

Forest Degradation and Desertification in a Changing Climate

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ABSTRACT

Forest degradation and desertification are closely connected components of a broader socio-ecological problem in which land-use pressure, climatic stress and declining ecosystem resilience interact across landscapes. Forest degradation does not necessarily involve complete removal of tree cover; it may occur through biomass loss, selective extraction, fire, fragmentation, altered species composition, soil deterioration and impaired regeneration. These changes can weaken the capacity of forests to protect soil, regulate water, store carbon and sustain biodiversity. In dryland and other environmentally vulnerable settings, such deterioration may increase susceptibility to land degradation and desertification. This integrative review synthesises evidence on the major anthropogenic and climatic drivers of forest degradation, the ecological pathways linking forest condition with land degradation, the environmental and socio-economic consequences of these processes, and the principal restoration and management responses. Recent literature shows that degradation is frequently underestimated when assessment relies only on forest area, because structural and functional losses may persist within areas still classified as forest. Climate change acts as a threat multiplier by increasing heat stress, drought risk, rainfall variability and fire susceptibility, while degraded ecosystems may become less capable of recovering from climatic extremes. The review further shows that restoration outcomes depend on ecological context, governance, local participation and long-term monitoring rather than on tree-planting numbers alone. Based on the evidence, a Forest–Land Resilience Framework is proposed, linking prevention, protection, sustainable management, restoration, participation, monitoring and policy integration. The central argument is that durable progress requires simultaneous reduction of degradation drivers and recovery of ecological functions; restoration without changes in land-use practices and governance is unlikely to provide lasting resilience.

Keywords: forest degradation; desertification; land degradation; climate change; ecosystem restoration; sustainable land management; forest landscape restoration; environmental resilience.

INTRODUCTION

Forests are fundamental to terrestrial ecosystem functioning. They regulate water and energy exchanges, store carbon, provide habitat for biodiversity, protect soil, and supply material and cultural resources to human societies. Their importance extends beyond the boundaries of forested areas because forest condition influences downstream water availability, sediment transport, regional climate processes and landscape connectivity. The 2025 Global Forest Resources Assessment reports that forests cover approximately 4.14 billion hectares, or about 32% of global land area, while also documenting continuing forest loss and substantial differences among regions and forest types (FAO, 2025).

A critical distinction in interpreting these trends is the difference between deforestation and forest degradation. Deforestation generally involves conversion of forest to another land use, whereas degradation can occur while an area remains legally or remotely classified as forest. Selective logging, repeated fire, fuelwood extraction, grazing, edge effects, drought and other disturbances may reduce biomass, canopy structure, species diversity, soil quality and regeneration without immediately eliminating forest cover. Recent pantropical evidence demonstrates the scale of this hidden component: selective logging and fire can substantially reduce forest

height, while agricultural and road expansion can affect biomass well inside remaining forest edges (Bourgoin et al., 2024).

Forest degradation is also closely linked to land degradation. Once vegetation cover and root systems are weakened, soils may become more exposed to rainfall impact, runoff and wind erosion. Declining organic matter and biological activity can reduce soil structure and water-holding capacity, while repeated disturbance can restrict natural regeneration. These processes are particularly important in drylands, where limited water availability already constrains ecosystem recovery. Desertification, in this context, is not the literal movement of a desert boundary but a process of land degradation in arid, semi-arid and dry sub-humid areas resulting from interacting climatic and human pressures (IPCC, 2019; Roy et al., 2024).

The global scale of the problem is substantial. The UNCCD SDG indicator 15.3.1 dashboard currently reports 1.56 billion hectares of reported degraded land, equivalent to 15.39% of the reported land area; the underlying global estimate is based on 167 estimates and is explicitly described by UNCCD as partial because not all countries report all indicators (UNCCD, 2026). This limitation is important: global numbers should not be interpreted as a complete inventory of degradation. Nevertheless, the available evidence clearly indicates that land degradation has consequences for food production, water security, biodiversity, carbon storage and livelihoods.

Climate change adds another layer of pressure. Warming increases evaporative demand and can intensify water stress; drought can reduce productivity and regeneration; altered rainfall regimes can increase both prolonged dry periods and high-intensity rainfall; and hot, dry conditions can increase fire risk. The IPCC identifies strong interactions among climate change, land degradation, desertification, sustainable land management and food security (IPCC, 2019). These interactions imply that degradation and climate change should be analysed as a coupled system rather than as separate environmental issues.

The purpose of this review is therefore to integrate ecological, climatic and socio-economic perspectives on forest degradation and desertification. Specifically, the review (i) examines the major drivers of degradation, (ii) explains the ecological mechanisms linking forest degradation to land degradation and desertification, (iii) evaluates environmental and socio-economic consequences, (iv) assesses restoration and sustainable land-management responses, and (v) proposes an integrated framework for strengthening forest and land resilience.

REVIEW METHODOLOGY

This paper uses an integrative narrative review approach rather than a formal systematic review or meta-analysis. The objective is to synthesise concepts and findings from forestry, ecology, soil science, climate science, land management and environmental policy, with particular attention to evidence that clarifies relationships among forest degradation, land degradation, desertification and climate change.

The evidence base combines authoritative international assessments with peer-reviewed research and recent review literature. Priority was given to sources that provide global assessments, quantitative evidence, conceptual synthesis, or practical evidence concerning restoration and sustainable land management. Core institutional sources include the Food and Agriculture Organization's Global Forest Resources Assessment, the IPCC Special Report on Climate Change and Land, the UNCCD Global Land Outlook, the UNCCD SDG 15.3.1 data platform and the IPBES assessment of land degradation and restoration. Recent peer-reviewed studies were used to update and critically interpret these assessments.

