

1 Chapter 12: Nature and the Economy

2 in the US

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1 Summary

2 The **economy** both relies on and transforms nature. While nature's full value cannot be
3 captured in monetary terms (1), several approaches exist to estimate how nature
4 contributes to the economy and how economic activity affects nature.

5 Nature powers the US economy, providing the energy, raw materials, and **ecosystem**
6 **services** that industries depend on. Sectors with the most direct reliance on nature—
7 agriculture, forestry, fisheries, energy, and outdoor recreation—collectively generate more
8 than \$700 billion annually, representing over 3% of the US **gross domestic product** (GDP)
9 and supporting more than six million jobs. Nature also underpins many other sectors,
10 although these contributions are indirect, interwoven across the economy, and difficult to
11 isolate. Beyond market transactions, **natural capital** delivers **nonmarket benefits**—clean
12 air and water, recreation, and biodiversity—that hold genuine economic value. National
13 statistics have traditionally overlooked these nonmarket benefits, although recent efforts
14 aim to incorporate them into economic reporting (2).

15 Economic activity has eroded natural capital in recent decades (3). A fundamental cause is
16 the longstanding treatment of environmental harms—such as pollution, deforestation, soil
17 degradation—as **externalities**, with costs borne by society and ecosystems rather than by
18 the businesses that generate them (4). These externalized burdens fall disproportionately
19 on marginalized and economically disadvantaged communities.

20 Economic actors are beginning to adopt nature-friendly practices through voluntary
21 initiatives, emerging reporting requirements, and policy initiatives. Yet these efforts remain
22 limited in scope and uneven in their reach, constrained by structural barriers that prevent
23 widespread adoption. The chapter excludes extractive industries in the energy sector such
24 as oil, gas, and coal in the calculations of economic impacts because they fall outside the
25 core focus of this Assessment (as explained in Chs. 1 and 2).

26 Background

27 Nature and the economy are closely intertwined. At the most fundamental level, nature
28 provides the life-support system for people and the foundation on which every part of the
29 economy ultimately depends (5,6). Many of nature's benefits are direct, such as
30 agricultural crops, fish, timber, and outdoor recreation. Other benefits are indirect: forests
31 filter water, wetlands reduce floods, coastal ecosystems buffer storms, and healthy soils
32 store nutrients and carbon. These contributions are often described as ecosystem
33 services, meaning the many ways nature contributes to human well-being and the
34 economy (7).

35 Different parts of the US economy rely on nature in different ways. Some sectors—such as
36 agriculture, fishing, forestry, and nature-based tourism—depend directly on ecosystems
37 for raw materials, productivity, and long-term viability. Other sectors depend on nature

1 indirectly. For example, manufacturing and food service industries rely on supply chains
2 that begin with natural resources; real estate values depend partly on the quality of nearby
3 natural spaces; and retail, logistics, and construction all depend on clean water, stable
4 climates, and predictable natural conditions. Households and communities also rely on
5 nature for mental and physical health benefits, cultural practices, and outdoor
6 opportunities (8,9). In economic terms, the stocks of biological and physical resources that
7 provide these ongoing benefits are called **natural capital**.

8 Nature provides many benefits that are not bought or sold in markets. Because clean air,
9 safe drinking water, healthy soils, and natural scenery do not have explicit prices,
10 researchers use a variety of economic approaches to estimate their value. These methods
11 include observing how people spend money on travel and recreation, how environmental
12 quality affects property values, and how people respond to surveys about their willingness
13 to pay for cleaner water, healthier ecosystems, and species protection (10–12). Although
14 these approaches differ, they consistently show that people place substantial value on
15 nature’s benefits, even when those benefits are not captured in markets.

16 Traditional economic indicators, such as GDP, generally do not include the value of these
17 nonmarket benefits or the condition of the natural systems that provide them (13,14). As a
18 result, economic growth may be overstated when the benefits of resource extraction are
19 counted but the associated losses in natural systems are not. To address this gap,
20 countries including the United States are beginning to develop natural capital accounts
21 (Box 12.1). These efforts build on the United Nations’ System of Environmental-Economic
22 Accounting (SEEA), which provides an international framework for tracking the extent,
23 condition, and economic contributions of ecosystems (15).

24 SEEA-inspired initiatives in the US include pilot natural capital accounts that measure land,
25 water, air emissions, and ecosystem services, with the goal of eventually complementing
26 GDP with more complete indicators of national wealth (2,16). Inclusive wealth measures
27 attempt to capture the value of all forms of capital assets, natural capital, manufactured
28 capital, and human and knowledge capital (13,17).

29 Another emerging approach is gross ecosystem product, a summary measure designed to
30 track the value of ecosystem services in a way that parallels how GDP tracks the value of
31 marketed goods and services (18,19). These accounting efforts are in early stages, but they
32 represent important steps toward recognizing nature as an essential component of
33 economic well-being.

34 **Box 12.1. Progress in Natural Capital Accounting in the US**

35 The US federal government in 2022 created a national strategy around Natural Capital
36 Accounts (20), a system for measuring and tracking the economic value of the Nation's
37 natural assets and the ecosystem services they provide, similar to a balance sheet for
38 nature. The US has made substantial progress in developing pilot accounts to demonstrate
39 the feasibility of developing these estimates for land, water, air emissions, and

1 environmental activities (21–23) while also identifying key challenges in creating these
2 estimates. Significant progress is also being made in marine resources, pollinations, urban
3 ecosystems, and natural hazards (24–27).

4 The US federal government also directed the development of a National Land Account to
5 map land by economic activity (20), providing new insights into how land contributes to the
6 economy and showing why the inclusion of natural assets such as land in official statistics
7 is necessary for accurately assessing the national wealth. In a Phase 1 pilot assessment,
8 the results showed that national land-cover estimates were relatively stable compared to
9 land asset values, which showed periods of boom, bust, and recovery from 2001 to 2016
10 (21).

11 *(Photo(s) illustrating land and water accounting to be added later)*

12 The Pilot National Water Account uses existing data to quantify the availability and use of
13 water across industries (agriculture, mining, and energy). Drawing on existing data to
14 estimate both water quantity and quality, this pilot has produced early results
15 demonstrating how water-use patterns vary by state and industry and how changes in use
16 and reliance on groundwater can be tracked. Estimates suggest that average water use in
17 the US has been declining nationally over the period 2000 to 2015. However, groundwater
18 use has been steadily increasing in key states that rely heavily on this resource (22).

19 [END BOX 12.1 HERE]

20 The relationship between nature and the economy is also shaped by cultural values and
21 worldviews, including Indigenous perspectives in which Tribal lands and waters may
22 underpin commercial activities (e.g., fisheries) or alternative economic systems based on
23 exchange, stewardship, and relational obligations. Some cultures view people and nature
24 as part of a connected, interdependent system (1). Others emphasize nature’s intrinsic
25 value—meaning that species and ecosystems have worth beyond the benefits they provide
26 to people. These different perspectives influence how communities define well-being, how
27 they approach stewardship, and how they weigh trade-offs in decisions about land, water,
28 and resources.

1 Figure 12.1: Relationship Between the Economy and Nature

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2

3 **In contrast to historical negative business impacts on nature, a modern symbiotic**
4 **perspective highlights the need for healthy ecosystems, sustainable harvests, and**
5 **other sources of natural capital (soil, water, etc.).**

6 *(a) The Historical relationship: Traditionally, nature served as a finite source of inputs for*
7 *economic function. In the process of extracting/harvesting these raw materials, processing*
8 *them into finished products, transporting them to desired destinations, and then having*
9 *customers dispose of those products at the end of their life, businesses have profited*
10 *greatly at the expense of nature (e.g., environmental degradation). (b) A shifting perspective*
11 *on the nature–economy relationship reveals the potential for a modern, symbiotic*
12 *relationship. In this model, businesses engage in sustainable harvesting and deploy*
13 *environmentally friendly emerging technologies, transitioning from mere extraction to less*
14 *damaging processes that proactively mitigate negative externalities by restoring degraded*
15 *landscapes, air, and water.*

16 Across the US, the specific ways that nature and the economy interact differ by region.
17 Farming dominates much of the Midwest and California’s Central Valley; forestry is central
18 to parts of the Pacific Northwest and Southeast; fishing is vital to coastal and freshwater
19 communities; and nature-based tourism supports many regions with mountains, lakes,
20 forests, and coastlines. Urban areas benefit from parks, trees, and waterways that can
21 improve health, reduce heat, and help manage stormwater (28,29). These varying regional
22 relationships shape both the benefits people receive from nature and the pressures placed
23 on natural systems. Economic activities can lead to depletion and degradation of natural
24 resources and systems. Habitat loss, pollution, and declining populations of various
25 species are often direct results of unsustainable economic practices.

