nature sustainability

Perspective

https://doi.org/10.1038/s41893-026-01915-7

The changing economics of public lands in the USA

Received: 18 June 2025

Accepted: 16 July 2026

Published online: 25 August 2026

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For over a century, economic ideas have shaped US public land management. This culminated with 'maximum sustainable yield' (MSY) becoming a central decision-making framework. However, the passage of major environmental legislation—echoing an American preservationist tradition—spurred the US Forest Service and other public agencies to reconsider this narrow utilitarian approach, setting the stage for the adoption of a social-ecological systems framework emphasizing ecosystem services and resilience—benefits that are largely public goods—aimed at achieving sustainability. However, a reorientation of US management priorities now may be afoot, with renewed emphasis on extractive uses of public lands.

In 1906, an earthquake and subsequent fire laid waste to much of San Francisco, focusing public attention on the need for an abundant and reliable water supply. This was used to justify the construction of the O'Shaughnessy Dam[1], which inundated the Hetch Hetchy Valley and devastated its ecosystems. John Muir, a pioneer of American environmentalism, said of the valley: "no holier temple has ever been consecrated by the heart of man"[2]. In contrast, Gifford Pinchot, the first chief of the US Department of Agriculture's Forest Service, advocated for the dam's construction. From the outset, Pinchot imbued the Forest Service with a utilitarian 'wise use' philosophy[3] and originated the agency's longstanding ethos of achieving "the greatest good of the greatest number in the long run"[4]. In the decades that followed, the tension between Muir's 'preservationism' and Pinchot's 'utilitarianism' broke in favour of the latter, which became the dominant management philosophy for US public lands[5]. Whereas nature had previously been treated as a frontier to be exploited; it began to be viewed as a resource to be rationally managed for the collective good, even if it was not often protected for its 'natural' value[3].

Economics often serves as the cognitive infrastructure of public policy[6]; as John Maynard Keynes colourfully observed: "Practical men, who believe themselves to be quite exempt from any intellectual influences, are usually the slaves of some defunct economist"[7]. This influence extends to public land management in the USA and elsewhere[8]. Indeed, by the mid-twentieth century, land management in the industrialized world had grown to resemble an economic system focused on maximizing and sustaining narrowly defined measures of productivity, often with unintended consequences for societies and ecosystems[9].

It could be said that public land management philosophy had crystallized into a 'maximum sustainable yield' (MSY) approach focused on the relatively narrow aim of resource harvesting. But as societies became more cognizant of their dependence on ecosystems, the economics of public land management became fertilized by knowledge and methods from ecology and other disciplines[10], broadening in recent decades into a 'social-ecological systems' (SES) framework[11]. In this Perspective, we chart this paradigm shift from MSY to SES through the institutional lens of the Forest Service, showing how evolving economic ideas about nature have responded to and driven this change. While the details of this shift are specific to the US context, many of the environmental challenges that an SES framework seeks to address are global and as a result, there may be transferrable lessons for researchers and practitioners.

MSY's rise and fall

During the 'American Gilded Age' of the late-nineteenth century, much of the country's natural resources were captured by 'robber barons', whose monopolies generated massive private wealth from the nation's natural capital[12]. In response, when the Forest Service was founded in 1905, its wise-use philosophy emphasized Progressive Era principles of efficiency and antitrust. The emphasis on efficiency was embodied in the technocratic use of scientific expertise to achieve the 'greatest good'[13], while antitrust ideals were reflected in the goal of assuring that benefits from public lands accrued to the 'greatest number' rather than being captured by monopolists[14].