The synthesis was organised around four linked dimensions: drivers, processes, impacts and responses. Drivers include land-use change, agricultural expansion, extraction, grazing, infrastructure, mining, fire and climatic stress. Processes include changes in vegetation structure, soil protection, hydrology, nutrient cycling and ecological resilience. Impacts include biodiversity loss, carbon loss, declining productivity, water insecurity and livelihood vulnerability. Responses include conservation, natural regeneration, ecological restoration, sustainable land management, monitoring, community participation and governance.

Because the literature uses different definitions, indicators and spatial scales, findings were not treated as directly interchangeable. Particular care was taken to distinguish forest area from forest condition, degradation from deforestation, and desertification from simple desert expansion. This distinction is important for avoiding overstatement and for interpreting apparently conflicting results across studies.

CONCEPTUALISING FOREST DEGRADATION, LAND DEGRADATION AND DESERTIFICATION

3.1 Forest degradation

Forest degradation can be understood as a decline in the ecological condition, structure or functional capacity of a forest without necessarily converting the area to a non-forest land use. Relevant indicators include biomass, canopy structure, species composition, deadwood, regeneration, soil properties, carbon stocks, habitat quality and resilience to disturbance. The distinction from deforestation is consequential because a forest can retain sufficient tree cover to remain classified as forest while losing substantial ecological function.

Recent global evidence supports this interpretation. Bourgoin et al. (2024) found that selective logging and fire can cause persistent reductions in forest structure and that agricultural and road expansion can produce measurable edge effects extending well into remaining tropical moist forests. Similarly, the global synthesis of Qu et al. (2024) shows that forest conversion can disrupt soil biodiversity and soil functions associated with nutrient cycling, organic matter decomposition and carbon storage. Together, these studies demonstrate that forest condition is multidimensional and that forest-area statistics alone are insufficient for evaluating ecological integrity.

3.2 Land degradation

Land degradation refers to a decline in the capacity of land to maintain ecological functions and provide goods and services. It may involve soil erosion, loss of organic matter, nutrient depletion, salinisation, compaction, declining vegetation productivity, altered hydrology and loss of biological activity. AbdelRahman (2023) emphasises that degradation is driven by interacting climatic and human pressures and that remote sensing and geospatial approaches are increasingly important for detecting changes across large areas.

Land degradation is therefore both biophysical and socio-economic. A decline in soil quality can reduce agricultural productivity; reduced vegetation can alter water regulation; and declining ecosystem services can increase livelihood vulnerability. The severity of these effects depends on ecological conditions, land-use intensity, institutional capacity and the ability of local users to adopt sustainable practices.

3.3 Desertification

Desertification is a specific form of land degradation associated with arid, semi-arid and dry sub-humid areas. It results from interactions between climatic variability and human activities rather than from climate alone. Common pressures include overgrazing, vegetation removal, unsustainable cultivation, inappropriate irrigation and water extraction, drought, warming and rainfall variability (IPCC, 2019; Roy et al., 2024).

This definition matters because desertification is not synonymous with desert expansion. A landscape may experience declining vegetation productivity, soil erosion or reduced water availability without becoming a desert in a geographical sense. The more useful analytical question is whether ecological and productive capacity is declining and whether the system is losing resilience.

MAJOR DRIVERS OF FOREST DEGRADATION AND DESERTIFICATION

4.1 Agricultural expansion and land-use change

Conversion of natural ecosystems for agriculture remains a major pressure on forests and land. Where expansion removes native vegetation, the immediate effect is loss of habitat and soil protection; repeated cultivation can then alter soil organic matter, nutrient cycling and aggregate stability. The risk becomes greater where cultivation extends onto steep, dry or otherwise fragile land. The literature on sustainable land management shows that technical measures such as conservation practices can reduce degradation, but adoption is shaped by land tenure, incentives, knowledge, labour and institutional support (Haregeweyn et al., 2023).

4.2 Unsustainable extraction and forest disturbance

Selective logging and fuelwood extraction can reduce biomass and simplify forest structure even when canopy cover remains. Repeated extraction can also create roads and access corridors, increasing the likelihood of additional disturbance. The evidence from tropical moist forests is particularly instructive because it shows that degradation can persist for decades and can increase vulnerability to subsequent deforestation (Bourgoin et al., 2024). This supports a prevention-first approach: protecting already degraded but recoverable forests can be as important as preventing complete conversion.

4.3 Overgrazing and vegetation removal

Grazing is an important livelihood activity in many drylands and mountain regions, so the issue is not grazing itself but a mismatch between grazing pressure and ecological carrying capacity. Persistent pressure can suppress seedlings, reduce ground cover and compact soil, thereby limiting regeneration and increasing erosion. In drylands, these effects can interact with drought to produce prolonged reductions in productivity.

4.4 Infrastructure and mining

Roads, settlements, mining and other infrastructure can directly remove vegetation and disturb soil. Their indirect effects can be equally important because new access routes may facilitate logging, hunting, fire ignition or agricultural expansion. Landscape fragmentation also reduces connectivity and can alter microclimatic conditions at forest edges.