1 Key Message 12.1: Nature contributes substantially to the US 2 economy

3 *Nature underpins the US economy by providing essential raw materials, energy, and*
4 *ecosystem services (well established). Many of nature’s contributions—such as clean air*
5 *and water, flood protection, and outdoor recreation—remain invisible in economic*
6 *accounts, causing the value of natural capital to be systematically understated (virtually*
7 *certain). The health of natural systems will directly influence the stability and long-term*
8 *performance of the US economy, supporting communities, households, industries, and*
9 *businesses (well established).*

10 State of Knowledge 12.1

11 The US holds vast and diverse stocks of natural capital—its lands, waters, and oceans—
12 which form the foundation of its economy. Nearly 2.26 billion acres of land provide the
13 physical base for production and economic activities.

14 The US **exclusive economic zone** further extends the Nation’s natural capital, spanning
15 approximately 3.4 million square miles of ocean and 90,000 miles of coastline (30). These
16 marine environments support 506 managed fisheries stocks that underpin both
17 commercial and recreational fishing (31), as well as sectors such as shipping, aquaculture,
18 and offshore wind energy (see Ch. 6: Marine Ecosystems).

19 Freshwater systems, including lakes, rivers, streams, and wetlands, form another essential
20 component of the US natural capital. About 7% of the total land area—270,000 square
21 miles—is covered by fresh water. The lower 48 states contain nearly 500,000 natural lakes
22 and reservoirs of at least one hectare (about 2.5 acres) (32), and around 38 principal and
23 regional aquifers provide most of the groundwater used for crop irrigation, public water
24 supply, and electricity generation across the continental US (33,34). These systems provide
25 many ecosystem services. For example, wetlands support and sustain many plants,
26 insects, and animal species; store carbon and filter pollutants; provide flood mitigation;
27 and protect shorelines (35).

28 The economic significance of nature-dependent sectors is partially reflected in the
29 Nation’s income and product accounts, which are the official systems used to track
30 economic activity in the US. These accounts record both the value of marketed goods and
31 services produced (captured through GDP) and the income earned from that production
32 (captured through National Income, which includes wages, salaries, and other earnings).
33 Because many industries—from agriculture and forestry to fisheries, recreation, and
34 energy—depend directly on natural resources, nature contributes to both production and
35 income generation across multiple sectors of the US economy as measured by the national
36 income and production accounts. The economic significance of nature also includes many
37 contributions to human well-being and the economy that are not captured in the income
38 and production accounts. These nonmarket ecosystem services include regulating

1 ecosystem services, such as air and water purification, flood mitigation, and storm
 2 protection, along with nonmaterial ecosystem services, such as aesthetic beauty,
 3 educational and scientific values, and cultural and spiritual values (36,37).

4 **Table 12.1. Market and Nonmarket Economic Benefits of Ecosystem Goods and**
 5 **Services**

6 *Ecosystem goods and services provide numerous market and nonmarket economic*
 7 *benefits. Categories of ecosystem goods and services are from the UN System of*
 8 *Environmental-Economic Accounting (SEEA) (<https://seea.un.org>).*

Ecosystem Goods and Services		Economic Benefit
Provisioning Services	Agricultural crops	Food, material, energy production
	Grazed biomass / livestock	Food, material production
	Aquaculture	Food, material production
	Wood (timber)	Timber production
	Wild fish	Food, material production
	Wild animals, plants, and other biomass provisioning services	Food, material production
	Genetic materials	Genetic prospecting for pharmaceutical and other products
	Water supply	Water use in agriculture, industry, domestic use
	Other provisioning services	Various

Regulating Services	Global climate regulation	Climate mitigation through carbon sequestration and other greenhouse gases
	Regional rainfall pattern regulation	Contributions to regional water supply through evapotranspiration and precipitation
	Local climate regulation	Urban cooling with energy savings and health benefits
	Air filtration	Health benefits from improved air quality
	Soil quality	Increased agricultural productivity through improved fertility
	Soil erosion control	Reduced soil loss contributing to agricultural productivity, reduced dredging costs
	Landslide mitigation	Reduced property damage, human health, and safety benefits
	Solid waste remediation	Solid waste treatment
	Water filtration	Improved water quality contributing to reduced water treatment costs and/or health benefits
	Water flow regulation	Contributions to base flow and maintenance of river flows, lake levels, and groundwater recharge
	Coastal protection	Reduced property damage, human health and safety benefits

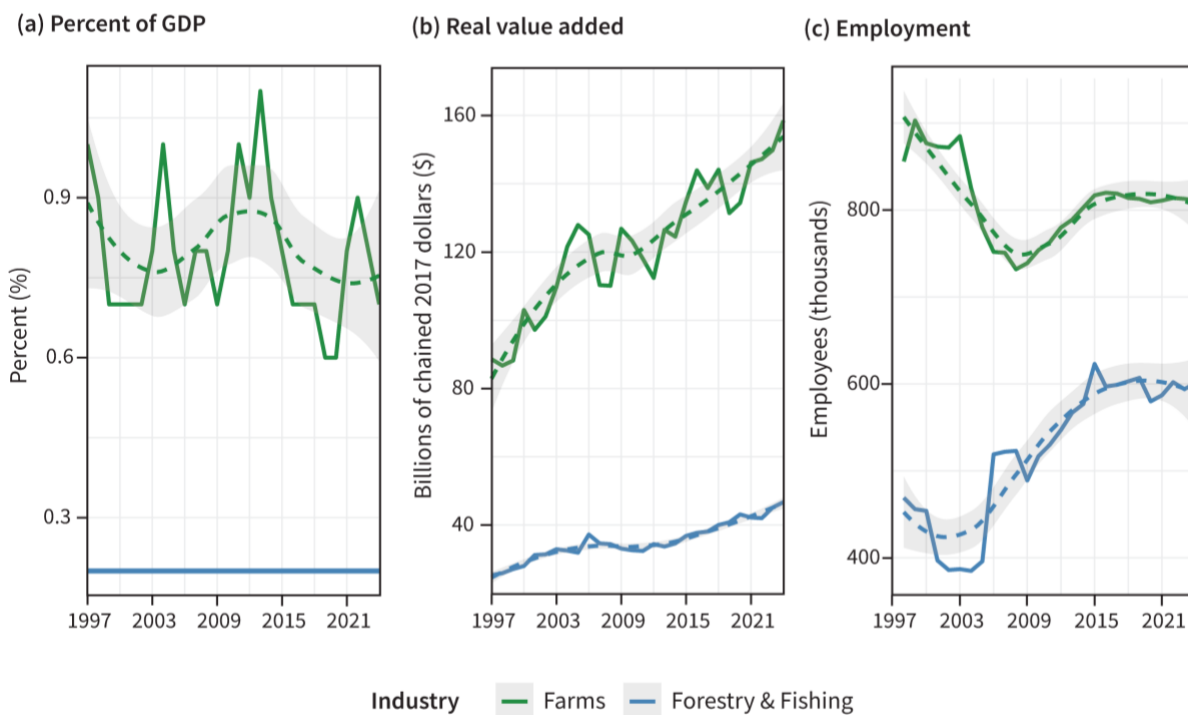
	River flood mitigation	Reduced property damage, human health and safety benefits
	Storm mitigation	Reduced property damage, human health and safety benefits or mitigation of windstorms, sand, dust
	Noise attenuation	Stress reduction and other benefits of noise reduction
	Pollination	Improved agricultural production and maintenance of other plant species
	Pest control	Improved agricultural production
	Disease control	Human and animal health benefits
	Nursery and habitat maintenance	Sustaining populations of species that may have economic benefits
	Other regulating services	Various
Cultural Services	Recreation	Health and enjoyment benefits of time spent in nature
	Visual amenities	Enjoyment from experiencing the beauty of nature
	Education and scientific	Benefits from intellectual interactions with nature
	Spiritual, artistic, and symbolic services	Cultural, historical, aesthetic, sacred or religious significance of nature
	Other cultural services	Various

<p>Ecosystem and Species Appreciation</p>	<p>Existence value</p>	<p>Benefits from existence and preservation of the environment for current and future generations irrespective of use</p>
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1 Natural capital affects the economy through markets where natural resources are
 2 exchanged for money. In 2023, the value added from renewable extractive natural
 3 resources industries—farms, forestry, fishing, and hunting—was \$270 billion, representing
 4 about 1% of US GDP (38). Farming accounted for roughly 80% of this value, with the
 5 remaining 20% generated by forestry, fishing, and hunting activities. These sectors have
 6 expanded in step with the broader economy, maintaining a relatively steady share of about
 7 1% of GDP for nearly three decades (Figure 12.2). Beyond extractive uses, the outdoor
 8 recreation sector contributed an additional \$474 billion in value added, or 2.3% of GDP, in
 9 2023 (39). This broader category encompasses not only traditional activities such as
 10 hunting, fishing, and hiking but also boating, RVing, skiing, wildlife viewing, and other
 11 leisure- and travel-related industries that depend on access to natural settings. Its
 12 contribution has remained relatively stable over time, except for a temporary decline in
 13 2020.

