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# Forests and ecosystem services: Nature's invisible economy

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Forests are primarily valued for the resources and products that are evident and can be extracted, such as wood, fuelwood, and fruits, as well as for their aesthetic value. However, their most vital contributions are made without the price tags, or market transactions. These benefits, termed ecosystem services, represent the invisible economy, the provider of clean water and food, the reduction of disaster risks, and the source of human well-being. The loss of forests does not immediately wipe out this economy; instead, it takes time for the effects to be felt in floods, droughts, declining crop yields, heat stress, and rising public costs. This article elaborates on the functioning of forests as natural capital, presents the data supporting their ecosystem services, and argues that forest conservation is economically necessary rather than environmentally luxurious.

**Keywords:** *forest ecosystem services, natural capital, climate regulation, biodiversity conservation, sustainable development, environmental economics*

## Introduction

Ecosystem services are the benefits people derive from ecosystems. The globally formalized concept, as outlined in the Millennium Ecosystem Assessment, classified services into four broad categories, as illustrated in Figure 1 and listed in Table 1.

- Provisioning services, material products such as food, fuel, timber, and medicines.
- Regulating services, e.g., climate regulation, water purification, flood control, and disease regulation.
- Supporting services, e.g., soil formation, nutrient cycling, and primary production, provide the basis of all other services.
- Cultural services, e.g., spiritual values, recreation, education, and cultural identity.

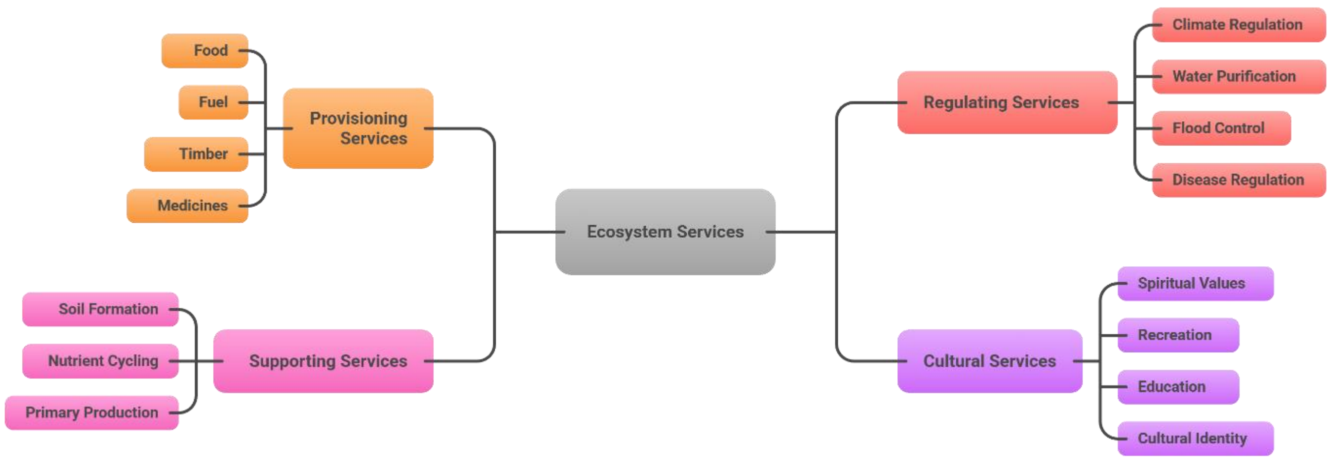


**Figure 1. Ecosystem services from forests**

**The size of the forest economy**

Forests cover about 4.14 billion hectares of land worldwide, about 31% of Earth's land surface (Basilashvili, 2021; Keenan et al., 2015). The Food and Agriculture Organization of the United Nations (FAO) reported that between 1990 and 2020, the world lost about 420 million hectares of forest, mainly due to conversion to farmland and infrastructure (FAO, 2020; Kumar et al., 2022). Even now, net deforestation is still occurring at about 10 million hectares per year (from 2015 to 2020). Each hectare lost means that ecosystem services like carbon storage, water regulation, and support for biodiversity that would have helped people for decades or even centuries are lost.

**Provisioning services: forests as biological storage spaces**

Forests provide significant benefits and goods that directly help people make a living:

- Food and nutrition: Wild fruits, nuts, mushrooms, honey, leafy greens, and bushmeat are essential for food security for millions of people, predominantly Indigenous and forest-dependent communities (Das & Mallick, 2024).

- Materials and energy: Wood, bamboo, rattan, fibers, and fuelwood are all needed for homes, tools, crafts, and home energy.

- Medicines and genetic resources: Many modern medicines come from plants, fungi, or microorganisms that grow in forests, or from traditional ways of knowing how to use them (Kumar, 2022).