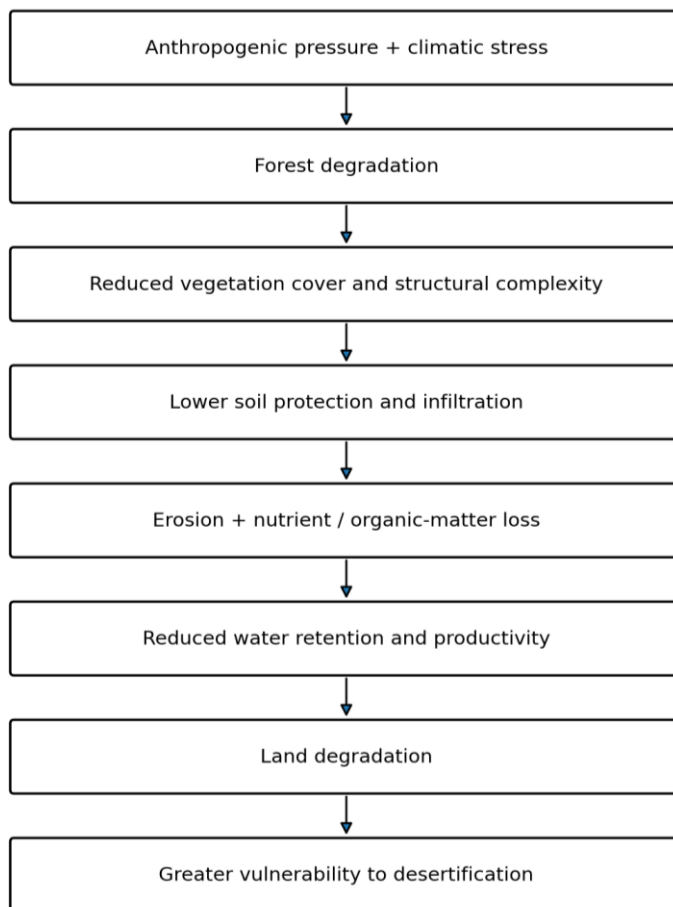
4.5 Fire

Fire is a natural ecological process in many ecosystems, but its effects depend on frequency, intensity, seasonality and ecosystem adaptation. Repeated severe fires can reduce biomass, damage soil organic matter, alter regeneration and release carbon. Under warmer and drier conditions, the probability of severe fire can increase in some regions, while degraded forests may be less able to recover after fire. This creates a potential interaction in which climate stress increases fire impacts and fire further reduces ecosystem resilience.

4.6 Climate change as a threat multiplier

Climate change does not replace direct human drivers; it modifies the vulnerability and recovery capacity of ecosystems already exposed to disturbance. Higher temperatures increase evaporative demand, while drought reduces soil moisture and plant productivity. Rainfall variability can produce alternating drought and intense precipitation, with the latter capable of causing severe runoff and erosion where vegetation has been lost. Roy et al. (2024) emphasise the combined role of climatic and geo-environmental factors in desertification, while Stavi et al. (2024) highlight the need for climate-smart forestry approaches in drylands.

Forest Degradation-Desertification Nexus



Feedback is not strictly linear: degraded soil and water stress can further restrict vegetation recovery.

Figure 1. Conceptual pathway linking anthropogenic and climatic pressures with forest degradation, land degradation and increasing vulnerability to desertification.

THE FOREST DEGRADATION–DESERTIFICATION NEXUS

The relationship between forest degradation and desertification is best understood as a network of interacting processes rather than a single linear chain. Loss of vegetation reduces interception and root reinforcement, exposes soil to erosive forces and can lower infiltration. Soil erosion and organic-matter loss then reduce fertility and water-holding capacity, which makes vegetation establishment more difficult. The resulting reduction in vegetation can reinforce the original soil degradation.

This mechanism is especially important where ecological recovery is constrained by water scarcity. Once a landscape crosses a threshold of severe soil degradation, natural regeneration may become slow or spatially patchy. Restoration may then require active interventions such as erosion control, assisted natural regeneration, soil amendment, water harvesting or carefully selected planting. The key point is that degradation can alter the conditions required for its own reversal.

The nexus also operates through carbon and climate feedbacks. Loss of biomass reduces carbon storage, while fire and soil degradation can contribute to additional greenhouse-gas emissions. At the same time, reduced vegetation and soil quality can increase sensitivity to heat and drought. The resulting feedback is not necessarily a globally uniform positive feedback, but it is a credible mechanism by which local degradation can amplify climatic vulnerability.

GLOBAL EVIDENCE AND REGIONAL EXAMPLES

Global assessments provide the broad context, but regional examples illustrate how the degradation process is expressed differently across landscapes. Tropical forests can experience selective logging, fire and road expansion without immediate complete deforestation; drylands may be dominated by grazing pressure, water scarcity and drought; and mountain landscapes can face combinations of forest extraction, infrastructure development, erosion and climatic stress.

In tropical moist forests, Bourgoin et al. (2024) found that degradation from selective logging and fire can substantially reduce forest height and that edge effects associated with agriculture and roads affect a large proportion of remaining forest. The study also found that strongly degraded forests were more vulnerable to subsequent deforestation. This is important for the present review because it demonstrates that degradation can function as a precursor to further land-use conversion rather than merely as a temporary decline in forest quality.

In India, the land-degradation literature reflects considerable ecological diversity and multiple interacting pressures. Mishra and Bauddh (2024) synthesised research across Indian agro-climatic regions and reported evidence concerning disturbances to forests, grasslands, agricultural systems and soils, together with restoration approaches including agroforestry, afforestation, organic amendments and agroecological interventions. The Indian context therefore reinforces the need for site-specific restoration rather than a single national prescription.