14 **Figure 12.2: Farms Versus Forestry and Fishing Data Over Time**

Farms, Forestry, and Fishing Industries (1997–2024)



Note: Dashed lines represent smoothed trend and shading indicates confidence interval

15

1 **Economic measures for industries that are highly dependent on nature have changed**
2 **over time.**

3 *(a) The percentage of total US GDP generated by farms and by forestry and fishing from*
4 *1997 to 2024. Although farms contribute a relatively small share of GDP (.8%), this reflects*
5 *how GDP measures value added in later stages of processing and manufacturing rather*
6 *than the foundational role of farms in supplying raw biological inputs to the food system.*
7 *Forestry and fishing account for a larger, but still modest, share (.2%), reflecting the*
8 *upstream position of these sectors in longer value chains. (b) Real value added (chained*
9 *2017 dollars). This panel shows inflation-adjusted (“real”) value added for both sectors,*
10 *expressed in chained 2017 dollars to remove the effects of price changes over time. In real*
11 *terms, forestry and fishing increased from roughly \$25 billion to over \$46 billion between*
12 *1997 and 2024, while farms increased from just over \$88 billion to nearly \$160 billion.*
13 *These trends reflect growth in physical production, productivity, and value created in these*
14 *nature-dependent industries. (c) Employment in farms and in forestry and fishing over the*
15 *same period. Farm employment declined slightly overall, from a high of 900,000 in 1999 to*
16 *about 800,000 in 2024, with a noticeable dip starting around 2006. Forestry and fishing*
17 *employment fell in the early 2000s and then rebounded, rising from under 400,000 to about*
18 *600,000 by 2024. Together, these trends illustrate how technological change, consolidation,*
19 *and productivity gains can increase economic output even as employment shifts. All dollar*
20 *values are expressed in real chained 2017 dollars (inflation-adjusted). Forestry and fishing*
21 *are combined following BEA industry classifications. Figure original to The Nature Record.*
22 *Data source: US Bureau of Economic Analysis.*

23 Nature-dependent sectors directly support millions of jobs across the US (Table 12.2). In
24 2023, farms employed about 812,000 people, while forestry, fishing, and hunting provided
25 employment for an additional 592,000. These employment levels have remained relatively
26 stable for many years (Figure 12.2). The outdoor recreation sector supported nearly 5
27 million jobs in 2023, a figure that—aside from the temporary downturn in 2020—has shown
28 steady growth since 2012, when the Bureau of Economic Analysis (BEA) began tracking this
29 sector (38).

30 **Table 12.2 Contribution of Nature-Dependent Sectors to the US Economy and**
31 **Employment**

32 *Several key sectors of the US economy are dependent on nature. Sources: US Bureau of*
33 *Economic Analysis (38,40,41). Intensity categories in the last column are determined as*
34 *follows: Not Dependent: <1%, Low Intensity: 1–5%, Medium Intensity: 5–20%, and High*
35 *Intensity: >20%. The Marine Economy and Outdoor Recreation values (last two rows) are*
36 *from BEA’s satellite accounts, which take a close look at a part of the economy and are*
37 *separate estimate from core BEA sectors.*

Sectors	Total Output (in Billion USD)	Total Value Added (in Billion USD)	Contribution to GDP (%)	Employment (in 1,000s)	Intensity of Intermediate Use of Farm and Forestry Outputs
Farms	565.0	222.3	0.80%	812	High
Forestry, fishing, and related activities	65.4	51.9	0.19%	592	High
Utilities	604.8	446.5	1.61%	577	Not Dependent
Construction	2333.0	1220.6	4.40%	8132	Not Dependent
Wood and paper products	371.7	136.8	0.49%	781	Medium
Machinery and equipment	1643.1	567.1	2.05%	2892	Not Dependent
Electronic products	581.7	384.2	1.39%	1517	Not Dependent
Other manufacturing	347.9	178.6	0.64%	1293	Low
Food and beverage and tobacco products	1160.1	335.2	1.21%	2078	High
Retail services	5104.1	3468.3	12.51%	22179	Not Dependent
Chemical and petroleum products	2080.1	846.3	3.05%	1740	Low

Transportation	1720.4	943.7	3.40%	6684	Not Dependent
Media and amusement services	2838.5	1727.0	6.23%	17837	Low
Data and telecommunication services	1682.2	962.4	3.47%	1726	Not Dependent
Financial services	3742.5	2015.6	7.27%	6725	Not Dependent
Real estate	5559.7	3796.0	13.69%	2487	Not Dependent
Other services	6516.8	4201.1	15.16%	29899	Not Dependent
Education and health services	3746.6	2350.9	8.48%	25493	Not Dependent
Government	5145.4	3105.1	11.20%	25052	Not Dependent
Marine economy	826.6	510.9	1.8%	2,554	N/A
Outdoor recreation	1,168.1	639.5	2.30%	4959	N/A

1

2 Natural resources also contribute indirectly to the economy through the supply chains of
3 other sectors. Outputs from the farm sector contribute to more than one third of
4 intermediate input use by the food and beverage and tobacco sectors, which support two
5 million jobs and contribute to 1.2% of GDP. Beyond the direct contribution of the forestry
6 sector (reported in Table 12.2), forest resources also support wood products
7 manufacturing (\$62 billion; 0.2% of GDP), food and beverage and tobacco products (\$347
8 billion; 1.2% of GDP), and paper products (\$74 billion; 0.3% of GDP). Agriculture and
9 fisheries are likewise foundational inputs into food manufacturing, as well as in emerging
10 uses such as biofuels. Ecological functions also support production in many industries; for
11 instance, insect pollinators contribute an estimated \$34 billion annually to the US
12 economy (42). In addition to the value captured in markets, nature provides many benefits

1 that do not appear in traditional economic statistics. Thousands of studies have attempted
2 to measure the many ways that nature benefits people and communities outside of
3 markets. This field—nonmarket valuation—focuses on benefits such as clean air, safe
4 drinking water, scenery, and thriving wildlife, but there have also been many applications of
5 nonmarket valuation applied to ecosystem services.

6 **Box 12.2. Value of Nature**

7 Examples of nonmarket valuation being applied to study the value of ecosystems,
8 ecosystem services, and natural resources include the following:

- 9 • **Wetlands:** On average, wetlands were valued at about \$915 per acre (1990 dollars)
10 (43,44). This value reflects both direct uses, such as flood protection, hazard
11 mitigation, and recreation, as well as nonuse values, including the importance
12 people place on the mere existence of wetlands that support wildlife and maintain
13 water quality, even if they never visit them.
- 14 • **Groundwater:** People place a high value on keeping groundwater clean and safe
15 (45,46). On average, households were willing to pay about \$369 per household
16 (1992 dollars) to prevent groundwater contamination. Willingness to pay increased
17 when specific health risks, such as nitrate pollution or cancer, were explicitly
18 mentioned.
- 19 • **Air quality:** Cleaner air generates value through improved health and visibility.
20 Households were willing to pay between \$31 and \$103 per household per year (1983
21 dollars) to reduce air pollution (10). People were also willing to pay about \$25 to
22 avoid a mild cough and \$77 to avoid a severe asthma attack (1995 dollars) (47).
23 Visibility itself has value: Visitors to national parks were willing to pay about \$5 per
24 household per month (1990 dollars) to preserve clear scenic views (48).
- 25 • **Outdoor recreation:** Nature-based activities such as hiking, fishing, and wildlife
26 watching generate significant value beyond their contribution to jobs and income
27 (49). People are willing to pay more for river-based recreation and for activities on
28 public lands than for similar activities on lakes. Big-game hunting, waterfowl
29 hunting, fishing, and rock climbing are among the activities with the highest
30 estimated values.
- 31 • **Water quality improvements:** Cleaner water has value both for direct uses—such
32 as drinking, swimming, or fishing—and for the assurance that ecosystems are
33 healthy. Estimated values vary widely depending on the extent of improvement and
34 the location studied (50).
- 35 • **Endangered species:** People value endangered species both for direct
36 experiences, such as seeing or studying them, and for simply knowing that they
37 exist. Species people can observe or interact with tend to have higher estimated
38 values than those they are unlikely to encounter. Birds, marine mammals, and
39 migratory fish tend to receive some of the highest valuations (12,51).

1 [END BOX 12.2 HERE]

2 Estimates of the nonmarket values of ecosystems, ecosystem services, and natural
3 resources can be used in policy evaluations such as cost–benefit analyses, where
4 decision-makers weigh the economic benefits of environmental protection against the
5 costs of action. However, the results of each study depend on its specific methods and
6 assumptions, which makes it difficult to combine findings into a single, nationwide total.
7 Aggregating results without adjustment could overstate the overall economic value of
8 nature, because it would ignore differences in income and the fact that people may
9 substitute one natural amenity for another, for example, visiting a nearby lake if access to a
10 river is lost. Even with these limitations, such studies make clear that the nonmarket value
11 of natural capital is substantial. In addition to the meta-analyses summarized in Box 12.2—
12 studies that combine results from many individual studies to show overall patterns—Box
13 12.3 highlights individual studies that also assess the nonmarket value of nature.

14 **Box 12.3. Value of Nature and Natural Spaces**

15 Access to nature delivers measurable health and economic benefits, beginning with
16 everyday healthcare costs. People living in the greenest neighborhoods spend about \$374
17 less per year on healthcare than those in the least green areas (52). At larger scales, even
18 modest increases in forest cover matter: Each 1% increase in county-level forest cover is
19 associated with \$4.32 less in Medicare spending per person per year, translating to an
20 estimated \$6–\$9 billion in annual Medicare savings nationwide (53).

