet federal, state, tribal and local environmental regulations. The Natural Resources Conservation Service (NRCS) administers funding and provides participants with professional conservation expertise.	https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/programs/financial/eqip/?cid = nrcs144p2_068634
Land and Water Conservation Fund	The Federal Land and Water Conservation Fund (LWCF) was established by law in 1965 to use revenues from offshore oil and gas leasing for financing US land and water conservation. Often, these finances have been used to purchase land and easements, some of which had been originally acquired by land trusts.	https://www.doi.gov/lwcf
The Healthy Forests Reserve Program (HFRP)	This program helps landowners restore, enhance and protect forestland resources on private lands through easements and financial assistance. HRFP aids the recovery of endangered and threatened species under the Endangered Species Act, improves plant and animal biodiversity, and enhances carbon sequestration.	https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/easements/forests/

(*Continued*)

Table 3. (Continued).

Program	description	source
Wetlands Reserve Program	The Wetlands Reserve Program (WRP) is a voluntary program offering landowners the opportunity to protect, restore, and enhance wetlands on their property. The USDA Natural Resources Conservation Service (NRCS) provides technical and financial support to help landowners with their wetland restoration efforts. The NRCS goal is to achieve the greatest wetland functions and values, along with optimum wildlife habitat, on every acre enrolled in the program. This program offers landowners an opportunity to establish long-term conservation and wildlife practices and protection.	https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/home/?cid = STELPRDB1049327
State Wildlife Grants	The Federal State Wildlife Grants Program is aimed at protecting wildlife. It requires participating states to develop wildlife action plans and then provides annual funding for the implementation of these plans. Many states place some of these funds with partners such as land trusts. The wildlife action plans themselves are a useful tool for land trusts to prioritize acquisition and stewardship decisions. This program is administered by the US Fish and Wildlife Service.	https://www.fws.gov/wsfrprograms/Subpages/AboutUs/AboutUs1.htm

2) The Shortleaf Pine Initiative involves a broad range of public and private organizations as well as key state and federal agencies working to restore the shortleaf pine ecosystem. A range-wide conservation plan for shortleaf pine was released in June 2016 to identify optimum restoration strategies, increase coordination among shortleaf proponents and maximize the effectiveness of ongoing efforts (Shortleaf Pine Initiative, 2020).

3) The White Oak Initiative is an initiative composed of private landowners, universities, state and federal agencies, conservation organizations, trade associations, and forest industries including wine/spirits, flooring, cooperage, and timber. Formed in late 2017, the group is committed to ensuring the long-term sustainability of white oak forests (White Oak Initiative, 2020).

Monitoring sustainable forest management in the USA

The U.S. has long-standing monitoring systems for different aspects of natural resource management, and it is continuously developing and improving systems as technologies advance. Major laws addressing the monitoring of natural resources are presented in Table 4. The Forest Inventory and Analysis (FIA) started monitoring U.S. forests in 1930.

Table 4. Main legislation related to the monitoring of natural resources.