Forests also store genetic diversity that is used to breed and adapt crops. Provisioning services are the most obvious, but they account for only a small part of the total economic value of forests.

**Regulating services: forests as natural infrastructure**

**Regulating the weather and storing carbon**

Forests play a crucial role in the global carbon cycle (Dinesh et al., 2025). Through photosynthesis, trees take in carbon dioxide ($CO_2$) and store it in biomass and soil. Recent FAO GFRA 2025 data show that global forest carbon stocks are estimated at around 714 gigatonnes (Gt), though trends vary regionally. (FAO, 2025). Natural systems are still protecting people from even faster global-scale climate change. The data from the Global Carbon Budget (GCB) 2025, building on IPCC assessments, shows land and ocean sinks absorbing about 50% (Lee et al., 2023) of annual human $CO_2$ emissions, with ocean about 10-11 Gt $CO_2$/yr and land about 11-12 Gt $CO_2$/yr over 2015-2024. Forests constitute a major component of the terrestrial carbon sink. Without forests, the amount of $CO_2$ in the air and the temperature of the Earth would rise much faster.

**Regulating and cleaning up water**

Forests function as a natural green infrastructure. Trees intercept rainfall, roots help water get into the soil, and forest soils filter out pollutants and chemicals. As a result, watersheds with trees usually provide cleaner, more reliable water than those without trees. The Catskill-Delaware watershed in New York City is a well-known example. The city chose to protect and manage forested catchments rather than build an expensive filtration plant. This method has saved billions of dollars in treatment costs that would have been needed, and it has also helped rural economies and protected biodiversity. The case shows that maintaining forests can be cheaper than building alternatives (Lamsal et al., 2024).

**Reducing the risk of floods, erosion, and disasters**

Forests help to reduce floods, landslides, and erosion by stabilizing soils and slowing runoff. Mangrove forests in coastal areas protect against storms and waves by acting as living barriers. Studies in science show that mangroves can reduce wave height by 20% to 90%, depending on the forest's width and structure. This dramatically reduces damage during storms and cyclones (McIvor et al., 2012; Zhou et al., 2022).

**Supporting services are what make ecosystems work.**

The supporting services provided by the forests are essential for the existence of human societies and biodiversity conservation.

- Making soil and cycling nutrients: Forest litter and roots create soil organic matter, increase microbial activity, and recycle nutrients such as nitrogen and phosphorus.
- Primary production: Forests turn sunlight into biomass, which is the base of food webs on land (Ferreira et al., 2023).
- Biodiversity and resilience: Tropical forests often estimated to contain over 50 % of terrestrial species, which makes them resilient to pests, diseases, and weather changes. (ICOMOS, 2019).

**Forests, pollination, and food systems**

Forests are vital to farming, mainly because they support pollination. Many pollinators depend on forests to live in and to find food year-round. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services reported that about 35% of global crop production depends to some extent on animal pollination (Klein et al., 2007). The value of pollination services is estimated at between US$235 and US$577 billion per year (Potts et al., 2016). Bee pollinators are essential to crops such as fruits, nuts, oilseeds, and vegetables. There is a link between forests and food security that is often overlooked: forest patches and tree-rich landscapes near farms help stabilize pollinator populations, which in turn improve crop quality and yield stability.

**Cultural services: forests and the health of people**

Forests offer deep cultural and psychological significance, in addition to material advantages:

**(1) Spiritual and cultural identity:** Many indigenous people consider forests as sacred and vital to their languages, traditions, and cosmologies;

**(2) Recreation and tourism:** Proper management of forest-based ecotourism generates revenue and encourages conservation (Raihan, 2023).

**(3) Mental and physical health:** The accessibility of forested areas for urban populations is linked to lower stress levels, better mental health, and overall health benefits. Moreover, it is hard to evaluate these cultural services, but they have a significant effect on people's quality of life.

**Putting a price on the hidden economy**

Most often, economic planners fail to regard forest ecosystem services because they aren't traded in markets. Costanza et al., (1997) estimated that the annual global value of ecosystem services exceeded the global GDP at the time, thereby emphasizing the substantial, yet largely unaccounted contribution of natural capital to human well-being and economic systems. Valuation not turning forests into products; instead, it helps people to see costs and benefits that are provided in terms of economic values. When trees are cut down for short-term gains, society often has to pay for disaster recovery, water treatment, health problems, and the long-term costs of climate change. The loss of forest ecosystem services has a domino effect:

(1) More greenhouse gas emissions and extreme weather

(2) Less water availability and quality

(3) More risk of floods and landslides

(4) Less agricultural productivity because of fewer pollinators and less fertile soil

(5) Loss of jobs and cultural heritage.