21 Nature also plays a powerful role in preventing premature deaths. The loss of trees can
22 have immediate and deadly consequences: The death of 100 million ash trees due to the
23 emerald ash borer has been linked to more than 21,000 additional deaths (54,55).
24 Reaching 20% canopy in Denver could avert about 200 deaths annually, and 25% tree
25 canopy in Phoenix could help avoid 368 deaths per year (56).

26 Trees improve air quality by filtering air pollution, contributing to reduced illness and
27 premature mortality, generating estimated benefits of \$6.8 billion to more than \$40 billion
28 per year in the United States (2015 dollars) (57,58).

29 At the national level, these effects add up. The combined health benefits of urban nature—
30 ranging from reduced cardiovascular disease and improved birth outcomes to better
31 school performance and lower crime—are estimated at \$2.7–\$6.8 billion annually across
32 US metropolitan areas (59). These benefits are especially significant given that air pollution
33 is still linked to roughly 80,000–200,000 premature deaths per year in the United States
34 (60–62).

35 [END BOX 12.3 HERE]

1 Description of Evidence Base

2 The evidence supporting this Key Message is strong, diverse, and well established. Federal
3 datasets from the USDA Economic Research Service, USGS, NOAA, and the Bureau of
4 Economic Analysis (BEA) provide consistent and long-term measurements of land use,
5 water use, fisheries, and GDP contributions from natural resource sectors. These data are
6 widely regarded as authoritative, publicly accessible, and regularly updated. Economic
7 accounts of agriculture, forestry, fishing, and hunting are documented in BEA's GDP by
8 Industry tables, while the Outdoor Recreation Satellite Account (39) provides direct
9 evidence of employment and output associated with nature-based industries. The
10 literature base—spanning environmental economics, resource management, and
11 ecological science—shows high agreement that natural resources and ecosystem
12 functions are essential to the structure and stability of the US economy, leading to an
13 assessed confidence level of *well established* for this finding.

14 The evidence base also draws on several decades of nonmarket valuation (NMV) research
15 in environmental and resource economics. Thousands of studies have quantified the
16 economic value of ecosystem services that do not have explicit market prices, such as
17 water quality, air clarity, species protection, and recreation. These studies use stated-
18 preference and revealed-preference methods to estimate willingness to pay for
19 environmental quality (63). Meta-analyses confirm the consistency and directionality of
20 these findings, leading to the finding that it is *virtually certain* that nature provides
21 measurable and positive economic benefits even outside markets and that the value of
22 natural capital is understated. Federal and academic reviews, such as those by the EPA,
23 NOAA, and USDA, further validate NMV's methodological credibility. Studies by the EPA,
24 USGS, and USDA link declining water quality and soil erosion to reduced crop yields, higher
25 treatment costs, and lost recreational revenue. Public health research documents how air
26 pollution lowers labor productivity and increases medical expenditures.

27 Key uncertainties lie in linking biophysical and economic data to capture the full
28 contribution of natural capital. Although GDP and employment data are comprehensive,
29 they primarily track market activity not ecological condition. Disaggregating the precise
30 economic dependence of non-extractive industries (e.g., construction, manufacturing) on
31 ecosystem inputs remains challenging. Uncertainties arise from differences in valuation
32 methods, geographic scope, and underlying assumptions, which make it difficult to
33 produce consistent national totals of nonmarket value. Individual studies estimate
34 willingness to pay using context-specific data, leading to variation in reported values
35 across locations and population groups. These differences reflect methodological diversity
36 rather than disagreement about the existence of nonmarket value. The degree to which
37 improved ecosystem health translates into economic gain varies by region, sector, and
38 timeframe. Existing national accounts do not routinely measure ecosystem degradation or
39 recovery, limiting comprehensive assessment.

1 Because natural capital underpins essential production processes, changes in ecosystem
2 condition directly affect future economic stability and performance. Evidence from
3 agriculture, fisheries, forestry, energy, insurance, and public health shows that ecosystem
4 degradation increases costs, amplifies shocks, and reduces productivity, while intact
5 systems enhance resilience and reduce losses from extreme events. These observed
6 linkages support the well-established, forward-looking assessment that the long-term
7 prosperity of US communities, households, and industries depends on maintaining the
8 health and regenerative capacity of natural systems.

9 Key Message 12.2: Economic activities have degraded natural 10 systems in the US, reducing the benefits nature provides to people 11 and the economy

12 *Economic activities across the US have altered, depleted, and damaged natural systems*
13 *through land-use change, pollution, water use, overharvesting, and greenhouse gas*
14 *emissions (very well established). The impacts are not uniform but vary across regions, with*
15 *areas experiencing multiple, interacting stressors, placing them at risk of crossing*
16 *ecological thresholds beyond which recovery becomes difficult or irreversible (established*
17 *but incomplete). These impacts remain largely unmeasured, leading traditional economic*
18 *indicators to miss declines in ecosystem health and overstate economic progress by*
19 *ignoring losses in the natural systems that support long-term prosperity (virtually certain).*

20 State of Knowledge 12.2

21 Economic activities in the US have altered, depleted, and damaged natural systems in
22 ways that reduce the benefits those systems provide to people and the economy. These
23 impacts occur through land and water use, pollution, harvest pressure, greenhouse gas
24 emissions, and the transformation or fragmentation of habitats. In many places, multiple
25 stressors act at the same time, creating cumulative impacts that are larger than any single
26 pressure alone.

27 Land-use patterns have changed substantially over time. National land-cover analyses
28 show declines in forests, croplands, and pastures, accompanied by increases in barren,
29 scrub/shrub, and developed areas (21,64). These shifts reflect interacting forces such as
30 agricultural expansion, urban growth, and infrastructure development. The impacts vary
31 across regions—for example, forest loss is concentrated in parts of the Southeast,
32 grassland conversion is highest in the Northern Plains and Midwest, and rapid development
33 places particular pressure on coastal regions and metropolitan areas. As landscapes
34 change, habitat quality declines, ecological processes are disrupted, and the capacity of
35 natural systems to filter water, support wildlife, support plant life via soil health, and store
36 carbon is reduced.

37 Pressures on water resources show similar patterns. While national water consumption
38 has declined in some sectors, the thermoelectric power sector remains dominant in the

1 eastern United States, and irrigation is the major user in the West; together these two
2 sectors account for hundreds of billions of gallons per day (22,65,66). At the same time,
3 water use has risen in industries such as aquaculture and technology infrastructure (e.g.
4 data centers). Industrial and agricultural pollution continues to degrade water quality
5 through nutrient runoff, mining discharges, and livestock waste (66,67). The combined
6 effects of excessive water usage, rising temperatures, altered precipitation patterns, and
7 pollution can push freshwater ecosystems toward thresholds where they experience
8 sudden and sometimes severe declines in health and function (see Ch.7: Inland Waters for
9 more).

10 Air pollution from economic activity also harms natural systems. Emissions from
11 transportation, electric power generation, industry, and other sources reduce air quality
12 and contribute to the degradation of vegetation, soils, and water (68). Greenhouse gas
13 emissions add additional stress by driving changes in temperature, precipitation, and
14 extreme events. These climate-related impacts can trigger nonlinear ecological
15 responses—for example, forests shifting from carbon sinks to carbon sources following
16 repeated wildfire years, coral reefs rapidly declining after crossing heat thresholds, or
17 drought causing abrupt reductions in freshwater availability. Such threshold behaviors can
18 sharply reduce the ability of ecosystems to provide services such as flood control, carbon
19 storage, and storm buffering.

20 Many industries also place direct pressure on natural systems through harvesting of natural
21 resources. While a number of US fisheries and forestry operations are sustainably
22 managed, others have experienced overharvesting or land degradation that weakens
23 ecosystem resilience. For example, 18% (47 of 263) federally managed fish stocks were
24 overfished in 2023 (69), including some species—such as Atlantic cod—whose declines have
25 rearranged marine food webs, preventing their recovery and reshaping local fisheries (Ch.
26 6: Marine Ecosystems) (70).

27 Poorly designed roads, destructive harvesting techniques, and insufficient restoration
28 practices can increase erosion, reduce soil productivity, fragment habitat, and introduce
29 invasive species. When harvests exceed natural regeneration, systems may cross tipping
30 points that lead to rapid ecological decline.

31 These pressures can create tensions between industries that depend on intact
32 ecosystems—such as outdoor recreation and tourism—and those that rely on resource
33 extraction, including forestry, mining, or fishing (36,37). These trade-offs vary across
34 regions. In the Intermountain West and parts of the Northeast, for example, recreation-
35 based economies depend on scenic and undisturbed landscapes that are sensitive to
36 development or extraction. Decisions about land and water use can therefore benefit one
37 sector while diminishing opportunities for another.