Law	Description	Source
Organic Administration Act of 1897, as amended (16 USC. 473–478, 479–482, 551).	Section 24, which established the National Forests, included provisions for the inventory and management of these lands.	https://www.publiclandsforthepeople.org/wp-content/uploads/2015/05/ORGANIC-ACT-OF-1897.pdf
Fish and Wildlife Coordination Act of 1934 (Ch. 55, 48 Stat. 401, as amended; 16 USC. 661, 662(a), 662(h), 663(c), 663(f).	This act authorizes surveys and investigations of the wildlife of the public domain lands including lands and waters of interest therein acquired or controlled by any agency of the United States.	https://www.fws.gov/laws/lawsdigest/fwcoord.html
Bankhead-Jones Farm Tenant Act of July 22, 1937 (Ch. 517, 50 Stat. 522 as amended; 7 USC. 1010–1012; 16. S.C. 551).	In Section 32(e) of this act, the Secretary of Agriculture is authorized to " . . . conduct surveys and investigations relating to conditions and factors affecting, and the methods of accomplishing most effectively the purposes of this title, and to disseminate information concerning these activities."	https://www.agriculture.senate.gov/imo/media/doc/Bankhead-jones%20Farm%20Tenant%20Act.pdf
Wilderness Act of 1964 (P.L. 88–577, 78 Stat. 890; 16 USC. 1121(note), 1131–1136).	Section 3 permits the gathering of resource information in wilderness areas.	https://wilderness.net/learn-about-wilderness/key-laws/wilderness-act/default.php
Soil Surveys for Resource Planning and Development Act of 1966 (P.L. 89–560).	Clarified the legal authority for the Soil Survey Program of the United States Department of Agriculture by specifying that the soil surveys are needed by " . . . states and other public agencies in connection with community planning and resource development for protecting and improving the quality of the environment, meeting recreational needs, conserving land and water resources, and controlling and reducing pollution from sediment and other pollutants in areas of rapidly changing uses." The Secretary of Agriculture " . . . shall make a reasonable effort to assure that the contributions of any State or other public agency under any cooperative agreement which may be entered into between the Secretary and such State or other public agency with respect to a soil survey shall be a substantial portion of the cost of such soil survey," " . . . technical and or other assistance needed for use of soil surveys be provided.	https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content = 17,596.wba
National Environmental Policy Act of 1969 (P.L. 91–190, 83 Stat. 852; USC. 4321 (Note), 4321, 4331–4335, 4341–4347).	Section 102 directs that all agencies of the Federal Government shall utilize a systematic, interdisciplinary approach that will ensure the integrated use of the natural and social sciences and the environmental design arts in planning and in decision-making, which may have an impact on man's environment.	https://www.govinfo.gov/content/pkg/USCODE-2017-title42/html/USCODE-2017-title42-chap55.htm
Endangered Species Act of 1973. (P.L. 93–205, 87 Stat. 884, as amended; 16 USC. 1531–1536, 1538–1540).	Section 6 directs each Federal Agency to conduct biological assessments to identify any endangered or threatened species.	https://www.fws.gov/laws/lawsdigest/ESACT.html

(*Continued*)

Table 4. (Continued).

Law	Description	Source
Forest and Rangeland Renewable Resources Planning Act of 1974 (P.L. 93–378, 88 Stat. 476, as amended; 16 USC. 1601 (Note), 1600–1614).	Sections 3–7 and 12 require the Secretary of Agriculture to conduct inventories of present and potential renewable resources, utilize information and data available from other Federal, state, and private organizations, and avoid duplication and overlap of resource assessment and program planning efforts. The law further requires a comprehensive and appropriately detailed inventory of all National Forest System lands and renewable resources.	https://www.fs.fed.us/emc/nfma/includes/range74.pdf
Federal Land Policy and Management Act of 1976 (P.L. 94–579, 90 Stat. 2743, as amended; 43 USC. 1701 (Note), 1702, 1712, 1714–1717, 1719, 1732b, 1740, 1744, 1745, 1751–1753, 1761, 1763–1771, 1781, 1782; 7 S.C.,1212a; 16 USC. 478a, 1338a).	This act requires that public lands and their resources be periodically and systematically inventoried and that an evaluation of the current natural resource use and values is made of adjacent public and nonpublic land.	https://www.blm.gov/or/regulations/files/FLPMA.pdf
National Forest Management Act of 1976 (P.L. 94–588, 90 Stat. 2949, as amended; 16 USC. 472a, 476, 500, 513–516, 518, 521b, 528 (Note), 576b, 594–2 (Note), 1600 (Note), 1601 (Note), 1600–1602, 1604, 1606, 1608–1614).	Sections 2, 6(f)(3), and 6(g)(2)) emphasize the stipulations of the Renewable Resources Planning Act of 1974. The act also requires that the Secretary of Agriculture establish quantitative and qualitative standards and guidelines for land and resource planning and management. Inventories shall include quantitative data making possible the evaluation of diversity in terms of its prior and present condition.	https://www.fs.fed.us/emc/nfma/includes/NFMA1976.pdf
Clean Air Act Amendments of 1977 (P.L. 95–95, 91 Stat. 685, as amended; 42 USC. 7401, 7418, 7470, 7472, 7474, 7475, 7491, 7506, 7602).	Sections 162 and 165 require classification of monitoring of Federal lands for air quality.	https://openscholarship.wustl.edu/cgi/viewcontent.cgi?article = 1604&context = law_urbanlaw
Soil and Water Conservation Act of 1977 (P.L. 95–192, 91 Stat. 1407; 16 USC. 2001–2009).	Section 5 authorizes the Federal Government to obtain and maintain information on the current status of soil, water, and related resources. The act further requires an integrated system capable of using combinations of resource data to determine the quality and capabilities for alternative uses of the resource base and to identify areas of local, State, and National concerns.	https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1041599.pdf
Forest and Rangeland Renewable Resources Research Act of 1978 (P.L. 95–307. 92 Stat. 353, as amended; 16 USC. 1600 (Note), 1641–1647).	Replaces earlier forestry research legislation, repeats the amendment contained in the RPA, and is the current agency mandate for conducting broad-scale resource inventories. In Section 3(a) of this act, the Secretary of Agriculture is authorized " . . . to obtain, analyze, develop, demonstrate, and disseminate scientific information about protecting, managing, and utilizing forest and rangeland renewable resources in rural, suburban, and urban areas." Forest Service inventory activities are a crucial component of this authority.	https://www.fia.fs.fed.us/documents/pdfs/Mandate%201-1978%20Research%20Act.pdf