In his philosophy of public land management, Pinchot made the crucial addendum of 'in the long run' to Jeremy Bentham's and John Stuart Mill's original definitions of utilitarianism, thereby recognizing the longer timescales over which land management decisions are felt[15]. It also directly linked the aims of the Forest Service with the economics

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https://doi.org/10.1038/s41893-026-01915-7

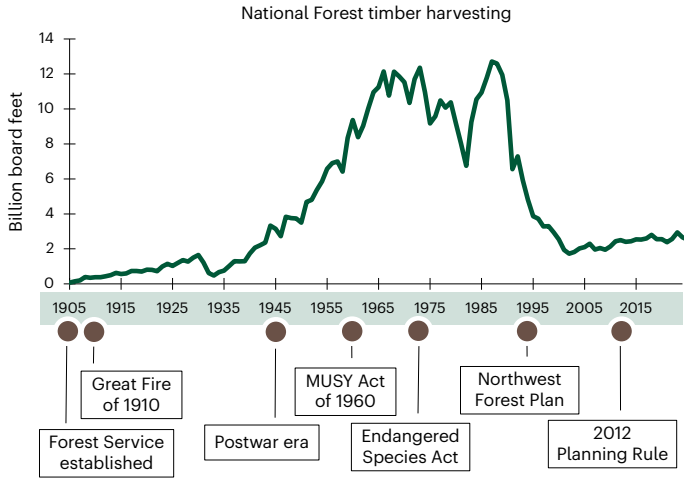

Fig. 1 | Harvest volumes from US National Forests. Trends in timber harvest volumes from US National Forests provide an informative backdrop for considering the policy priorities for US public lands. The trends also show the signals of macroeconomic drivers, with harvest declines occurring during the Great Depression. The early years of Forest Service management have been characterized as custodial 'wise use' of resources. After the Great Fire of 1910, the Forest Service emphasized rapid response to contain wildfires and eschewed the use of fire as a management tool[80]. The postwar years saw rapidly increasing timber harvesting, which was indicative of an MSY approach to management. A mid-century rise in public environmental consciousness coincided with the passage of laws codifying multiple use and biodiversity preservation. A series of court cases, beginning with a 1989 injunction, curtailed timber harvesting within northern spotted owl habitat in the Pacific Northwest. In 1994, the Northwest Forest Plan, implemented to comply with environmental laws, codified limits to harvesting in the area. These protections were associated with reductions in timber industry employment in the region[81] and contributed to declines in National Forest timber harvesting, which peaked in 1987 and declined through the 1990s, as more timber was imported and domestic production shifted towards private land in the southeast. This shift opened the door for new goals and values to guide management, which was evident in the inclusion of sustainability and ecosystem services in the Forest Service's 2012 Planning Rule. Forest Service harvesting trends based on cut and sold reports data[82].

of discounting[16], one of the most fundamental and controversial issues in the economics of what is today called sustainable development[17]. With utilitarianism as its lodestar, economic ideas have been foundational to the Forest Service's—and the US government's—approach to natural resource management[6]. This was evident in the decision to dam the Hetch Hetchy Valley, prioritizing the more economically immediate water supply over less tangible environmental values[1]. Today, environmental impacts have led scholars to more critically scrutinize the rationales for further dam building not only in the region but around the world[18].

After the Second World War, the management of US public lands increasingly narrowed towards a focus on extraction, contributing to a marked increases in timber harvesting from National Forests (Fig. 1). This trend is reflective of an MSY approach (we use this terminology to encompass a range of approaches that apply optimization to natural resource management, typically focused on a single resource and benefit stream). The emergence of this framework drew on neoclassical economic models that identified the optimal rotation age for a forest stand[19]. Indeed, Faustmann's highly influential formula forms the foundation of modern forestry economics[20] and presaged concepts central to optimal natural resource management and bioeconomics[21].

This era has been described as a time in which a 'conspiracy of optimism' contributed to a singular emphasis on maximizing timber harvest, often to the detriment of other uses and values that could not be readily priced in the market or extracted from National Forest lands[9]. However, the unavoidability of management trade-offs soon became evident with the growing demand for raw materials. Consequently, the Multiple Use Sustained Yield (MUSY) Act of 1960 codified the consideration of a broader range of uses and values in public forest management. This included recreation, range, timber, water and wildlife. The act's passage presaged a slow reorientation away from what had become an increasingly unidimensional MSY approach.