38 Many of the environmental costs associated with economic activity—such as the loss of
39 clean water, healthy soils, or wildlife habitat—are not captured in national income and
40 product accounts. As a result, traditional measures of economic performance may

1 overstate progress by counting the benefits of extraction while overlooking the loss of
2 natural systems that support long-term well-being. Together, these lines of evidence show
3 that economic activities have significant, widespread, and often accelerating effects on
4 natural systems, reducing their ability to support the US economy and communities.

5 Description of Evidence Base

6 Evidence for this Key Message is extensive and consistent across land, water, air, and
7 resource sectors. National land-cover data show clear trends in forest loss, grassland
8 conversion, and expanding development (21,64). These patterns correspond with well-
9 documented drivers such as agricultural expansion, urban growth, and infrastructure
10 development, all of which reduce habitat quality and disrupt ecological processes. Water-
11 use data demonstrate similarly strong patterns. Irrigation and thermoelectric power
12 generation remain dominant users, collectively withdrawing hundreds of billions of gallons
13 per day (22,65).

14 Pollution studies show long-term degradation of water quality driven by nutrient runoff,
15 mining waste, and livestock operations (66,67). Air pollution and greenhouse gas emissions
16 from transportation, power generation, and industry also exert well-documented stresses
17 on natural systems (68). These stressors interact with land- and water-use pressures to
18 reduce the capacity of ecosystems to filter water, store carbon, and support wildlife.
19 Extraction-based industries provide additional evidence. Overharvesting, unsustainable
20 forestry practices, and poorly designed roads increase erosion, fragment habitats, and
21 reduce resilience. The existence of competing demands, such as recreation versus
22 extraction, has been documented in multiple regions (36,37).

23 Based on this evidence, it is *very well established* that the economic activities noted above
24 have altered, depleted, and damaged natural systems.

25 Land-cover analyses show that forest decline is concentrated in parts of the Southeast,
26 grassland conversion in the Midwest and Northern Plains, and development pressure in
27 coastal and urban regions (21,64). Water-use patterns also differ across regions:
28 Thermoelectric power dominates in the East while irrigation dominates in the West (22,65).
29 Pollution patterns exhibit similar variation, with nutrient runoff and livestock waste
30 affecting agricultural basins and mining discharges concentrated in specific regions
31 (66,67). The evidence also shows that many regions experience multiple stressors
32 simultaneously—for example, high temperatures combined with altered precipitation or
33 development layered on top of habitat fragmentation. These cumulative pressures lead to
34 ecological declines larger than those caused by any single stressor. Tension among
35 sectors, such as recreation and tourism versus extraction industries, further illustrates the
36 uneven spatial distribution of impacts (37,36). Collectively, this evidence, tempered by
37 some uncertainties described below, leads to a confidence assessment of *established but*
38 *incomplete* in the finding that there is substantial regional and sectoral variation in
39 environmental pressures and that interacting stressors put some regions at risk of crossing
40 critical thresholds.

1 Robust evidence with strong agreement leads to the conclusion that it is *virtually certain*
2 that extraction-driven gains (e.g., timber harvest, mineral extraction) appear as positive
3 economic output, while the associated ecological depletion does not appear as an
4 economic loss. International trade adds another dimension: Imports can be linked to
5 environmental degradation abroad, yet these impacts are also excluded from domestic
6 accounts (71,72).

7 Uncertainties in evidence relate primarily to quantifying how multiple stressors interact
8 across regions. While land-cover change, water use, and pollution are well measured
9 individually, combined effects on ecosystem functioning are more difficult to assess. Some
10 landscapes lack consistent monitoring, limiting the ability to track long-term declines or
11 recovery. Some regions, particularly mixed-use and rapidly changing areas, lack consistent
12 monitoring of ecological condition. While the direction of impacts is well understood,
13 consistent national metrics for valuing degraded natural systems remain limited.

14 Key Message 12.3: Nature-friendly business practices to preserve 15 natural capital are emerging but face barriers

16 *There are multiple emerging efforts toward developing transparent, nature-friendly*
17 *approaches to business practices and economic activities, even beyond sectors most*
18 *reliant on nature (well established). These approaches face significant barriers to increased*
19 *adoption (well established). Despite these barriers, there is evidence of growing interest*
20 *among business and society to accelerate progress toward a more reciprocal and resilient*
21 *nature–economy relationship (established but incomplete).*

22 State of Knowledge 12.3

23 The negative impacts of economic activities on nature can in part be mitigated by adopting
24 **nature-friendly business practices**, defined here as those practices that have lower
25 impact on nature compared to conventional practices. Many of these nature-friendly
26 practices focus on addressing climate change through emissions reduction, carbon
27 removal, and adaptation, reflecting the bidirectional relationship in which climate change
28 affects nature and nature, in turn, affects climate change. Some companies in forestry,
29 agriculture, mining, fisheries, infrastructure, and outdoor tourism have made efforts in this
30 direction, driven by both regulatory requirements and voluntary initiatives.

31 In the regulatory domain, different industries must adhere to various rules regarding
32 minimizing negative environmental impacts. For example:

- 33 • Sustainable forest management practices are typically part of state-level policies
34 that guide forestry companies' actions.
- 35 • Farmers must comply with restrictions on pesticide usage, implement soil
36 conservation measures, and adhere to water management guidelines to safeguard
37 ecosystems.

- 1 • Fisheries must adhere to the catch levels set by the federal fishery management
2 council for most commercially and many recreationally caught species, as well as
3 measures to mitigate impacts on habitats or non-target species.
- 4 • Building infrastructure and other development projects that affect wetlands or
5 habitat for protected species are often subject to compensatory mitigation
6 requirements under federal and state permitting systems, obliging project
7 developers to restore, create, or permanently protect habitats to offset ecological
8 damage. These requirements have given rise to conservation and mitigation banking
9 markets, where restored or protected habitats generate credits that developers can
10 purchase, particularly in California, Washington, Florida, Michigan, and Oregon.
- 11 • Outdoor tourism adheres to regulatory caps on visitor numbers in ecologically
12 sensitive areas to balance tourism impacts with nature preservation.

13 More broadly, economy-wide regulatory measures exist to protect nature, including laws
14 such as the Lacey Act (a federal law that prohibits buying, selling or transporting illegally
15 sourced fish, wildlife, or plants); Clean Water Act; Dingell–Johnson Act (a law that funds
16 state fish and wildlife programs to restore, manage, and conserve sport fish and aquatic
17 habitats); Magnuson–Stevens Fishery Conservation and Management Act; Migratory Bird
18 Treaty Act; National Wildlife Refuge System Act; Land and Water Conservation Fund Act;
19 Federal Insecticide, Fungicide and Rodenticide Act (which gives the EPA authority to
20 regulate pesticides to protect human health and the environment); and the Farm Bill (which
21 includes voluntary conservation programs to support farmers in improving soil health,
22 water quality and wildlife habitats). However, the evidence is mixed regarding how
23 effectively such regulations alone can protect ecosystems from negative impacts driven by
24 economic activity (73).

25 Many businesses have adopted voluntary measures—often in response to market or
26 stakeholder pressures — to address the impact of their operations and supply chains on
27 nature (74). These measures often involve sector-wide, multi-stakeholder initiatives that
28 can become industry norms. Prominent initiatives include the Forest Stewardship Council,
29 Marine Stewardship Council, Field to Market, Better Cotton Initiative, Roundtable on
30 Sustainable Palm Oil, and Zero Emission Maritime Buyers Alliance. More localized,
31 voluntary actions include cover-cropping and no-till or reduced-till farming to improve soil
32 health on individual farms (75), wildlife corridors and eco-sensitive designs for roads and
33 bridges (76), and community partnerships to preserve/restore natural ecosystems (77). For
34 some of these initiatives, businesses engage Indigenous and local communities who
35 steward landscapes and conserve biodiversity, but these efforts often remain limited in
36 scope and scale. Despite the apparent proliferation of voluntary initiatives and
37 improvements in business practices (78), their overall effectiveness in achieving desired
38 ecological outcomes remains uncertain (79–81).

39 Financial institutions are also showing concern for nature, and innovative nature finance
40 mechanisms have begun to emerge: carbon and biodiversity credits, the incorporation of

1 the hazard mitigation benefits of nature into risk-transfer models (see Ch. 14: Risk), and
2 even insurance linked to natural assets directly (Box 12.4).

3 **Box 12.4. Insuring a Coral Reef in Hawai'i**

4 US coral reefs significantly contribute to the economy through services such as
5 ecotourism, habitat and food provisioning, and protection of coastal infrastructure
6 protection (82–84). Despite these benefits, funding to maintain reef health is often
7 insufficient.

8 In 2022, Hawai'i became the first US state to implement a new approach: directly insuring
9 the reef (85). A partnership between The Nature Conservancy, private insurers, and the
10 state's Department of Land and Natural Resources, the policy uses a form of insurance
11 known as parametric insurance, which triggers an immediate payout when specific
12 conditions are met, such as wind speeds exceeding a certain threshold during a storm.
13 This payout is used for actions such as debris removal or reattaching broken coral, which, if
14 done quickly, supports recovery of the reef. Although parametric insurance for natural
15 assets has limitations (86,87), using insurance to pay for protecting nature is an innovative
16 approach to ensuring the viability of these important ecosystems.