(*Continued*)

Table 4. (Continued).

Law	Description	Source
Cooperative Forestry Assistance Act of 1978 (P.L. 95–313, 92 Stat. 3 16 USC. 2101 (Note)).	Section 8(b)(1) authorize the Secretary of Agriculture to conduct surveys to detect and appraise insect infestations and disease conditions and man-made stresses affecting trees and establish a monitoring system throughout the forests of the United States to determine detrimental changes or improvements that occur over time, and report annually concerning such surveys and monitoring.	https://www.fs.fed.us/spf/coop/library/SPF-CF%20handbook.pdf
Public Rangelands Improvement Act of 1978 (P.L. 95–514, 92 Stat. 1806; 43 USC. 1752–1753, 1901–1908; 16 USC. 1333(b)).	Section 4 directs the Secretary of Agriculture to inventory and identify current public rangelands conditions and trends as part of the inventory process required by Section 201 (a) of the Federal Land and Management Act of 1976 (43 USC. 1711) and to keep such inventories current.	https://uscode.house.gov/view.xhtml?path = /prelim@title43/chapter37&edition = prelim
Energy Security Act of 1980 (P.L. 96–294, 94 Stat. 611; 42 USC. (Note). 8854, 8855 Sec. 261).	This act emphasizes the need for biomass information for energy projects.	https://www.govinfo.gov/content/pkg/STATUTE-94/pdf/STATUTE-94-Pg611.pdf
Forest Ecosystems and Atmospheric Pollution Research Act of 1988 (P.L. 100–521, 102 Stat 260 l; USC. 1680	Section 3 directs the Secretary of Agriculture to increase the frequency of forest inventories in matters that relate to atmospheric pollution and conduct such surveys as are necessary to monitor long-term trends in the health and productivity of domestic forest ecosystems.	https://www.govinfo.gov/content/pkg/STATUTE-102/pdf/STATUTE-102-Pg2601.pdf

The FIA program is the nation's forest census, collecting and analyzing information on all 830 million acres (336 million ha) of public and private forest land. FIA completed its first inventory of the U.S. 48 contiguous states in 1960. Since that time FIA has continued to build its coverage, expanding operations to Hawaii and Alaska, incorporating new variables to be measured, and moving to an annual rolling inventory cycle. For more than 80 years the US Forest Service Forest Inventory and Analysis program has been recognized as a world leader in conducting national-scale forest inventories. FIA information is the most trusted source of information for a broad spectrum of interests and communities, including forest owners, county, state, federal, and tribal leaders, non-governmental interest groups, investors, and firms. In fiscal year 2020, the U.S. Forest Service spent $88 million on its FIA program.