This shift was also driven by a sea change in environmental ethics and public awareness, notably represented by Aldo Leopold's and Rachel Carson's work. Leopold articulated a 'land ethic' in which people were seen as an integral part of nature. Having worked at the Forest Service for nearly two decades, he argued that the lumber-focused policies of his time constituted 'land pillage'[22]. Addressing the widespread use of pesticides, Carson's landmark book *Silent Spring* revealed humanity's capacity for systemic ecological impacts—in contrast to the discrete forms of degradation identified by more traditional preservationist outlooks[23]. Together, their work contributed to a broad shift in public attitudes that saw people as an integral part of nature.

In the USA, this growing environmental movement culminated in a series of policy wins for preservationism, including the Wilderness Act of 1964. A decade later, the Endangered Species Act and the National Forest Management Act established a legislative mandate for biodiversity preservation by government agencies. This imperative was enforced in a series of Federal Court rulings that substantially curtailed timber harvesting in the National Forests of the Pacific Northwest, thereby protecting old-growth forests that serve as habitat for the northern spotted owl[24]. This dramatically restructured the US timber industry, shifting the hub of domestic timber production from public lands in the Pacific Northwest to private lands in the southeast[25]. It also deeply impacted local communities, as the focus of public land management shifted from commodity timber production towards biodiversity protection[26]. While also affected by global economic forces[27], these policy changes contributed to a pronounced decrease in timber harvests from public lands.

The passage and enforcement of the aforementioned acts initiated the institutionalization of the non-extractive values of nature in policy and management. They also precipitated what has been described as an 'identity crisis' for the Forest Service[28], leading to a reevaluation of its central mission[29]. Part of this reevaluation was the recognition that natural resources were components of complex ecosystems, requiring management informed by an interdisciplinary understanding that went beyond a narrow focus on maximizing yield[30]. This destabilization of the MSY status quo enabled a broader range of ideas and values to be included in management philosophy, paving the way for the gradual emergence of an SES framework.

An SES framework

In the latter half of the twentieth century, new ideas in economics opened the discipline to more expansive notions of nature's benefits and recognition of ecosystems as a form of capital that provides a range of valuable—if not yet precisely valued—goods and services[31]. This was reinforced by accumulating scientific evidence on the extent and severity of human impacts on the biosphere[32]. These developments cast into further doubt the unidimensional MSY imperative of resource extraction, as feedback effects and the complexity they generate are unavoidable when managing ecosystems[33].

As ecology has advanced from a descriptive discipline towards a more mechanistic science that grapples with the complexity of ecosystems and their emergent properties[34], its insights have come to inform the economic understanding of human–nature interactions[35]. In effect, this reflects a growing scientific understanding of society's interdependence with nature—which is a core tenet of SES theory[36] (Table 1). This awareness has long existed in other contexts, from Swiss communal grazing lands to Nepali irrigation systems[37], but only in recent decades has an SES perspective come to inform the economics

Table 1 | MSY and SES frameworks

	MSY framework	SES framework
Principles of human–nature interaction	Humanity is distinct from nature: from the utilitarianism outlook, this licenses the use of ecosystems and the non-human species that comprise them.	Humanity is embedded in nature: this outlook sees people as being inextricable from, and dependent on, the life-supporting and enhancing services that nature provides; only through the stewardship of resilient ecosystems can societies successfully develop over the long run.
Goals of management and policy	Promoting efficiency in resource extraction for revenue; often treats forests (and other ecosystems) as individual stocks; concerned with sustainability in the pursuit of assuring current logging does not compromise future yields.	Promoting systemic resilience, so that a broad range of benefits to society can be maintained over the long run; sees ecosystems as complex and multi-dimensional (in part because of human–environmental feedbacks).
Social values of nature	Typically concerned with timber, which is seen as the foremost source of economic value from public lands, which can then be sold in markets for revenue.	Concerned with a diverse array of ecosystem services, including material (which includes timber), regulating (such as soil retention and flood mitigation), as well as non-material (sense of place and biodiversity in and for itself); many of these services lack markets but are nonetheless treated as socially valuable.
Typical conceptual scale	Resource optimization: focused on local or regional issues, with national imperatives as the uppermost geographic scale; forests and other ecosystems, while subject to quantitative changes, are nonetheless seen as having static, even timeless, elements and processes that should be 'wisely used'.	Stewardship of the whole: geographically multi-scalar in outlook, with ecological conditions at one scale understood to be influenced by processes (both human and natural) at lower and higher ones (including all the way up to the planetary); temporally, management is understood relative to the rapidly shifting biogeographic and climatic baselines and horizons of the Anthropocene, with the future likely defined by uncertainty and surprises.