17 The insurance sector can also support nature in several other ways: insuring additional
18 habitats, incentivizing nature restoration through property insurance discounts, and
19 lowering the risk to investors of funding mechanisms (such as "blue bonds") for projects
20 with positive environmental impact (86). Insurance can also mitigate risks in nature-
21 dependent economic sectors, such as insuring against crop failures or revenue loss,
22 although this can introduce unintended consequences and implementation may be
23 challenging for some resources (88,89).

24 [END BOX 12.4 HERE]

25 **Barriers to Wider Adoption of Nature-Friendly Business Practices**

26 A number of barriers hinder the broader adoption of nature-friendly business practices.
27 One key challenge is the corporate focus on short-term profitability and the prioritization of
28 shareholder value over other stakeholder considerations (90). Indeed, traditional corporate
29 performance metrics such as profitability and stock price have not taken into consideration
30 a company's impacts and dependencies on nature.

31 A second challenge is that consumers have not shown a strong willingness to support
32 companies for nature-friendly business practices that often appeal to niche segments and
33 may mean consumers pay higher prices (91).

34 A third key barrier is that the environmental impacts of business activities have historically
35 been treated as externalities—costs borne by society and the environment rather than by
36 businesses (92). This disconnect has allowed companies to prioritize financial
37 performance over nature protection. Also, nature-protecting regulations also remain weak,

1 and a significant time lag exists in adapting approaches or updating regulations (93). Efforts
2 to establish more stringent regulations are also undermined by industry pushback (94),
3 particularly in extractive and polluting industries (95). Varying regulatory efforts are also
4 often misaligned. For example, Farm Bill legislation balances multiple policy goals, which
5 can lead to conflicting incentives for farmers where production-focused incentives may
6 financially outweigh incentives for conservation.

7 Fourth, companies operating at national or global scales often struggle to engage
8 effectively with Indigenous and local communities and other small-scale producers, even
9 though such local engagement is essential for shifting from extractive to regenerative
10 resource use. While organizations such as the Accountability Framework Initiative (96), the
11 Taskforce on Nature-related Financial Disclosures (97), and Conservation International (98)
12 offer guidance on engagement, persistent challenges around power imbalances, cultural
13 alignment, scalability across complex supply chains, and measuring costs and impacts
14 continue to limit widespread adoption. Even for companies genuinely committed to
15 transformative practices, practical challenges remain, including difficulties in changing
16 supply chains (99) due in part to reluctance or inability of supply-chain partners to
17 cooperate. Overcoming these and other challenges requires operational, economic,
18 technological, and cultural shifts, which tend to occur at a slow pace.

19 While many adoption barriers are general, some are sector-specific. In agriculture,
20 approximately 39% of US farmland is leased (100), which can discourage adoption of
21 conservation practices that require multiyear investments to deliver benefits (e.g.,
22 improved soil health), particularly if land lease renewal is uncertain (101). In addition, the
23 reversibility of practices such as no-till agriculture—where soil carbon gains can be lost if
24 management changes—reduces benefit durability and further constrains adoption.

25 Emerging Trends in Nature-Friendly Business Practices

26 Despite challenges, movement toward more nature-friendly business practices is
27 occurring. Companies are increasingly aware of the need to protect their long-term ability
28 to access these essential nature-based inputs (102). For example, the growing footprint of
29 data centers is raising the technology sector's interest in protecting water-related
30 resources—although this interest has arisen alongside increasing concerns about
31 community access to those same resources, impacts on water quality, and drawdown in
32 drought-prone areas.

33 One key trend is the recent emergence of reporting frameworks designed to enhance
34 transparency in how companies measure and account for their corporate sustainability
35 actions, sometimes referred to as environmental, social, and governance performance.
36 While numerous reporting frameworks for sustainability are emerging globally, the rise of
37 nature-related corporate disclosures is particularly significant (Box 12.5) Research shows
38 that mandatory reporting of environmental impacts could lead to net decreases in
39 emissions (103,104). However, without independent verification, the risk of selective

1 reporting could result in **greenwashing** (105) or obscuring real environmental impacts
2 (106).

3 **Box 12.5. Major Sustainability Reporting Frameworks**

4 The following frameworks, also referred to as protocols, guide companies' efforts to
5 disclose their impacts and dependencies on nature.

- 6 • **Global Reporting Initiative (GRI):** The GRI, the most widely used framework, offers
7 established reporting protocols to guide companies' identification of risks and
8 opportunities related to biodiversity loss, water scarcity, pollution, and other
9 environmental factors that directly or indirectly affect their operations. See
10 www.globalreporting.org/
- 11 • **Climate Disclosure Project (CDP):** The CDP operates a global disclosure system
12 that enables companies to measure, manage, and report their environmental
13 impacts, with a particular focus on climate change, water, forests, plastics and
14 biodiversity. See www.cdp.net/en
- 15 • **Corporate Sustainability Reporting Directive (CSRD):** The CSRD is a European
16 Union directive to increase transparency and quality of environmental, social, and
17 governance reporting for large companies, including US companies with a
18 substantial European footprint. See www.csrdreadiness.com/
- 19 • **Taskforce on Nature-related Financial Disclosures (TNFD):** The TNFD aims to
20 help businesses assess and report on their nature-related risks and dependencies,
21 drawing attention to how natural capital affects financial stability. See
22 <https://tnfd.global/>
- 23 • **Science Based Targets Network (SBTN):** The SBTN provides a science-driven
24 framework that helps companies assess their environmental impacts and set
25 measurable targets to reduce harm and enhance positive outcomes, aligning with
26 the climate goals of its sister organization, the Science Based Targets Initiative
27 (SBTI). See <https://sciencebasedtargetsnetwork.org/>
- 28 • **Natural Capital Protocol (NCP):** This protocol provides a standardized framework
29 for businesses to measure and quantify their impacts and dependencies on natural
30 capital. See [https://capitalscoalition.org/capitals-approach/natural-capital-
31 protocol/](https://capitalscoalition.org/capitals-approach/natural-capital-protocol/)
- 32 • **Integrated Reporting Framework:** This framework, part of the International
33 Financial Reporting Standards Foundation, integrates financial and nonfinancial
34 factors (e.g., natural capital) to connect environmental stewardship with financial
35 performance and sustainability. See [www.ifrs.org/issued-standards/integrated-
36 reporting/](http://www.ifrs.org/issued-standards/integrated-reporting/)

37 The sheer number of frameworks makes it difficult for a company to know which framework
38 might be best for it to use. Moreover, although many US companies have begun using these

1 frameworks, adoption remains far lower than in other regions, particularly the European
2 Union (74). Moreover, it is unclear whether the evolution of reporting frameworks is actually
3 driving more nature-friendly business practices.

4 [END BOX 12.5 HERE]

5 In addition to these international reporting frameworks, the United States has its own
6 reporting mandates. In 2024 the US Securities and Exchange Commission introduced
7 mandates for sustainability reporting for qualifying companies, including disclosures on
8 the financial impacts of weather events and natural conditions (e.g., hurricanes, flooding,
9 sea level rise). The Greenhouse Gas Reporting Program (GHGRP), administered by the EPA,
10 in 2010 began requiring reporting of GHG data under specific conditions and for specific
11 amounts; however, the agriculture sector and emissions from energy consumption were
12 excluded.

13 A second key trend is the emergence of voluntary carbon markets (VCMs)—decentralized
14 markets where actors can buy or sell carbon credits to offset emissions. Because the
15 GHGRP mandates disclosure but not emissions reductions, VCMs provide a voluntary
16 mechanism for firms to compensate for emissions beyond regulatory requirements. After
17 surging in 2021, VCM activity declined in 2023 amid growing concerns about credit quality
18 and effectiveness, alongside falling carbon prices.

19 Third, and related to emissions mitigation, is the emergence of natural or **nature-based**
20 **climate solutions (NbCS)**, which aim to address climate change while protecting or
21 restoring ecosystems (see Ch.10: Climate Change). NbCS are most prominent in forestry
22 and agriculture, where carbon durably stored in forests, soils, or other ecosystem
23 components can be intentionally increased through targeted practices, such as soil carbon
24 enhancement via altered tillage or cover-cropping, and forest management approaches
25 that increase overall carbon stocks. Alternatively, companies that protect or restore
26 ecosystems can also earn carbon credits for avoided emissions, such as through actions
27 that limit deforestation. While some NbCS—such as conserving native grasslands or
28 forests—have clear mitigation potential, concerns about their overall effectiveness persist
29 (107,108). At present, NbCS are one of the limited set of science-based carbon removal
30 approaches that can be supported at scale through carbon markets and related economic
31 frameworks.

32 VCMs have an important role to play in the development of reliable NbCS. However,
33 crediting NbCS projects that don't deliver real climate benefits diverts climate-targeted
34 resources away from effective outcomes and can entrench ineffective protocols into the
35 market. Although efforts are underway to improve NbCS governance, transaction
36 processes, and transparency, an effective national regulatory framework to govern VCMs
37 may improve the effectiveness of such programs (109). VCMs can encourage stronger
38 NbCS actions by continuing to improve and utilize crediting, monitoring, reporting, and
39 verification procedures that ensure true climate benefits from NbCS in addition to the
40 economic benefits to the buyers and sellers.