Dryland forestry also illustrates why climate adaptation must be integrated with restoration. Stavi et al. (2024) argue that dryland forestry faces simultaneous pressures from drought, intense rainfall, soil erosion and land-use mismanagement. Restoration strategies in such settings must therefore be designed around water availability, species suitability, soil condition and future climatic risk rather than simply maximising tree numbers.

Table 1. Selected evidence relevant to forest and land degradation

Evidence / indicator	What it shows	Interpretive significance
Global forest extent (FAO, 2025)	Forests cover about 4.14 billion ha, ~32% of global land.	Forest condition and management remain globally consequential even where total area is stable or changing slowly.
Reported degraded land (UNCCD, 2026)	1.56 billion ha; 15.39% of reported land area.	A major global pressure, but the dashboard notes that the estimate is partial.
Healthy/productive land degradation, 2015–2019	At least 100 million ha/year; ~1.3 billion people directly exposed.	Shows the continuing human significance of land degradation.
Tropical forest degradation (Bourgoin et al., 2024)	Selective logging, fire, agriculture and roads produce persistent structural effects.	Degradation can be extensive and long-lasting even without complete deforestation.
Soil biodiversity (Qu et al., 2024)	Forest conversion reduces soil biodiversity and several soil ecosystem functions.	Above-ground forest loss can propagate into below-ground ecological processes.

ECOLOGICAL CONSEQUENCES

7.1 Soil erosion and fertility decline

Vegetation protects soil by intercepting rainfall, reducing runoff and binding soil through roots. When vegetation cover declines, the balance between soil formation and soil loss can shift toward net erosion. Loss of topsoil removes nutrients and organic matter and can reduce rooting depth and agricultural productivity. The effects are often cumulative: once soil structure deteriorates, infiltration falls, runoff increases and vegetation recovery becomes more difficult.

7.2 Hydrological disruption

Forests influence water through canopy interception, infiltration, evapotranspiration and soil-water storage. Degradation can change the timing and distribution of runoff, increase sediment delivery and reduce the ability of soils to retain water. These changes do not imply that every degraded forest necessarily increases downstream flooding or reduces water availability in the same way; hydrological outcomes depend on climate, topography, soil properties and the type and intensity of disturbance. Nevertheless, degradation can weaken important regulating functions at landscape scale.

7.3 Biodiversity loss and habitat fragmentation

Forest degradation can reduce habitat quality without eliminating forest cover. Structural simplification, edge effects, repeated fire and selective extraction may alter microhabitats and species composition. Qu et al. (2024) further demonstrate that forest conversion affects soil biodiversity and functions, showing that degradation extends below ground. These findings support a broader interpretation of biodiversity conservation in which soil organisms, vegetation structure and ecosystem processes are considered together.

7.4 Carbon loss and climate vulnerability

Degraded forests generally have lower biomass and may store less carbon than intact forests. Carbon loss is therefore both a consequence of degradation and a climate-policy concern. However, carbon should not be treated as the sole restoration metric. A forest can accumulate biomass while remaining ecologically simplified, species-poor or poorly adapted to local conditions. Restoration should therefore pursue carbon, biodiversity, soil and hydrological recovery as complementary objectives.

7.5 Declining ecosystem resilience

Resilience refers here to the capacity of an ecosystem to absorb disturbance while retaining its core functions and to recover after stress. Degradation can reduce resilience by removing biological diversity, seed sources, soil organic matter and structural complexity. Climate change can then expose the system to additional stress. This interaction is one reason why preventing severe degradation is generally more cost-effective and ecologically reliable than restoring a system after it has crossed a major ecological threshold.

8. SOCIO-ECONOMIC CONSEQUENCES

Environmental degradation has direct social consequences because forests and productive land provide food, fuel, fodder, water regulation, materials and income. The severity of these effects depends on livelihood strategies and institutional conditions. Rural households with limited access to alternative resources may be particularly exposed to declining forest productivity or water insecurity.

8.1 Food security and agricultural productivity

Soil erosion, declining fertility and reduced water availability can lower agricultural productivity. In dryland areas, even modest reductions in vegetation or soil-water retention can have disproportionate effects because

the baseline water constraint is already strong. Sustainable land management can reduce these risks, but global evidence shows that adoption is uneven and depends on institutional and socio-economic conditions (Haregeweyn et al., 2023).