The FIA program provides nationwide monitoring through repeated inventories that provide consistency over time and at a high level of detail. The USA Forest Assessment System is a set of computer models designed to forecast alternative futures for USA forests. It accounts for changes driven by multiple vectors, including biological, physical, and human factors. Its models address the influence of climate change, market-driven timber harvesting, and land use changes, along with changes resulting from the natural succession of forest conditions. (Wear & Greis, 2013, Southern Forest Resource Assessment Consortium, 2022). FIA information is widely used to address local and

regional issues related to trends in forest extent, health, productivity, land cover and land use change, and the demographic changes of private forest landowners. FIA data also establish current baseline conditions, report on recent trends, and support adaptation and mitigation analyses of climate change effects and policy proposals.

FIA data are used to report annual greenhouse gas emission levels for forests and land use changes to the EPA and the United Nations (USDA Forest Service, 2021b). FIA information on forest area and stocking, tree volumes, and productivity are used to estimate total forest biomass and subsequently the amount of carbon sequestered, emitted, and cycled in forests. FIA data are also used for modeling climate change impacts on future forests. These models are developed, calibrated, and tested with FIA data to forecast future forest health and productivity. Regional and national estimates of climate change impacts include both negative and positive impacts for forests (USDA Forest Service, Forest Inventory and Analysis, 2021c).

FIA data track historic changes in the geographic range of tree species. Comparing recent species range maps to historic maps from the 1930′s and 1950′s illustrate how tree species' ranges have changed over time. Forest and tree species migration information is of intense interest in evaluating the adaptive abilities of the U.S. native forests in response to climate change and other disturbances (Handler et al., 2018).

In addition to its core inventory activities, FIA compiles information on wood product production and related factors through its Timber Products Output Survey (TPO), and on forest ownership characteristics through its National Woodland Owners Survey (NWOS) (USDA Forest Service, Forest Inventory and Analysis, 2021d). Several indicators of forest health are also measured in conjunction with the Forest Service's Forest Health Protection program (Potter & Conkling, 2020).

Since 1974, the Forest and Rangelands Renewable Resources Planning Act (RPA) mandates a periodic assessment of the conditions and trends of the USA renewable resources on forests and rangelands every 10 years. The USDA Forest Service monitors the sustainability of natural resources and looks into their future by conducting the RPA Assessment, which provides an evaluation of the current situation, assesses trends, identifies factors of change, and projects future conditions in a long-term horizon for forest and rangeland conditions on all ownerships. The 2010 RPA Assessment was based on three future scenarios derived from the IPCC 4th Assessment Report. Each scenario has common assumptions about population growth, economic growth, climate change, and land use change that influence the condition of future forests and rangelands and the goods and services they provide. The 2010 RPA scenarios and the associated socio-economic and climate projections were used in various natural resource models to project a range of futures for water yield and water use, forest inventory and wood markets, wildlife habitat, recreation use, and other resources (USDA Forest Service, 2012).

Several updated reports for the 2020 RPA assessment regarding future scenarios projections, as well as forests, forest ownership, and forest products have been released (Forest Service, 2021e). The main characteristics of these reports are presented in Table 5.

Table 5. Updated reports supporting the 2020 RPA assessment.

