

# Forest Ecosystem Services Across Iceland's Millennial Forest Transition

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## ABSTRACT

Iceland's forest trajectory, from extensive birch woodland at settlement to near-total deforestation by the early twentieth century and now recovering through active afforestation, represents one of Europe's most dramatic landscape transformations. This systematic literature review applies the Common International Classification of Ecosystem Services (CICES v5.2) to inventory the services and disservices associated with Iceland's forests and evaluate trade-offs across different forest development pathways. Regulating and maintenance services dominated the literature, with carbon sequestration the most frequently documented service, reflecting the centrality of climate policy in modern Icelandic forestry. Biodiversity and habitat services exhibited mixed directionality across divergent pathway profiles: non-native plantations offer enhanced carbon sequestration efficiency and novel habitat types attracting previously unrecorded bird species, while native birch restoration strengthens indigenous ecological networks. Cultural services — recreation, aesthetics, and heritage — proved substantial, with forests near urban areas serving as critical interfaces reconnecting society with forest-derived benefits after prolonged absence. Together, these findings demonstrate that ecosystem service outcomes depend not on forest cover gain alone, but on the restoration, pathway pursued and the spatial relationship between expanding forests and the communities they serve.

## INTRODUCTION

Forests constitute one of Earth's most important ecosystems, delivering a wide spectrum of ecosystem services (ES) across provisioning, regulating, and cultural domains (Brockhoff et al., 2017; IPBES, 2019). Yet global assessments reveal a persistent tension between area-based metrics and functional outcomes: forest area may be increasing in some regions while ecological condition and ES capacity continue to decline (IPBES, 2019; FAO, 2025). Within EU member states, 47% of forested areas display multiple indicators of degradation despite a net increase of 13 million hectares over 25 years (Maes et al., 2020). Understanding the conditions under which forests recover — and which services they provide during recovery — has therefore become central to restoration and conservation policy.

Forest transition theory (FTT) offers a framework for this question, describing the reversal from net forest loss to net gain as a U-shaped curve driven by socioeconomic transformation (Mather, 1992; Rudel et al., 2005). While originally conceived to explain land cover change, FTT has increasingly been extended to examine how ES evolve across transitional phases, shifting analytical focus from area metrics to the functional capacity of recovering landscapes (Chazdon, 2008; Wilson et al., 2017). This reveals that ES development follows predominantly non-linear trajectories characterised by differential recovery rates, threshold effects, and temporal lags (Wilson et al., 2017; Shimamoto et al., 2018). Critically, the pathway of forest recovery — whether through natural regeneration, plantation establishment, or community-led restoration — fundamentally shapes which services emerge and at what rate.

Most national-level ES assessments focus on regions with substantial existing forest cover, systematically underrepresenting countries at early stages of forest transition (Maes et al., 2020). Nations recovering from near-total forest loss face a distinct analytical challenge: there is no established baseline from which to measure change. The cultural, regulatory, and provisioning service context is fundamentally different when forests must be rebuilt from near-absence rather than incrementally restored from a functioning ecosystem.

Iceland addresses this gap. At settlement (~874 CE), birch woodland covered an estimated 25–40% of the island. Through a cumulative ratchet of deliberate land conversion, chronic regeneration suppression by free-roaming livestock, climatic-volcanic compounding during the Little Ice Age, and institutional paralysis under colonial governance, forest cover declined to less than 1% by the early twentieth century (Figure 1). This trajectory departs from classical FTT models — the deforestation phase was driven not by a single socioeconomic shift but by four interacting mechanisms operating as a self-reinforcing cycle, while the turning point was delayed by approximately 200 years of colonial governance that structurally disabled institutional responses despite documented awareness of forest scarcity from ~1700. The near-complete loss creates a natural experiment for observing ES emergence during the earliest phases of forest transition.

Today, three concurrent restoration pathways — native birch regeneration, non-native conifer plantation, and community woodland — are recovering forest cover through fundamentally different mechanisms, each generating distinct ES portfolios. This systematic review applies CICES v5.2 to inventory the services associated with Iceland's forests and evaluate how ES outcomes vary across these divergent recovery pathways.

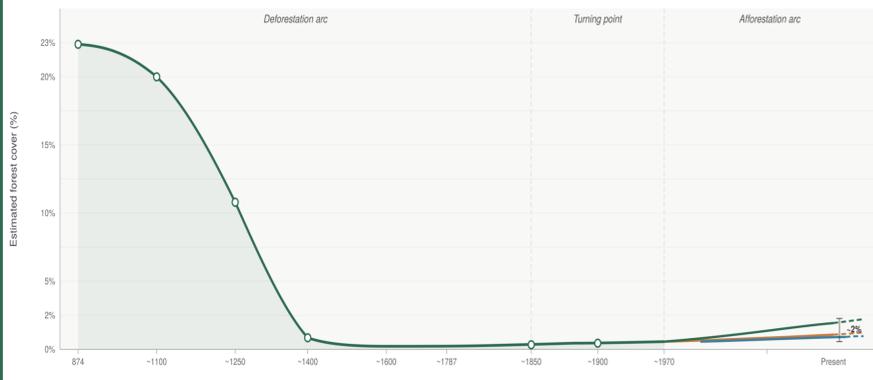


Figure 1. Estimated forest cover decline with deforestation mechanism periods, inflection points, and three divergent recovery pathways.