Respective features of the MSY and SES frameworks for the economics of the public land management of forests.

of land management in the USA (even if the interdisciplinary focus has not yet entered the mainstream of economics education)[38]. SES theory is anchored by the key ideas of sustainability, ecosystem services and resilience[36,39]—ideas that found growing expression in the way the Forest Service framed its management aims.

The landmark 1987 United Nations report, *Our Common Future*, defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs"[40]. This shares notable similarities with the mission of the Forest Service to manage the nation's forests and grasslands to "meet the needs of present and future generations," which could be described as pursuing sustainable development of the nation's forests and grasslands. Much of the economics of sustainability has been an attempt to operationalize that such criteria.

Critical to this operationalization is the idea that nature is a productive asset that can be bequeathed to future generations, much like other forms of capital[41]. Theoretical debates on the economics of sustainability often centre on substitutability between natural capital and other capital types. A proposed criterion, now called 'weak sustainability', allows for declining natural capital if this is more than offset by investment in human-made substitutes[42]. Others have advocated for 'strong sustainability', which argues for the irreplaceability of nature's contributions to human well-being[43]. When considering resource extraction from public lands under multiple-use management, these conceptual distinctions can result in divergent management approaches[44].

With the substantial decline of timber harvesting from National Forests in the 1990s, researchers and practitioners began to question the Forest Service's unifying mission[29]. 'Sustainability' emerged as a candidate, yet its inclusion in the Forest Service's proposed 2000 Planning Rule sparked major scientific and policy debates; a central point of contention for this ultimately unimplemented rule was that it sought to place ecological sustainability as the foundation for social and economic sustainability, in effect aligning with strong sustainability[45]. Nonetheless, a shift towards broadening environmental priorities was underway at the Forest Service[46]. A decade later, sustainability was explicitly integrated into forest planning with ecological, social and economic as three coequal pillars—a definition aligned with weak sustainability[47].

The 1990s also saw the development and increased adoption of the 'ecosystem services' concept[48]. This helped operationalize sustainability by defining the flows of benefits that people receive from natural capital[49]. The scientific and policy influence of the ecosystem services concept, and associated ones such as nature-based solutions, capture the growing recognition that nature makes important contributions to human well-being beyond those that can be readily sold on existing markets[50]. In other words, many ecosystem services are public goods with benefits that are shared broadly across society and through time[51]. In the context of forest management, an ecosystem services lens may consider timber harvesting (provisioning/material service), a forest's capacity to sequester carbon (regulating service), and its scenic properties and opportunities for recreation (cultural/non-material service)[48].

In the USA, ecosystem services have been progressively mainstreamed into public land management over the past two decades. The Forest Service's 2012 planning rule was the first to include the consideration of ecosystem services, with the requirement that forest plans supply "people and communities with ecosystem services and multiple uses that provide a range of social, economic, and ecological benefits"[47]. In 2022, the US federal government announced the creation of a national natural capital accounting strategy that aims to incorporate the contributions of nature into the system of national accounts[52]. Globally, natural capital accounting and complementary indices such as gross ecosystem product have experienced growing adoption at local and national levels[53].