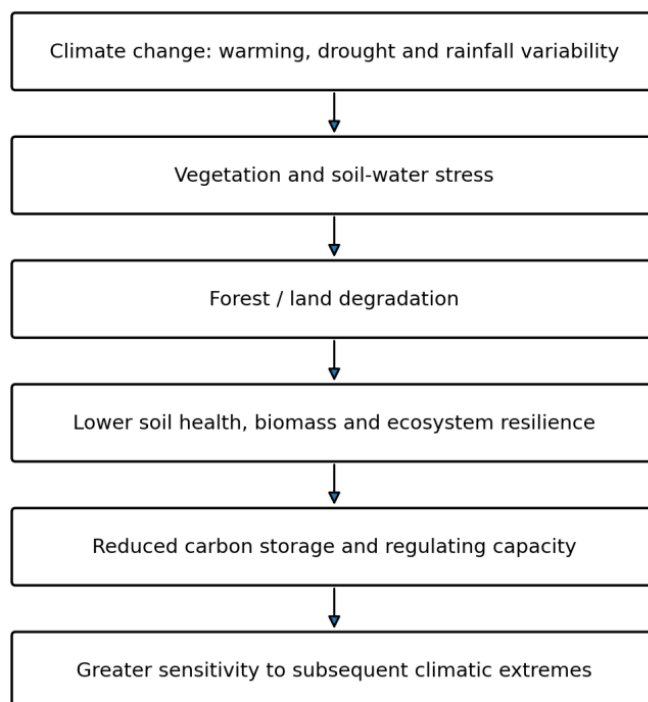
8.2 Livelihood vulnerability

Forest-dependent communities may experience reduced access to fuelwood, fodder, non-timber products, water and other ecosystem services as forest condition declines. These impacts can increase labour demands, reduce household income and intensify competition over resources. Responses therefore need to consider livelihood security alongside ecological objectives.

8.3 Water insecurity and migration pressures

Land degradation can contribute to water insecurity by reducing infiltration and storage or increasing sedimentation. Environmental stress may also interact with economic and social factors to influence migration decisions. Migration should not be attributed to environmental degradation alone, because employment, conflict, education, infrastructure and public policy also shape mobility. A careful review therefore treats environmental degradation as one component of a wider livelihood-risk system.

Climate-Land Degradation Feedback



The loop can be weakened through prevention, soil protection, restoration, adaptation and sustainable land management.

Figure 2. Conceptual climate–land degradation feedback. The loop illustrates how climatic stress and ecosystem degradation can reinforce vulnerability, while management interventions can weaken the cycle.

RESTORATION AND SUSTAINABLE LAND MANAGEMENT

9.1 Prevention and conservation

Prevention is the first component of a resilience strategy because intact or lightly disturbed ecosystems retain ecological functions that may be expensive or impossible to recreate. Conservation measures include protection of high-value forests, control of illegal extraction, appropriate fire management, maintenance of habitat connectivity and prevention of avoidable land conversion. Evidence from tropical forests indicates that preventing degradation can be particularly important where degraded forests become more vulnerable to later deforestation (Bourgoin et al., 2024).

9.2 Natural regeneration

Natural regeneration can be more ecologically appropriate and less expensive than intensive planting where seed sources, soil conditions and disturbance regimes remain suitable. Its success depends on continued protection from grazing, fire and repeated cutting. Assisted natural regeneration can help overcome barriers without replacing local ecological processes.

9.3 Ecological restoration and afforestation

Restoration should be defined by recovery of ecological functions rather than by planting targets. Site selection, native species, genetic suitability, soil condition, water availability and long-term survival all influence outcomes. Afforestation may be appropriate in some degraded landscapes, but indiscriminate tree planting can produce poor outcomes where species are unsuitable, water is limiting, or natural grassland and shrubland ecosystems are being converted. Recent restoration literature therefore supports context-dependent approaches and functional indicators (Mansourian & Stephenson, 2023; Dor-Haim et al., 2023).

9.4 Sustainable land management

Sustainable land management encompasses soil conservation, agroforestry, controlled grazing, water harvesting, watershed management, reduced soil disturbance and practices that maintain or rebuild soil organic matter. A global review by Haregeweyn et al. (2023) found extensive evidence and experience with sustainable land management but also identified barriers in the dissemination and uptake of effective practices. The implication is that technical suitability is necessary but not sufficient: land users must also have incentives, secure access, knowledge and institutional support.

9.5 Monitoring and adaptive management

Monitoring should measure ecological condition rather than relying on a single indicator. Useful indicators include canopy and biomass trends, species composition, regeneration, soil organic carbon, erosion, soil moisture, fire occurrence, habitat connectivity and socio-economic outcomes. Remote sensing can provide repeated landscape-scale observations, but field measurements remain important for interpretation and validation. Mansourian and Stephenson (2023) emphasise that restoration monitoring is challenging precisely because ecological and social outcomes occur across different spatial and temporal scales.

Table 2. Comparative assessment of major response strategies

Strategy	Main benefit	Key limitation	Best application
Forest conservation	Prevents further ecological loss	Does not restore already degraded sites	Intact and high-value forests

Natural regeneration	Uses local ecological processes; often cost-effective	Requires viable seed sources and protection	Lightly to moderately degraded sites
Active restoration / planting	Can accelerate recovery where natural recovery is constrained	Species/site mismatch and water limitation can cause failure	Severely degraded or strategically selected sites
Sustainable land management	Reduces erosion and maintains productivity	Adoption may be limited by socio-economic barriers	Agricultural and dryland landscapes
Agroforestry	Combines production with ecological functions	Requires local design and long-term management	Farming landscapes and livelihood-oriented restoration
Community-based management	Can improve stewardship and legitimacy	Depends on institutions, tenure and participation	Landscapes with strong local dependence
Remote-sensing monitoring	Provides repeated landscape-scale evidence	Needs field validation and careful interpretation	Large-area monitoring and early detection

COMMUNITY PARTICIPATION AND ENVIRONMENTAL GOVERNANCE

Forest and land degradation are not purely technical problems. People make decisions about land use, grazing, extraction and restoration within economic and institutional systems. Restoration programmes that ignore local users may fail because the practices required for ecological recovery conflict with livelihood needs. Conversely, community participation can improve legitimacy, local monitoring and maintenance when participation is supported by meaningful rights and responsibilities.