1 A fourth trend in nature-friendly business practices is seen in conservation and restoration-
2 focused efforts that simultaneously advance economic development and nature
3 protection. Often dubbed the restoration economy, these initiatives involve coordinated
4 efforts to restore, rehabilitate, and regenerate natural ecosystems. Some of these
5 initiatives, such as coastal forest restoration, can enhance disaster preparedness (110)
6 and thus mitigate impacts of climate change.

7 A fifth trend is the emergence of new approaches to benefit nature, such as enhanced rock
8 weathering. Farmlands with degraded soils can see benefits from the application of
9 weathering substrate, such as crushed basalt rock, which converts and sequesters
10 atmospheric CO₂ and increases farm economic output (111,112). Although the majority of
11 the public is still unaware of this approach (113), industry efforts are expanding, such as
12 organizing into consortia (114). The magnitude of potential climate benefits is uncertain
13 because it depends on accurate measurement, monitoring, reporting, and verification, as
14 well as on the specific geographies and feedstocks involved (115). Another example of an
15 innovation that benefits nature and may also offer climate benefits is the use of biochar, a
16 charcoal-like material made by heating wood, agricultural waste, or manure as a soil
17 amendment; biochar can reduce methane and nitrous oxide while also increasing soil
18 carbon and productivity (116). New approaches are also being considered and developed
19 for multiple protocols in the VCM.

20 Despite the appeal of these new approaches to benefit nature, there is also a risk that they
21 could inadvertently trigger undesirable outcomes. For example, bioplastics (materials
22 derived from organic, renewable sources like plants as an alternative to conventional
23 petroleum-based plastics, not all of which are biodegradable) and third-generation biofuels
24 (derived from algae and other non-food sources to create fuels such as biodiesel,
25 bioethanol, and biogas) consume significant amounts of water and can drive land
26 conversion and associated carbon loss from disturbed ecosystems, potentially
27 undermining climate benefits (117,118). Climate change mitigation measures can thus be
28 nature-harming, leading to what is termed the green–green dilemma (119), with unintended
29 increases in GHG emissions due to land-use change. This trade-off is inherent in most
30 activities, and managing relative benefits and harms, and correctly measuring (and if
31 possible mitigating) the impacts, is key to ensuring nature-friendly or nature-beneficial
32 business practices.

33 Enhancing the resilience and sustainability of nature–economy relationships involves
34 complex decisions and trade-offs. Voluntary corporate efforts may fall short, markets may
35 be inefficient, regulations may lack effectiveness, and commonly touted win–win
36 approaches may amount to little more than positive rhetoric (120). However, a growing list
37 of pilot initiatives provides some encouragement. And while the path forward is uncertain,
38 creative combinations of technological, policy, institutional, and financial innovations—
39 alongside stringent regulations—have the potential to help build a reciprocal and resilient
40 relationship between the economy and nature. However, a growing list of pilot initiatives
41 provides some encouragement. And while the path forward is uncertain, creative

1 combinations of technological, policy, institutional, and financial innovations—alongside
2 effective regulations—have the potential to help build a reciprocal and resilient
3 relationship between the economy and nature. Box 12.6 offers insight into one of these re-
4 imagined relationships, the circular economy.

5 **Box 12.6. Imagining a Resilient Relationship Between the Economy and Nature**

6 An economy that thrives in a symbiotic relationship with nature, rather than at the expense
7 of nature, requires rethinking the context within which business processes operate (Figure
8 12.3). A traditional linear view of the nature–economy relationship assumes that nature
9 provides inputs and resources that are processed industrially—with associated waste
10 streams and environmental impacts—to create outputs (goods). These goods are then
11 transported and sold to customers who use them and, when they are depleted (used up or
12 worn out), discard what remains, often contributing to landfill waste.

13 **Figure 12.3. Evolving Business Views of Nature**



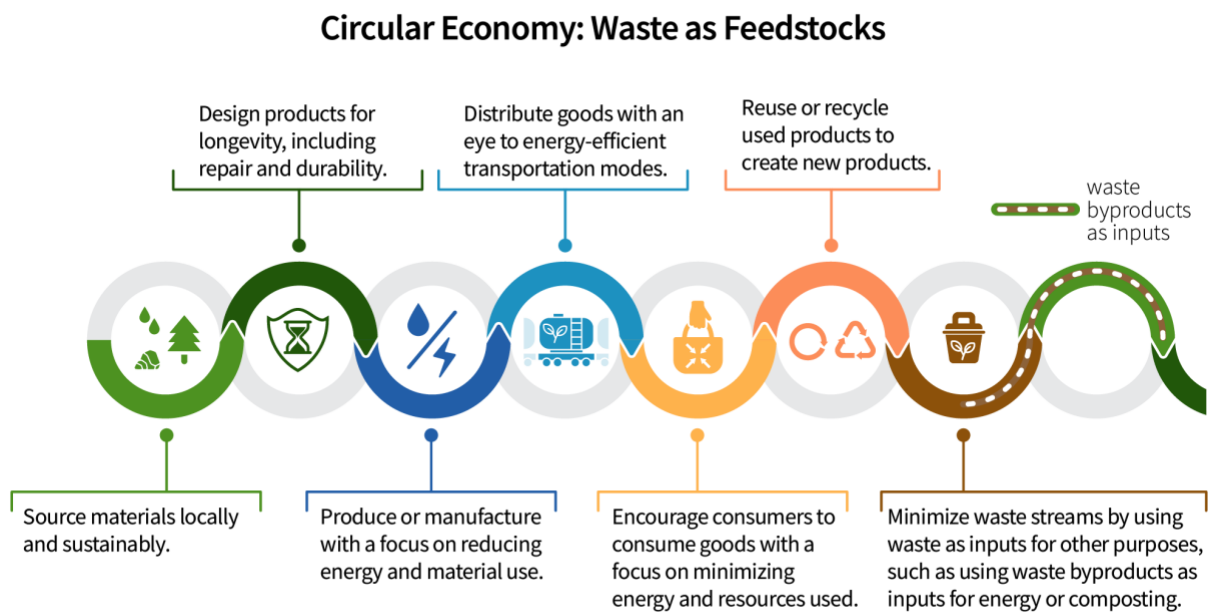
15 **To contrast the extractive, profit-driven historical relationship between the economy**
16 **and nature with a modern, regenerative model in which businesses actively sustain**
17 **and restore the ecosystems on which they depend.**

18 *(left) The Historical Relationship: Traditionally, nature provided the raw materials and*
19 *inputs necessary for economic function. However, the extraction and conversion of these*
20 *resources into finished products often prioritized business profits at the expense of*
21 *ecological health (right) A Modern Synthesis: A new perspective reveals the potential for a*
22 *symbiotic relationship. In this model, businesses value ecosystem services and natural*
23 *capital, practice sustainable harvesting, and utilize emerging technologies to minimize*
24 *environmental impact. By proactively mitigating externalities, such as air, water, and soil*

1 *pollution, industry can transition from being damaging to becoming nature-positive. (left)*
 2 *Adapted from Mohr et al. 2016 (122); (right).*

3 One alternative approach is dubbed the **circular economy**, in which business processes
 4 are designed to eliminate waste and pollution in the processes themselves and to keep
 5 materials and products in use in order to ensure that natural systems are regenerated
 6 rather than degraded (Figure 12.4). Other perspectives, such as a sustainable economy
 7 (121), a restorative and regenerative economy (122), and nature-positive (net-positive)
 8 business views (123,124), also offer a new approach to the nature–economy dynamic.

9 **Figure 12.4. The Circular Economy Model**



10

11 **The circular economy is designed to ensure that the full business cycle, from sourcing**
 12 **inputs to managing waste streams, has minimal impacts on nature.**

13 *The circular economy relies on principles such as keeping materials and products in use*
 14 *and ensuring that natural systems are regenerated rather than degraded. Figure original to*
 15 *The Nature Record.*

16 As shown in Figure 12.4, key principles of the circular economy include the following:

- 17 1. Source materials locally and sustainably.
- 18 2. Design products for longevity, including repair and durability.
- 19 3. Produce or manufacture with a focus on reducing energy and material use.
- 20 4. Distribute with an eye to energy-efficient transportation modes.
- 21 5. Consume with a focus on minimizing energy and resources used.

- 1 6. Reuse or recycle, relying on used products to create new products.
- 2 7. Manage waste to be used as inputs for other purposes and to minimize waste
- 3 streams, such as using waste by-products as inputs for energy or composting.

4 These seven principles offer a different approach to designing, producing, and consuming
5 goods, in which the whole economy prioritizes environmental sustainability and resource
6 efficiency. Moreover, collectively these principles aim to create a regenerative system that
7 benefits both the environment and the economy, rather than exhausting one to the
8 detriment of the other.