The ability of the land to sustainably supply ecosystem services is influenced by its resilience, which in the SES literature is defined as the capacity of a system to maintain its essential functions, and therefore its qualitative characteristics, in the face of stresses and shocks[39]. In the context of forests and many other ecosystems, this crucially means resilience to severe wildfires and other extreme event impacts. For instance, the capacity for a forest to avoid stand-replacing crown fires is essential to its role as natural capital and this type of resilience has been identified as a form of economic insurance[54]. In addition, many SES are at risk of crossing tipping points from which recovery may be prohibitively costly[55]. This risk is likely to enhance the value of proactive investments that reduce the likelihood of critical global tipping points occurring (for example, the potential shift of the Amazon from forest to savannah)[56]. As the magnitude of human impacts on the Earth system continues to increase, investing in resilience to extreme events and tipping points may become critical to sustainable land management[57].

https://doi.org/10.1038/s41893-026-01915-7

Fig. 2 | A changing Yosemite Valley. The view east from Columbia Rock towards Half Dome, showing a changing ecosystem composition in Yosemite Valley. The land around Yosemite Valley was designated as a forest reserve in 1890 by an act that called for the preservation of the 'natural condition' of its resources and the classification of people occupying the land as 'trespassers' subject to removal[83]. This obscured the longstanding history of Indigenous presence and management[84]. Subsequent policies of fire suppression contributed to increased stand density and elevated wildfire risk[60]. Credits: left, Henry G. Peabody/ Yosemite NP Archives; right, Ted Barone/NPS.

Managing forests for social-ecological resilience has gained traction in US policy[58]. Notably, there is growing emphasis on the need to build forest resilience in the face of increasing and interlinked disturbances from a changing climate, wildfires, and pests and pathogens. For example, in response to escalating impacts of wildfires and the rising share of public land management budgets dedicated to their management, substantial investments have been made to improve the resilience of communities and forests through a national fuels reduction strategy aimed at high-risk firesheds[59]. Wildfire risk depends on climatic conditions, weather, ecosystem conditions (such as the presence of ladder fuels) and social factors such as the extent of the wildland–urban interface[60]. These considerations are consistent with SES insights into the complex and cross-scale dynamics of human-modified ecosystems, and also underscore the relevance of traditional ecological knowledge and Indigenous burning practices that were used for millennia to promote landscape resilience[61].

Public land management in the Anthropocene

The systemic impact of human activity on the planet, which is a defining characteristic of the Anthropocene, is manifest in the intensifying 'wildfire crisis'[59] and other social-ecological challenges confronting US land management. Increasing wildfire risk in public forests is thought to be the legacy of decades of fire suppression and the growing impacts of a changing climate[60] (Fig. 2). Wildfires have put communities at risk and contributed to unhealthy levels of air pollution across North America[62]. These developments complicate the evaluation of alternative land management actions.

In this context of social-ecological complexity, the economics of a fundamental land management question, such as the possibility of expanding timber harvesting, can be examined within an SES framework. When assessing whether a timber sale increases social welfare, the principal criterion is the balance of social costs and benefits of the sale relative to the status quo. In a competitive market with no externalities and an exclusive focus on timber, the marginal social benefit of a sale corresponds to the stumpage price. This has led policymakers to question so-called below-cost timber sales, where administrative costs exceed the stumpage revenue from the sale[63]. These concerns have endured for decades, with current agency leadership stating an intention to improve the public's return on investment by "covering more of the costs of the timber program through revenue generated"[64].

However, timber harvesting entails externalities as it also may alter the flow of other ecosystem services. Relatedly, multiple-use management implies the consideration of values beyond timber, implying that avoiding below-cost sales may no longer serve as a definitive criterion for welfare-enhancing management[65]. Applying an SES approach can help resolve this ambiguity. For example, while harvesting provides a direct provisioning service, it can also increase erosion, degrade water quality and increase sedimentation in rivers, thereby limiting their hydroelectric generation capacity[66]. Forests are also the planet's largest terrestrial carbon sink[67]. The economic consequences of altering the flow of these ecosystem services due to harvesting can be estimated with ecological production functions and corresponding valuation methods[68].