## METHODS

Systematic literature review. 222 peer-reviewed papers (1899–2025) addressing forest ecosystem services in Iceland were identified and coded against three frameworks: CICES v5.2 for ES typology at the class level, SALSA for systematic review quality, and a historical timeline spanning pre-settlement to the present. Papers were classified by species pathway — native (*Betula pubescens*), non-native (*Picea*, *Larix*, *Pinus* spp.), community woodland, or general/mixed — enabling cross-pathway comparison. This produced 597 individual ES code assignments across 11 CICES groups.

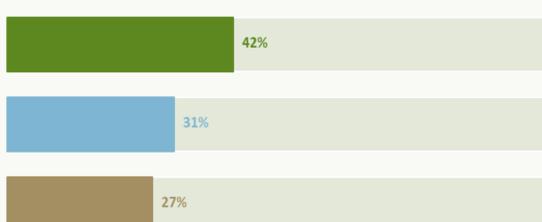
222 papers

597 ES codes

11 CICES groups

3 pathways

### ES papers by CICES section



### Dominant ES class by pathway

#### Native Birch

1st: Regulating & Maintenance  
2nd: Cultural  
3rd: Provisioning

#### Non-native Plantation

1st: Provisioning  
2nd: Regulating & Maintenance  
3rd: Cultural

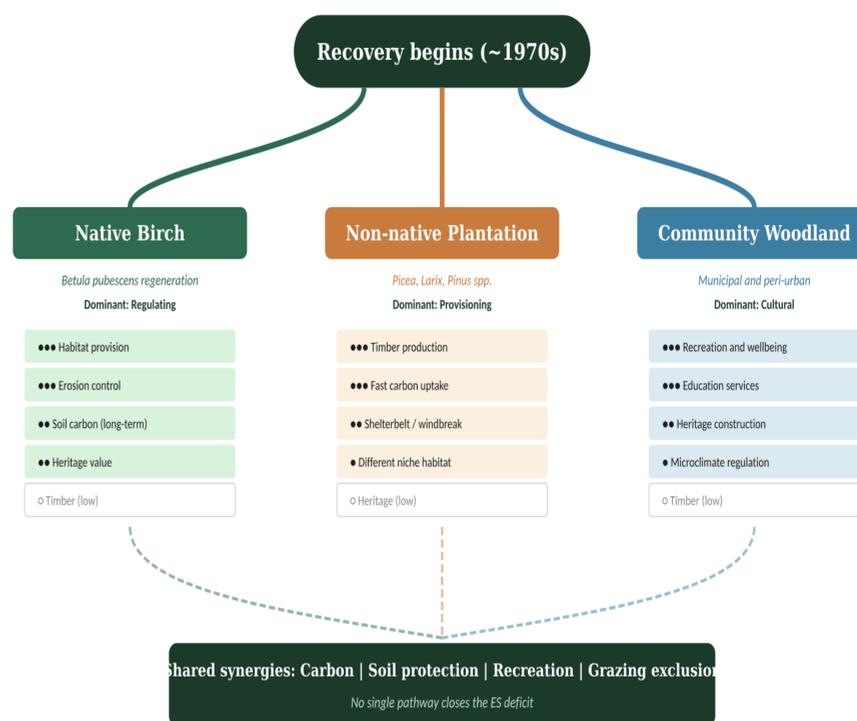
#### Community Woodland

1st: Cultural  
2nd: Regulating & Maintenance  
3rd: Provisioning

## RESULTS

Regulating and maintenance services dominate the literature (42% of all code assignments), followed by cultural (31%) and provisioning (27%). This reflects a degraded baseline where ecosystem recovery — not resource extraction — is the primary function of new forests. Critically, each pathway recovers a structurally different ES profile:

### Three Pathways, Three Different ES Portfolios



### Trade-offs and Synergies Across the Three Pathways

Trade-offs are not universal properties of forest cover gain — they are pathway-specific. Each pathway gains where others lose, creating structural complementarity.

ES Category	Native Birch	Non-native	Community
Carbon Sequestration	●● High	●●● High	● Moderate
Biodiversity & Habitat	●●● High	● Different niche	● Urban-limited
Erosion Regulation	●●● High	●● Moderate	○ Low
Timber / Provisioning	○ Low	●●● High	○ Low
Recreation	● Low-Mod	●● Moderate	●●● High
Heritage & Sense of Place	●● Moderate	○ Low	●● Active construction

The non-native biodiversity contribution is framed as 'different niche' rather than deficit — exotic stands attract previously unrecorded bird species. The question is not native vs. non-native value, but which services, for whom, and at which successional stage.

## KEY FINDINGS

- Net forest cover gain does not determine ES outcomes — pathway does. Three concurrent pathways generate structurally distinct ES bundles from the same landscape.
- Trade-offs are pathway-specific, not universal properties of reforestation. Each pathway gains where others lose, creating complementarity rather than competition.
- No single pathway closes the ES deficit. Pathway combination — deploying native, non-native, and community woodland across appropriate landscape positions — is required.
- Forest management and certification should assess full ES portfolios, not sustained timber yield alone — particularly in landscapes recovering from extreme degradation.
- Iceland's extreme case reveals dynamics that operate in all recovering forests but are invisible at higher baseline cover — making it a natural experiment for ES-aware forest governance.

## REFERENCES

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