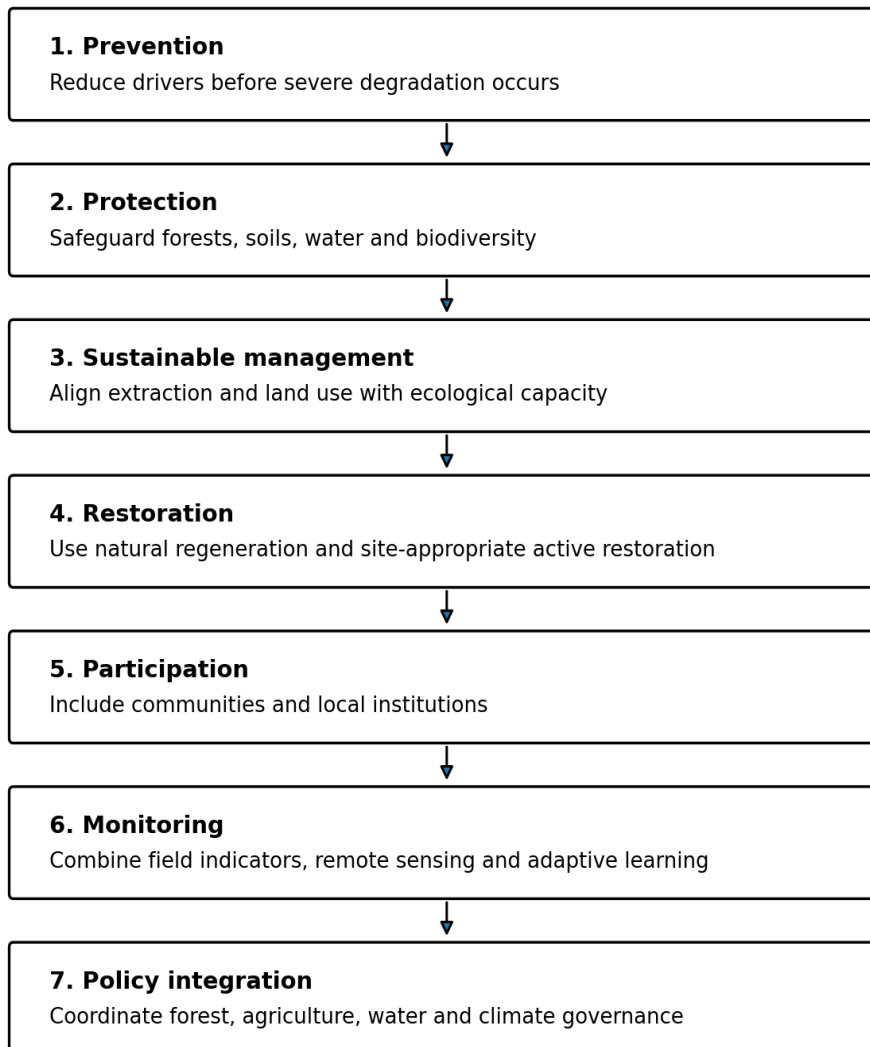
Governance also matters because degradation frequently crosses administrative and sectoral boundaries. Forest departments, agriculture agencies, water authorities and climate programmes may pursue objectives that are individually reasonable but collectively inconsistent. Integrated landscape planning can reduce such fragmentation by aligning conservation, production and restoration objectives. The UNCCD's Global Land Outlook 2 emphasises place-based restoration, enabling institutions and long-term land stewardship as central elements of land recovery (UNCCD, 2022).

Participation should nevertheless not be treated as a symbolic requirement. Effective participation involves access to information, recognition of local knowledge, secure and transparent resource rights, involvement in decision-making, and mechanisms for resolving conflicts. In this sense, social resilience and ecological resilience are closely connected.

FOREST–LAND RESILIENCE FRAMEWORK

Based on the reviewed evidence, this paper proposes a Forest–Land Resilience Framework that places prevention and protection before restoration, while treating participation, monitoring and policy integration as cross-cutting requirements. The framework is intended as a conceptual synthesis rather than a universal prescription. Different ecosystems will require different combinations of interventions.

Forest-Land Resilience Framework



Outcome: resilient ecosystems + healthier soils + water security + biodiversity + sustainable livelihoods

Figure 3. Forest–Land Resilience Framework proposed by this review. The framework emphasises prevention and protection, followed by context-specific management and restoration, supported throughout by participation, monitoring and policy integration.

The framework differs from a simple restoration sequence in three ways. First, it treats prevention as a primary intervention rather than as an afterthought. Second, it defines restoration in terms of ecosystem function and resilience rather than planting numbers. Third, it recognises governance and monitoring as continuous processes. This reflects evidence that restoration is unlikely to remain effective if the drivers of degradation continue and that monitoring must support learning and adaptive management (Mansourian & Stephenson, 2023; UNCCD, 2022).

DISCUSSION

The reviewed evidence supports the central proposition that forest degradation and desertification are linked through interacting ecological and socio-economic processes. The relationship is strongest where vegetation loss, soil degradation and water limitation occur together. Forest degradation reduces the physical protection of soil and can alter hydrological regulation; soil degradation then constrains regeneration; and continued vegetation loss can further increase exposure to climatic stress. The process is therefore better represented as a set of feedbacks than as a one-directional chain.

An important implication is that forest area is an incomplete indicator of environmental condition. A landscape may show relatively stable forest extent while experiencing declining biomass, altered species composition, reduced soil function or increasing fragmentation. The findings of Bourgoïn et al. (2024) illustrate this problem at continental-to-global tropical scales, while Qu et al. (2024) show that changes above ground can be accompanied by deterioration of soil biodiversity and functions. For monitoring and policy, this means that forest condition should be assessed alongside forest extent.