Once ecological limits are crossed, it may take decades for things to improve, or it may not be possible at all within the time frame of humans (Brando et al., 2025).

**Table 1. Major forest ecosystem services, underlying processes, evidence and socio-economic uses at global scale**

| Ecosystem service | Category | Forest processes | Evidence | Uses | References |
|---|---|---|---|---|---|
| Global forest extent | General | Forest cover across biomes | Global forest area is ≈ 4.14 billion ha (31% of land area) | Baseline for estimating global ecosystem services | (FAO, 2020) |
| Deforestation rate | Anthropogenic pressure | Land-use change (agriculture, infrastructure) | Net forest loss ≈ 10 million ha $yr^{-1}$ (2015–2020); ≈420 million ha lost since 1990 | Loss of carbon sinks, water regulation, and livelihoods | (FAO, 2020) |
| Carbon storage (forests) | Regulating services | Biomass + deadwood + litter + soil carbon | Global forest carbon stock estimated at 714 Gt (2025). | Climate mitigation: avoided emissions | (FAO, 2025) |
| Climate regulation (global sinks) | Regulating services | Net ecosystem exchange (land & ocean) | Land + ocean sinks absorb ≈ 50% of annual anthropogenic $CO_2$ emissions. | Slows the rate of global warming | (Lee et al., 2023) |
| Water regulation | Regulating services | Rainfall interception; infiltration; baseflow maintenance | Forested catchments provide more stable streamflow than deforested basins | Water security for cities and agriculture | (Millennium Ecosystem Assessment, 2005) |
| Water purification | Regulating services | Sediment trapping; nutrient retention | New York City avoided a multi-billion-dollar filtration plant by protecting its forest watersheds. | Reduced drinking-water treatment costs | (National Research Council, 2005) |
| Flood and erosion control | Regulating services | Root reinforcement; reduced runoff velocity | Forest loss linked to increased sediment loads and flood peaks | Disaster risk reduction | (Reckien & van Aalst, 2022) |
| Coastal protection (mangroves) | Regulating services | Wave attenuation; shoreline stabilization | Mangroves reduce wave height by ≈ 20–90%, depending on stand width and density. | Reduced cyclone and storm-surge damage | (Barbier et al., 2011) |
| Soil formation | Supporting services | Litter decomposition; humus build-up | Forest soils are among the largest terrestrial carbon pools | Sustains long-term productivity | (Lal, 2004) |
| Nutrient cycling | Supporting services | Microbial activity; mycorrhizal networks | Nutrient recycling underpins forest regeneration | Reduced fertilizer dependence | (Millennium Ecosystem Assessment, 2005) |
| Pollination support | Regulating services | Habitat for wild pollinators | Pollinator-dependent crops account for ≈ 35% of global crop production volume. | Food security; yield stability | (Klein et al., 2007; Potts et al., 2016) |

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|---|---|---|---|---|---|
| Economic value of pollination | Regulating services | Biodiversity-driven ecosystem function | Global value estimated US$235–577 billion $yr^{-1}$ | Supports fruits, nuts, and oilseeds | (Potts et al., 2016) |
| Crop dependence on pollinators | Regulating services | Biotic pollination | Many global crops show moderate to high pollinator dependence | Agricultural resilience | (Klein et al., 2007) |
| Biodiversity conservation | Supporting services | Habitat heterogeneity; genetic reservoirs | Tropical forests often estimated to contain over 50 % of terrestrial species | Ecosystem resilience | (ICOMOS, 2019) |
| Cultural services | Cultural services | Sacred groves; recreation; education | Cultural and spiritual dependence is documented globally | Mental health; identity | (Millennium Ecosystem Assessment, 2005) |
| Overall economic value | Ecosystem Services | Integrated ecosystem functions | Global ecosystem services value comparable to global GDP (order of magnitude) | Justifies conservation as an investment | (Costanza et al., 1997) |

**Putting money into forests: making the unseen seen**

During the recent times, forest protection and restoration are considered as a good investment. Community forestry, payments for ecosystem services, and nature-based solutions are among the ways people are trying to make a living while also keeping ecosystems healthy in the long run. International programs like REDD+ within the UN climate framework aim to provide countries with funding to keep their forests healthy and reduce deforestation (Cadman & Kohl, 2025). When people think of forests as infrastructure, like roads, dams, and power plants, it makes sense from an economic point of view to protect them. Table 2 lists the different types of ecosystem services valuation methods for forest ecosystems.