9 [END BOX 12.6 HERE]

10 Description of Evidence Base

11 Evidence for this key message comes from a broad and growing body of research and
12 documentation on corporate sustainability initiatives to be more environmentally friendly,
13 environmental regulation, and voluntary market mechanisms. The narrative draws on
14 diverse sources: federal policy frameworks, sectoral certifications, and voluntary
15 sustainability alliances across industries. These sources demonstrate that efforts to
16 reduce the ecological impact of business activities are already established across a wide
17 variety of industries. Further evidence of businesses' increased attention to its impacts and
18 dependencies on nature is provided by the expansion of sustainability reporting and
19 disclosure frameworks. The emergence of nature-based finance mechanisms further
20 illustrates how companies are beginning to internalize nature-related risks and
21 dependencies. These examples show moderate to high consistency across sources in
22 documenting active experimentation and adoption of nature-oriented business practices,
23 resulting in an assessed confidence level of *well established* for this finding.

24 Empirical studies, policy analyses, and business sustainability assessments identify
25 recurring obstacles to widespread adoption of nature-friendly practices. The literature
26 consistently cites institutional, economic, and cultural barriers, including the prioritization
27 of short-term profitability, weak market incentives, fragmented regulations, and consumer
28 reluctance to pay price premiums for sustainable products. The narrative references
29 examples from multiple sectors: regulatory misalignment in agriculture (e.g., competing
30 Farm Bill incentives), industry resistance in extractive sectors, and evidence of symbolic or
31 greenwashed actions where market or regulatory pressure is weak. Peer-reviewed studies
32 confirm that while many voluntary initiatives exist, their implementation and scaling are
33 often constrained by complex supply chains, insufficient monitoring, uncertain financial
34 benefits, and inconsistent performance metrics. Thus, the finding that there are significant
35 barriers to adoption is assessed to be *well established*.

36 While evidence of emerging practices is widespread, variation in quality, scale, and
37 verification remains substantial. Most corporate initiatives are pilot programs or limited in
38 scope, and their outcomes have not been systematically evaluated. Reporting frameworks
39 differ in metrics, scope, and enforcement, making cross-company comparisons difficult.

1 Empirical data on the environmental effectiveness of these measures—beyond self-
2 reporting—are limited. While evidence on barriers is abundant, studies on what works and
3 why remain limited. Few studies provide longitudinal evidence linking corporate behavior
4 changes to measurable improvements in ecological indicators such as biodiversity, soil, or
5 water quality. As a result, the evidence for the finding that there is growing interest across
6 business and society to move toward a more reciprocal and resilient relationship between
7 nature and economy is assessed to be *established but incomplete*.

8 Environmental Justice and Equity Highlights

9 Economic systems shape the distribution of benefits and burden by determining how
10 resources and wealth are allocated (125). While nature contributes substantially to the US
11 economy, the benefits are not equally dispersed across populations. Disparities in
12 environmental quality, access to natural spaces, as well as inequities embedded in
13 estimating the economic value of nature raise significant concerns for environmental
14 justice, equity, and resource decision-making. The following sections cover these issues
15 and the current research findings.

16 Environmental Burdens

17 More than four decades of research has demonstrated that communities of color and
18 economically disadvantaged communities face a disproportionate exposure to
19 environmental burdens (126,127). Across a range of exposure metrics, spatial scales, and
20 proximity measures, studies consistently and repeatedly find that environmental burdens
21 are inequitably distributed along lines of race and income (128–130).

22 Understanding the drivers of these findings is fundamental to addressing environmental
23 injustices through economics and policy. Research reveals two distinct but related
24 mechanisms. First, there is evidence that polluting facilities are systematically sited in
25 communities that are already vulnerable (131,132); preventive zoning reforms could
26 counter discriminatory siting practices. Second, sorting models show that income-
27 constrained individuals have limited residential choices, which often lead to their homes
28 being concentrated in polluted or higher-risk areas (130,133,134). Both of these factors
29 could be addressed through rezoning and a longer-term structural approach to tackling
30 issues associated with income inequality.

31 Access to Nature

32 Access to nature has also been shown to be determined by socioeconomic factors. Urban
33 green spaces such as parks, tree canopies, and other natural areas are unevenly
34 distributed across income levels and racial demographics, with greener spaces often
35 concentrated in wealthier neighborhoods (135–139), suggesting systematic barriers to
36 equitable access to natural environments. This inequitable distribution highlights that
37 access to nature functions as an economic good. As natural assets help reduce
38 environmental risks (such as flooding) and influence health outcomes (Ch. 14: Risk and

1 Ch. 13: Health and Well-Being), income disparities can further exacerbate social inequality,
2 given strong evidence that higher real estate prices are associated with proximity to
3 nature—a phenomenon known as environmental gentrification (140,141).

4 Biases in Economic Value Estimates

5 Methods of estimating economic value, discussed in Key Message 12.1, can also reinforce
6 social, economic, and racial inequities (142). For example, wealth—which is correlated
7 with race—shapes demand for environmental goods, and thus individual willingness-to-
8 pay or willingness-to-accept estimates may also vary systematically by race. Experiences
9 or fears of harassment, violence, and exclusion among historically marginalized groups
10 may distort welfare estimates and artificially lower the calculated value of recreational
11 sites located near communities of color (143–145). When such values are aggregated,
12 these disparities can become embedded in decision-making processes, thereby rendering
13 environmental actions that benefit disadvantaged communities less economically
14 valuable in cost–benefit analyses (146). Methodological approaches to mitigate these
15 biases, such as including unequal impact measures or weighting estimates from
16 disadvantaged communities by applying equity weights in cost–benefit analyses, are
17 emerging but remain far from standard practice.

18 Inequity in Resource Decision-Making

19 Documented inequities—often income-driven and therefore correlated with race and
20 gender—affect who can access or participate in decision-making processes regarding
21 natural resources (147). These venues, in turn, make critical resource allocation decisions
22 that directly influence local economies and resource industry participants.

23 Emerging Issues

24 Bias in Nonmarket Valuation

25 Potential biases in nonmarket valuation estimates—discussed in the Environmental Justice
26 and Equity Highlights section—could have significant implications for the accuracy,
27 interpretation, and policy use of these estimates. These biases have only recently been
28 recognized, and both research and methodological solutions remain nascent (142). The US
29 Federal Government provides guidance for incorporating distributional effects across
30 populations in benefit–cost analyses (148–150).

31 Climate Adaptation and Economic Trajectories

32 How the US mitigates and adapts to climate change will profoundly shape the Nation’s
33 economic trajectory. This is true across all sectors but is especially consequential for
34 nature-dependent industries. While projections of economic costs resulting from climate
35 change exist, these impacts and resulting human responses, including adaptation, inject
36 considerable uncertainty into those projections. Incentives to promote new, nature-friendly

1 economic opportunities compared to historically entrenched systems that may be more
2 nature-harmful (and any associated subsidies/incentives) are subject to political
3 calculations. Furthermore, the resilience of communities connected to these sectors—and
4 the extent to which adaptive strategies that support resource producers also align with the
5 needs of downstream industries—remains insufficiently understood (151).

6 Technology and Environmental Footprints

7 The technology sector is the fastest growing segment of the US economy (152), but its high
8 energy demand and environmental footprint—from hardware manufacturing to
9 infrastructure such as data centers—are not fully understood (153). Demands of company
10 inputs for production for these raw materials such as minerals, energy, water, and land may
11 generate access conflicts, while associated environmental impacts could affect human
12 health directly or through diminished ecosystem services (8,29). The extent to which such
13 impacts may impact labor productivity, and intersect with other fast-growing sectors such
14 as healthcare services, remains uncertain.

15 Durability and Effectiveness of Voluntary Initiatives

16 Several recent exits by large companies have raised questions about the durability and
17 effectiveness of major voluntary climate and environmental initiatives. It remains unclear
18 whether such initiatives meaningfully improve environmental outcomes or primarily serve
19 as buffers that deflect pressure for stronger regulation. Evidence suggests that voluntary
20 environmental initiatives often achieve limited pollution abatement compared to
21 mandatory approaches (154). Moreover, voluntary corporate measures can reduce public
22 support for new environmental regulation, especially when oversight is weak (155). If these
23 initiatives do produce positive environmental gains, then withdrawal likely results in
24 corresponding losses in nature's inputs and services. In the current sociopolitical
25 environment, efforts to design markets that operate in harmony with nature appear more
26 precarious than at any point in recent memory.

27 Business Education and Leadership Training

28 How future corporate leaders are trained will profoundly shape how the economy engages
29 with nature. Even climate change–related material has yet to be fully mainstreamed in
30 most college business curricula, despite nudges from accreditation bodies such as the
31 Association to Advance Collegiate Schools of Business and from global agencies that
32 score and rank university business programs. Where coverage of the nature–business
33 relationship does exist, curricula typically focus on compliance, risk management, or
34 reputational issues rather than on understanding the deeper interdependencies between
35 nature and the economy. Core courses in finance, strategy, and operations rarely address
36 how ecological systems underpin economic activity. As a result, many business managers
37 continue to be educated to manage the economy as if nature were external to it.
38 Embedding nature–economy relations into business education represents both a pressing
39 challenge and an ecological imperative.

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