Report	Characteristics	source
Future scenarios: A technical document supporting the USDA Forest Service 2020 RPA Assessment	Describes in more detail the selection process that was used to identify and select climate scenarios, climate models, and climate projections for the RPA Assessment. While the scenarios, models, and projections were selected to be applied at the scale of the conterminous United States, 50 years into the future, they were also evaluated as to their utility at the scale of a national forest region, at a timeframe extended to 2100.	https://www.fs.usda.gov/treesearch/pubs/59,976
Climate scenarios and projections: A technical document supporting the USDA Forest Service 2020 RPA Assessment.	It describes the process used to select the scenarios, climate models, and climate projections that will be used to project renewable resource conditions 50 years into the future. Downscaled climate data selected are the MACAv2-METDATA developed by Abatzoglou and others at the University of Idaho. The dataset covers the conterminous United States at a grid size of approximately 4 km (1/24 degree) on a side.	https://www.fs.usda.gov/treesearch/pubs/60,113
Forest Resources of the United States, 2017: a technical document supporting the Forest Service 2020 RPA Assessment.	It provides current information on the Nation's forests. Resource tables present estimates of forest area, volume, mortality, growth, removals, and timber-product output in various ways within the context of changes since 1953.	https://www.fs.usda.gov/treesearch/pubs/57,903
Family forest ownerships of the United States, 2018: results from the USDA Forest Service, National Woodland Owner Survey.	It provides results from the 2017–2018 iteration of the National Woodland Owner Survey. The main focus is family forest ownership with 10+ acres of forest land.	https://doi.org/10.2737/NRS-GTR-199
Status and trends for the U.S. forest products sector: a technical document supporting the Forest Service 2020 RPA Assessment	It provides trends in U.S. forest products consumption, production, and trade to assess the forest products sector status to date.	https://doi.org/10.2737/SRS-GTR-258
Defining the United States land base: a technical document supporting the USDA Forest Service 2020 RPA assessment	It provides trends in US land use and land cover and summarizes how the RPA Assessment uses these different data sources to support analyses of forest trends.	https://www.fs.usda.gov/treesearch/pubs/59,691
Greenhouse Gas Emissions and Removals from Forestland, Woodlands, and Urban Trees in the United States,1990–2018	It provides an overview of the status and trends of Green House Gases emissions and removals from forest land, woodlands in the grassland category, harvest wood products, and urban trees in settlements in the United States from 1990 to 2018. The estimates for the United States summarized in the publication are based on the compilation reported in the *Land Use, Land-Use Change, and Forestry* chapter of the US EPA (2020) submission to the UNFCCC. New in this report, most of the national scale estimates are also reported by individual US states and are available online for the entire 1990–2018 time series*	https://www.fs.fed.us/nrs/pubs/ru/ru_fs227.pdf https://www.fs.fed.us/nrs/pubs/download/RU-FS-227_Appendix_1.pdf

Engagement in national and international monitoring networks/platforms

The USDA Forest Service participates in several national and international monitoring networks related to forests. The networks described below are by no means comprehensive but showcase the types of collaborative efforts in which the USA is involved.

The United States is one of the country members of the Montreal Process (Montreal Process, 2021) that work together on a common framework to describe, monitor, assess, and report on national forest trends and progress on seven criteria and 54 indicators which are designed to provide a comprehensive assessment of forest sustainability across ecological, social, and economic dimensions. These Criteria and Indicators (C&I's) also provide a common understanding within and across countries of what is meant by sustainable forest management and may be understood to constitute an implicit definition of sustainable forest management at the country level. The latest report the U.S. published is the 2010 National Report on Sustainable Forests, produced under U.S. engagement in the Montréal Process for the Sustainable Management of Temperate and Boreal Forests (Robertson et al., 2011).

The USA FIA participates in the European Cooperation in Science and Technology (COST) Action E4:3 Harmonization of National Inventories in Europe: Techniques for Common Reporting. The main objective is to improve and harmonize the existing national forest resource inventories in Europe. The secondary objectives are to support new inventories in such a way that inventories will meet national, European, and global level requirements in supplying up-to-date, harmonized, and transparent forest resource information; and to promote the use of scientifically sound and validated methods in forest inventory designs, data collection, and data analysis. USDA FS has had considerable influence in this movement via its participation in COST Action E43 on harmonizing National Forest Inventories.