The evidence also suggests that climate change should be interpreted as a threat multiplier rather than as a single cause. Drought, heat and rainfall variability can intensify the consequences of pre-existing land-use pressure, but the magnitude of the response depends on local ecological and social conditions. Stavi et al. (2024) emphasise this complexity in drylands, where forestry and restoration must account for both chronic water limitation and increasingly variable extremes. Roy et al. (2024) similarly highlight the combined influence of climate and geo-environmental factors in desertification. This reinforces the need for place-based strategies rather than uniform restoration prescriptions.

The review further challenges the tendency to equate restoration with tree planting. Trees are an important component of many restoration programmes, but planting density is a weak proxy for ecological recovery. A restoration project should ask whether soil function, regeneration, biodiversity, hydrological regulation and ecosystem resilience are improving. Functional restoration may be more realistic than attempting to recreate an exact historical ecosystem, especially where climate conditions have shifted (Dor-Haim et al., 2023).

Another important finding concerns the social dimensions of restoration. Sustainable land management has a large global evidence base, but implementation is uneven because ecological recommendations compete with short-term livelihood needs and institutional constraints (Haregeweyn et al., 2023). Consequently, technically effective interventions may fail when tenure is insecure, incentives are misaligned, or local users are excluded from decision-making. The practical contribution of an integrated framework is therefore to connect ecological measures with governance and livelihood considerations rather than treating them as separate domains.

Finally, the evidence points toward prevention as the most reliable long-term strategy. Restoration remains essential, particularly in already degraded landscapes, but the ecological and financial costs of restoring severely damaged systems can be high. Preventing unnecessary forest disturbance, maintaining soil cover, reducing unsustainable extraction and managing fire and grazing pressures can preserve recovery potential. The most defensible policy position is therefore not restoration versus conservation, but a hierarchy in which avoidance and protection are prioritised, sustainable use follows, and active restoration is targeted where degradation has already occurred.

POLICY IMPLICATIONS AND RECOMMENDATIONS

- Strengthen forest-condition monitoring. National and local monitoring systems should complement forest-area statistics with biomass, canopy structure, regeneration, biodiversity, soil condition, fire exposure and fragmentation indicators.
- Prioritise prevention. Policies should reduce avoidable forest disturbance, unsustainable extraction, destructive land conversion and inappropriate development before ecological thresholds are crossed.

- Adopt site-specific restoration. Restoration plans should be based on local climate, soil, hydrology, species ecology and land-use history rather than uniform planting targets.
- Promote natural regeneration where feasible. Natural and assisted regeneration should be preferred where seed sources and ecological conditions remain viable.
- Scale up sustainable land management. Soil conservation, agroforestry, controlled grazing, water harvesting and watershed management should be supported through technical assistance and appropriate incentives.
- Integrate climate adaptation. Restoration and forest-management plans should incorporate expected changes in drought, temperature, rainfall variability and fire risk.
- Strengthen community participation and tenure security. Local users should be involved in planning, implementation and monitoring, with transparent rights and responsibilities.
- Use integrated governance. Forest, agriculture, water, biodiversity and climate policies should be coordinated at landscape scale.
- Evaluate restoration using ecological outcomes. Survival, regeneration, soil recovery, biodiversity and ecosystem function should be tracked over multiple years rather than relying only on planting counts.
- Combine remote sensing with field verification. Satellite observations can identify landscape change, while field measurements are required to understand ecological mechanisms and validate restoration outcomes.

LIMITATIONS AND RESEARCH PRIORITIES

This review has several limitations. First, it is an integrative narrative review rather than a systematic review with a reproducible database search protocol and quantitative meta-analysis. Second, definitions and indicators of forest degradation, land degradation and restoration vary among studies and institutions, making direct comparison difficult. Third, global datasets remain incomplete in some regions, and remote-sensing indicators may not capture all dimensions of ecosystem condition. These limitations do not invalidate the synthesis, but they indicate where future work should be strengthened.

Future research should prioritise harmonised indicators of forest condition, better integration of above- and below-ground measurements, long-term restoration monitoring, and stronger evaluation of socio-economic outcomes. There is also a need for more region-specific evidence on how climate projections interact with local degradation processes. In India and other ecologically diverse countries, comparative research across agro-climatic zones could help identify which combinations of natural regeneration, agroforestry, soil conservation and active restoration provide the most durable benefits. Improved use of remote sensing, LiDAR and field ecological data may also help distinguish temporary disturbance from persistent degradation.

CONCLUSION

Forest degradation and desertification are interconnected expressions of declining ecological resilience under combined human and climatic pressures. Forest degradation can occur without complete deforestation and may involve persistent changes in biomass, biodiversity, soil condition, hydrology and regeneration. Once vegetation and soil functions decline, the landscape can become more vulnerable to erosion, water stress, declining productivity and, in drylands, desertification.

Climate change intensifies these risks by increasing heat stress, drought pressure, rainfall variability and, in many settings, fire risk. At the same time, degraded ecosystems may have reduced capacity to recover from climatic extremes. The resulting interaction means that climate adaptation, forest conservation and land restoration should be planned together.

The evidence reviewed here indicates that no single intervention is sufficient. Durable progress requires a hierarchy of prevention, protection, sustainable land management and context-specific restoration, supported by community participation, monitoring and coordinated governance. Restoration should be judged by recovery of ecological functions and resilience rather than by tree-planting numbers alone. The Forest–Land

Resilience Framework proposed in this review provides a practical conceptual structure for linking these elements.