**Table 2. Overview of major economic valuation methods for forest ecosystem services**

| Valuation Method | Category | Underlying Basis | Value Type Captured | Applicable ES Category | Forest ES Application Example | References |
|---|---|---|---|---|---|---|
| Market Price Method (MPM) | Market-based | Uses observed prices of traded ecosystem goods in existing markets | Direct use value | Provisioning | Timber, non-timber forest products (NTFPs), fuelwood, medicinal plants | Frey et al., 2020 |
| Production Function Approach (PFA) | Market-based | Treats ecosystem as an input into production of a marketed commodity; links biophysical change to economic output | Indirect use value | Provisioning, Regulating | Forest watershed protection for downstream agricultural productivity; carbon sequestration modelling | Monge et al., 2016 |
| Travel Cost Method (TCM) | Revealed Preference | Infers recreational value from costs (transport, time, entry fees) incurred by visitors to forest sites | Direct use value | Cultural | Ecotourism value of national forests; recreation demand in tropical forest parks | Xu, 2016 |
| Hedonic Pricing Method (HPM) | Revealed Preference | Isolates environmental quality component from the price of a differentiated market good (typically residential property) | Indirect use value | Cultural, Regulating | Urban forest canopy effect on residential property values; proximity to forests and housing prices | Bayramoğlu et al., 2025 |
| Contingent Valuation Method (CVM) | Stated Preference | Elicits willingness-to-pay (WTP) or willingness-to-accept (WTA) compensation via structured surveys | Use + Non-use (Existence, bequest, altruistic) | All ES categories | Forest biodiversity conservation WTP; watershed protection payments; NTFP valuation in tropical forests | Solikin, 2016 |

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| | | presenting hypothetical scenarios | | | | |
| Choice Experiment Method (CEM) | Stated Preference | Respondents choose among multi-attribute hypothetical alternatives; marginal WTP derived for individual ES attributes via random utility modelling | Use + Non-use | All ES categories | Multi-service forest valuation (carbon + water + biodiversity); designing payment-for-ecosystem-services (PES) schemes | Aslam et al., 2017 |
| Replacement/Restoration Cost Method (RCM) | Cost-based | Estimates ES value as the cost of replacing the natural function with an engineered or man-made substitute of equivalent capacity | Indirect use value | Regulating, Provisioning | Forest watershed water filtration valued against cost of building equivalent water treatment infrastructure ( New York Catskill watershed, >$1.7 billion invested) | Richmond et al., 2007 |
| Avoided Damage Cost Method (ADCM) | Cost-based | Values an ecosystem service as the economic damage or loss that would be incurred in the absence of the ecosystem function | Indirect use value | Regulating | Riparian forest flood mitigation value; forest soil erosion prevention in hillside agricultural catchments | Jones et al., 2008 |
| Benefit Transfer Method (BTM) | Transfer-based | Adapts monetary value estimates from existing 'study sites' (primary studies) to new 'policy sites' where original data are unavailable | Use + Non-use | All ES categories | Regional forest ES valuation in developing nations; global natural capital assessments (e.g., Costanza et al., 1997; TEEB reports) | Bartczak et al., 2008 |

**Note:** ES = Ecosystem Services; WTP = Willingness to Pay; WTA = Willingness to Accept; NTFPs = Non-Timber Forest Products; PES = Payments for Ecosystem Services; TEEB = The Economics of Ecosystems and Biodiversity. Value types follow the Total Economic Value (TEV) framework. ES categories follow the Millennium Ecosystem Assessment (MEA, 2005) classification.

## Conclusion

Forests are dynamic systems that quietly power an invisible economy essential to climate stability, water security, food production, disaster risk reduction, and cultural well-being. The scientific evidence is clear: cutting down trees costs societies money, while protecting them brings long-term benefits that far outweigh the short-term profits from cutting them down. One of the best things that we can do for a strong and sustainable future is to make forest ecosystem services clear in policy, planning, and public awareness. There is an urgent need to find consensus between forest conservation and development.

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## Author contributions

Karuppaiah Ravichandran Dharshini - Written – Original Draft; Govindaraj Kamalam Dinesh - Conceptualization, Supervision; Chandrasekaran Nivaethaa - Writing – Review & Editing; Archana Anokhe – Visualization; Nath Karthika – Review and Editing; Poomalai Vasanth – Review and Editing, Kannappan Manikandan – Review and Editing, Suresh Parvathy – Visualization, Puthenveetil Ali Shahidha – Review and Editing, Chelladurai Dharani – Review and Editing, Mohan Packialakshmi - Conceptualization, Veluswamy Venkatramanan – Review and Editing, Punabati Heisnam – Review and Editing.

## Conflict of interests

The authors declare that they have no conflict of interest. The research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. The manuscript has not been submitted for publication in any other journal.

## Ethics approval

Not applicable.

## AI tool usage declaration

During the preparation of this work, the author(s) used Grammarly and QuillBot to correct grammatical errors and improve readability, content flow, and language. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the publication's content.

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