Some of these values have been integrated into economic models of optimal timber harvesting[69]. For example, when considering the social value of carbon storage, studies have shown that the optimal harvest age can become infinite for forests with low economic productivity, especially if the social cost of carbon increases[70]. The current state of the US timber economy may (perhaps coincidentally) align with this result. Privately owned, intensively managed, high-productivity forests in the southeastern USA comprise a substantial share of domestic timber markets, while forests on public lands, which often have lower productivity (for example, slower growing, more costly to harvest given rugged and remote terrain) make up only a small proportion of the domestic timber market[25].

Management histories and changing climatic conditions that magnify wildfire risk induce further complexity. Wildfires are a major contributor to particulate matter ($PM_{2.5}$) pollution[62], with large public health and economic impacts[71]. As a result, management that reduces wildfire risk may improve social welfare. A meta-analysis found that a combination of mechanical thinning and prescribed fire can reduce wildfire risk in the western USA[72]. However, prescribed fire can also contribute to particulate matter pollution[73]. Therefore, realizing the benefits of investments in wildfire risk reduction may require a deeper understanding of the links between management actions, wildfire risk and the health impacts of air pollution from prescribed burns versus wildfires, especially over long timescales as management influences forest ecosystem states. The inclusion of these additional values beyond timber yield, along with their potential feedback effects and other complex interactions, lends itself naturally to an SES framework. Although we approached this synthesis through the institutional lens of the USA, globally transferrable lessons for practitioners and researchers emerge. For practitioners, consideration of a broad portfolio of values may give a clearer picture of the management trade-offs that must be navigated and help facilitate the stewardship of natural resources. Improving the methods for comprehensively evaluating alternative

management approaches while considering complex social-ecological dynamics presents an important research opportunity. While many of the elements of the SES framework are well developed, economics research that applies the approach comprehensively remains an active frontier[74].

A crossroads for US public lands

In recent years, California's skies have again reddened with smoke, this time from wildfires. The annual economic losses of these conflagrations in the USA have exceeded US$100 billion[75]. The country's wealth inequality has also risen to levels not seen since the early twentieth century[76]. Both developments uncannily evoke the era when the Forest Service was founded. However, more than a century of scientific advances have delivered new methods to understand and address pressing social-ecological challenges. Building on these advances, the Forest Service and other agencies charged with public land stewardship have incorporated SES concepts such as sustainability, resilience and ecosystem services into decision-making in recent decades[59]. However, a governance shift towards a re-emphasis of MSY-inspired management may be underway.

Since 2025, US federal policy has placed increasing emphasis on extractive uses of public lands. Executive orders have called for the expansion of timber harvesting[77] and non-renewable resource extraction[78]. Simultaneously, a rescission of the 2001 Roadless Rule, which limits road construction and thus constrains extractive uses across a substantial portion of National Forest lands, is being advanced[79]. The specific ways these changes may manifest on the landscape are currently unclear. Nonetheless, longstanding challenges about what it means to uphold the Forest Service's founding ethos remain: how 'the greatest good' is measured, who constitutes 'the greatest number', and how to ensure that benefits are sustained 'in the long run'.

These challenges highlight the role that interdisciplinary intellectual traditions have played in broadening definitions of economic value in public land management. As Keynes noted, "the power of vested interests is vastly exaggerated compared with the gradual encroachment of ideas"[7]. At a moment when the future of US public lands governance is uncertain, the development, refinement and application of ideas by researchers and practitioners may determine whether governance emphasizes an MSY approach or a broader social-ecological interpretation of 'the greatest good'.

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Acknowledgements

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

Author contributions

A.R.T. and T.W. jointly contributed to conceptualization, writing and revision of the paper.

Competing interests
The authors declare no competing interests.

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Peer review information *Nature Sustainability* thanks Sumeet Gulati and the other, anonymous, reviewer(s) for their contribution to the peer review of this work.