The National Ecological Observatory Network (NEON) is a continental-scale research platform for gathering long-term data on ecological responses of the biosphere to changes in land use and climate. There are twenty sites (Ecological Domains) across the United States, nine of which involve Forest Service lands. NEON's scientific steering group includes several U.S. and foreign government agencies as well as universities and research institutions. Federal agencies including USDA Forest Service, EPA, DOE, and others host numerous other datasets. The US Forest Service hosts 17 NEON field sites (The National Ecological Observatory Network (NEON), 2020).

The Long-Term Ecological Research (LTER) Network was founded in 1980 by the National Science Foundation. It works to generate and share useful and usable information to provide the scientific community, policy makers, and society with the knowledge and predictive understanding necessary to conserve, protect, and manage the nation's ecosystems, their biodiversity, and the services they provide. The LTER Network receives its greatest funding from the U.S. National Science Foundation (NSF); but other Federal agencies such as the USDA Forest Service and Agricultural Research Service, the National Aeronautics and Space Administration, the US Geological Survey, the US Environmental Protection Agency, and the US Department of the Interior's National Park Service and Fish and Wildlife Service also support various projects at site and network levels. The US Forest Service hosts five LTER field sites (Long-Term Ecological Research (LTER), 2020).

Several public-private collaborations aggregate and analyze large quantities of soil data. For example, scientists have created the International Soil Carbon Network (International Soil Carbon Network, 2020), a platform working to develop a globally integrated database of soil carbon measurements. ISCN partners with several federal programs, including the interagency U.S. Global Change Research Program (USGCRP) and the NSF-funded National Ecological Observatory Network (NEON).

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Enforcement

In general, federal regulations (e.g., ESA, CWA, NFMA, NEPA, PPA, FIFRA, CZMA, and the CAA) all contain enforcement provisions and are enforced through the U.S. legal system, as are their subordinate rules and regulations. Federal or state management actions can be, and often are, challenged in the federal courts. The U.S. has a robust history of civil society engagement on environmental and social issues as well as a judicial system for litigation, resolution, and penalties when issues are identified.

At the state level, state agencies are responsible for the regulation of forestry practices; and their activities are extensive. In 2000 1,453 state government agencies or entities (departments, bureaus, divisions, and commissions) were known to implement policies and programs that influenced the condition (use, management, protection) of nonfederal forests. Of that total, approximately 540 were engaged in some manner in the regulation of forestry practices on nonfederal forests, 37 of which had regulatory functions as their sole responsibility (issuance of permits, enforcement of rules, licensing of occupations). The remaining 500 or so entities of state government exercised regulatory duties that were viewed as part of broader program responsibilities focused on nonfederal forests (for example, chemical and pesticide abatement, resource protection [fire, insects, diseases], water pollutant management, air pollutant management, forest and wildlife management, mine and mineral reclamation, watershed and wetland management, waste management, and public health programs) (Ellefson et al., 2004).

State level BMP's apply to private and state forest lands across the U.S. and can be either mandatory (regulatory) or voluntary (non-regulatory) in nature. In all cases, these forest lands are subject to certain federal regulations that must be complied with, as mentioned earlier. States self-report through the National Association of State Foresters (NASF), and compliance is generally rated as high (National Association of State Foresters, 2015).

The Environmental Protection Agency (EPA) works with its federal, state, and tribal regulatory partners through a comprehensive Clean Water Act compliance monitoring program to protect human health and the environment by ensuring that the regulated community obeys environmental laws/regulations through on-site visits by qualified inspectors. A review of the information is required to be submitted by the EPA, state, or tribe is required to be submitted (US Environmental Protection Agency, 2021).

Each federal land management agency and state government has some form of law enforcement division that deals with enforcing federal laws and regulations that protect natural resources, agency employees, and the public.

Main highlights of USA sustainable forest management and future sustainability challenges

The general concept of sustainability has not changed dramatically over the last 300 years from its basic foundation. It is worth mentioning that the so-called three foundations of sustainability (environment, social, and economic factors) have always been the main drivers for conservation and sustainability through the history of forest management, although politics have had some influence.

Long term strategic planning requires assessing simultaneous consideration of economic, environmental, and social aspects of current management of forests; the development of human interventions; and anticipated natural impacts.