Ultimately, the long-term success of forest and land restoration will depend on whether societies can reduce the pressures that cause degradation while creating social and institutional conditions that allow ecosystems to recover. Protecting remaining ecological integrity, managing land within its capacity and restoring degraded functions are therefore complementary components of climate-resilient landscape management.

REFERENCES

1. AbdelRahman, M. A. E. (2023). An overview of land degradation, desertification and sustainable land management using GIS and remote sensing applications. *Rendiconti Lincei. Scienze Fisiche e Naturali*, 34, 767–808. <https://doi.org/10.1007/s12210-023-01155-3>
2. Bourgoin, C., Ceccherini, G., Girardello, M., Vancutsem, C., Avitabile, V., Beck, P. S. A., Beuchle, R., Blanc, L., Duveiller, G., Migliavacca, M., Vieilledent, G., Cescatti, A., & Achard, F. (2024). Human degradation of tropical moist forests is greater than previously estimated. *Nature*, 631, 570–576. <https://doi.org/10.1038/s41586-024-07629-0>
3. Dor-Haim, S., Brand, D., Moshe, I., & Shachak, M. (2023). Functional restoration of desertified, water-limited ecosystems: The Israel desert experience. *Land*, 12(3), 643. <https://doi.org/10.3390/land12030643>
4. Eliades, F., Sarris, D., Bachofer, S., Michaelides, S., & Hadjimitsis, D. (2024). Understanding tree mortality patterns: A comprehensive review of remote sensing and meteorological ground-based studies. *Forests*, 15(8), 1357. <https://doi.org/10.3390/f15081357>
5. Food and Agriculture Organization of the United Nations. (2025). *Global Forest Resources Assessment 2025*. Rome: FAO. <https://doi.org/10.4060/cd6709en>
6. Gunawardena, M. A., Lokupitiya, E., & Gunawardena, P. (2024). Land degradation neutrality and carbon neutrality: Approaches, synergies, and challenges. *Frontiers in Forests and Global Change*, 7, 1398864. <https://doi.org/10.3389/ffgc.2024.1398864>
7. Haregeweyn, N., Tsunekawa, A., Tsubo, M., Fenta, A. A., Ebabu, K., Vanmaercke, M., Borrelli, P., Panagos, P., Berihun, M. L., Langendoen, E. J., Nigussie, Z., Setargie, T. A., Maurice, B. N., Minichil, T., Elias, A., Sun, J., & Poesen, J. (2023). Progress and challenges in sustainable land management initiatives: A global review. *Science of the Total Environment*, 858, 160027. <https://doi.org/10.1016/j.scitotenv.2022.160027>
8. Intergovernmental Panel on Climate Change. (2019). *Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems*. Geneva: IPCC.
9. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. (2018). *The IPBES assessment report on land degradation and restoration*. Bonn: IPBES. <https://doi.org/10.5281/zenodo.3237392>
10. Kong, L., Xiong, K., Zhang, S., Zhang, Y., & Deng, X. (2023). Review on driving factors of ecosystem services: Its enlightenment for the improvement of forest ecosystem functions in karst desertification control. *Forests*, 14(3), 582. <https://doi.org/10.3390/f14030582>
11. Mansourian, S., & Stephenson, P. J. (2023). Exploring challenges and lessons for monitoring forest landscape restoration. *Current Landscape Ecology Reports*, 8, 159–170. <https://doi.org/10.1007/s40823-023-00092-z>
12. Mishra, N., & Baudh, K. (2024). Land degradation and development in India: Status quo, challenges, and opportunities. *Land Degradation & Development*. <https://doi.org/10.1002/ldr.5108>
13. Oraon, P. R., Sagar, V., & Beauty, K. (2023). Ecological restoration of degraded land through afforestation activities. In *Land and Environmental Management through Forestry*. Wiley. <https://doi.org/10.1002/9781119910527.ch8>
14. Qu, X., Li, X., Bardgett, R. D., Kuzyakov, Y., Revillini, D., Sonne, C., Xia, C., Ruan, H., Liu, Y., Cao, F., Reich, P. B., & Delgado-Baquerizo, M. (2024). Deforestation impacts soil biodiversity and

- ecosystem services worldwide. *Proceedings of the National Academy of Sciences*, 121(13), e2318475121. <https://doi.org/10.1073/pnas.2318475121>
15. Roy, P., Pal, S. C., Chakraborty, R., Chowdhuri, I., Saha, A., Ruidas, D., Islam, A. R. M. T., & Islam, A. (2024). Climate change and geo-environmental factors influencing desertification: A critical review. *Environmental Science and Pollution Research*, 31, 18642–18662. <https://doi.org/10.1007/s11356-024-32432-9>
 16. Stavi, I., Xu, C., & Argaman, E. (2024). Climate-smart forestry in the world's drylands: A review of challenges and opportunities. *Anthropocene*, 45, 100409. <https://doi.org/10.1177/20530196231182354>
 17. United Nations Convention to Combat Desertification. (2022). *Global Land Outlook, Second Edition: Land Restoration for Recovery and Resilience*. Bonn: UNCCD.
 18. United Nations Convention to Combat Desertification. (2026). *SDG Indicator 15.3.1: Proportion of Land That Is Degraded Over Total Land Area*. UNCCD Data Dashboard.