Civil society, industry, and different levels of government have developed a range of tools such as criteria and indicators, certification systems, BMPs, and guidelines to evaluate the state and progress towards sustainability of forest resources.

In current times, the management of a forest unit and its sustainability is influenced by complex and interdependent factors far beyond its local physical and socio-economic context. Trade flows and emerging sustainability policies, market preferences, international and national public opinions/perceptions of forests about climate change, and initiatives led by governments and NGO's are increasingly influencing the use and conservation of natural resources.

Sustainable forest management success in the U.S. can be demonstrated by the fact that during the last 100 years, its forest area has remained stable while also being one of the world's top timber producers. This sustainability framework is pursued within a unique context of private and public ownerships; stakeholder collaboration; a federalist system with overarching federal laws that also give freedom to state and local jurisdictions to use regulatory and voluntary means to achieve those aims; and a variety of government incentive programs offering technical assistance, financial assistance, and tax relief for landowners who proactively practice responsible forest management. The legal framework

is reinforced through consistent enforcement of laws, strong civil society engagement, a vigorous monitoring and reporting of changing forest conditions, and an array of future modeling to inform management actions.

Future sustainability challenges

World forests are under constant pressure from rising population growth, increasing demand for goods and ecosystems services, and the environmental impacts of climate change all of which affect their sustainability. The U.S. Global Change Research Program (USGCRP) Climate Science Special Report (USGCRP, 2017) indicated that it is extremely likely that human activities are the dominant cause of the observed warming since the mid-20th century, especially the emissions of greenhouse gas es resulting in changes in the intensity and frequency of extreme events that affect human safety, infrastructure, agriculture, water quality and quantity, and forest ecosystems.

The U.S. sustainability framework will increasingly be tested by climate change impacts (droughts, insects and disease attacks, propensity to wildland fire among others), population growth, land use change from forest to other uses, forest ecosystem fragmentation, and society's shifting preferences.

To help adapt to these challenges, there is a need to develop new scientific tools for more accurate monitoring and quasi real time trends assessment at the landscape level to facilitate the decision-making process, and to adapt to increasingly rapid changes of forest ecosystems to assure long term sustainability.

Platforms for cross-sectoral and multi-stakeholder dialogue, as well as the availability of public science-based data to inform conversations, will continue to be important, especially in light of increased interest in forests caused by climate changes and the need to balance conservation goals with livelihood realities.

There will be a need to find creative and proactive ways to stop the rapid loss of biodiversity to avoid natural resources deterioration (i.e., increasing carbon sequestration, soil health) and to restore degraded lands.

Land management programs that continually restore forests to healthy and productive conditions will help ensure the long-term maintenance and transformation of forest carbon stocks. Forest systems managed to adapt to changing conditions will capture carbon and store it more securely over the long term, while also furnishing wood-based materials, other goods, and ecosystem services that will contribute to sustainability.

Sustainable forest management is critical in implementing a circular economy model that ensures that goods and services from forest ecosystems meet the needs of current and future generations where building a circular economy will have to consider multiple socio-economic expectations and forest ecosystem services, including the production of renewable biological products and the conversion of waste streams into value-added bio-based products and bioenergy. In implementing this model, however, the critical challenge and question are whether increased use of renewable biological products is possible without neglecting global sustainability (Winkel, 2017). According to Duncker et al. (2012), one of the most important questions for the future is how to manage the forest for timber production while conserving or improving other important ecosystem services.

And last but not least, there must be economic means to retain and manage forests within a landscape. This will entail creating new markets for the diverse goods and services coming from forests, including providing a supportive environment for industry to develop

innovative forest products and the research needed to develop them as well as new public and private financing models for ecosystem services such as water and carbon markets.

Author contributions

CRF: conceptualization, methodology, writing the original draft, and editing. JC: validation, writing, reviewing, and editing.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Disclaimer

The findings and conclusions in this publication are those of the authors and should not be construed to represent any official USDA or USA Government determination or policy.

Funding

The USDA Forest Service supported this work

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