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REVIEW

Balancing Ecosystems and Economies: Advances in Environmental Resource Management under Sustainable Development Goals

Qing Wang [1], *Jingjing Chai* [2*]

[1] *School of Tourism and E-commerce, Baise University, Baise 533000, China*
[2] *School of Business Administration, Baise University, Baise 533000, China*

ABSTRACT

Expanding economic potential and protecting the environment, while facing mounting climate and biodiversity stress, is becoming the challenge of environmental resource management. This review explores developments and ongoing obstacles in six areas of resource of the Sustainable Development Goal (SDG) that include water; land, soils, and food systems; forests and terrestrial carbon biodiversity governance; oceans, coasts, and fisheries; biodiversity connectivity; and extractives and energy-transition supply chains. Most of the interventions continue to ignore ecological thresholds, accruing effects, and cross-system feedbacks, whereas monitoring systems focus on measures of activity rather than confirmed results. Conversely, sustained improvement is most frequently associated with integrated governance, which incorporates open measurement, implementation, rights-based participation, and fair distribution of benefits. Local conservation is often overwhelmed by market forces of demand and structural forces, including subsidies, supply chains, and investment in infrastructure, which fail to stop leakage or war, unless accountability mechanisms are in place. Climate change also aggravates set baselines and puts forward the importance of adaptive regulation, spatial planning, and diversified portfolios, which combine engineered reliability with ecosystem resilience. The review brings out current SDG priorities, which include outcome-based indicators, causal evaluation, governance structures that enhance legitimacy, and transition planning that harmonizes the mineral sourcing, renewable deployment, biodiversity, and water limits. Combined, these observations indicate that striking the balance between ecology and economy is possible when ecological boundaries are

*CORRESPONDING AUTHOR:
Jingjing Chai, School of Business Administration, Baise University, Baise 533000, China; Email: chaijingjing@bsuc.edu.cn

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under consideration as binding constraints and equity is perceived as a source of sustainability.

Keywords: Sustainable Development Goals; Environmental Resource Management; Ecosystem Services; Governance and Equity; Climate Adaptation

1. Introduction

In both high- and low-income areas, environmental resource management is increasingly characterized by one conflict: economies need to grow and stabilize the level of economic opportunity, and not to cross the ecological boundaries that are becoming narrower due to climate change, land conversion, biodiversity loss, and pollution [1]. This has commonly been cast as a decision between ecosystems and economies, but this is a misguided notion in two aspects. To begin with, neither water security, soil fertility, coastal protection, climate regulation, nor biodiversity is external to economies: production, health, and resilience are based on ecosystems. Second, most significant decisions are hardly ever made regarding whether to save nature or develop the economy, but regarding the way of confronting trade-offs and unlocking synergies across sectors, scales, and time horizons, particularly when the benefits and the burdens are not distributed equally.

The Sustainable Development Goals (SDGs) are a realistic, though not flawless, roadmap in trying to keep these tensions at bay. The SDGs explicitly incorporate the fact that development and environmental management should go hand in hand by linking environmental objectives (e.g., SDG 6 clean water, SDG 13 climate action, SDG 14 life below water, SDG 15 life on land) to economic and social ones (e.g., SDG 7 affordable energy, SDG 8 decent work, SDG 12 responsible consumption and production) [2,3]. Simultaneously, the SDGs increase the pressure on resource management, as advances in one of the goals may harm the development of another if policies are established separately. Expansion of Irrigation has the potential to increase food production and destroy rivers and wetlands. Renewable energy placement has the potential to hasten decarbonization and can break up habitats or occupy land and water. Coastal development has the potential to increase the revenues of tourism but diminishes natural defenses, which minimize the risk of a disaster. They are not peripheral issues; they are the structural aspects of the development paths in a world where resources are limited.

The core of this SDG coherence issue is environmental resource management (ERM) [4]. Here, the notion of ERM comes in whereby the array of strategies, institutions, and tools can be employed to manage the natural resources such as water, land and soils, forests, fisheries and coastal systems, biodiversity, and mineral/energy resources in a manner that ensures the ecological functions are preserved as societies achieve material needs and economic aspirations. ERM in the past has typically been sectoral, operationalized by distinct agencies, policies, and data systems, and has very little ability to assess cross-sector interactions. However, the forces that define resource performance are growing in their interactions: agricultural intensification changes water demand and quality; land-use change transforms flood risk and carbon processes; coastal ecosystem degradation generates new environmental footprints and social struggles; and global energy transition raises minerals and infrastructure demand, creating new environmental footprints and social struggles. In this respect, ERM is moving towards becoming multi-objective governance, aiming at resilience, equity and ecological integrity as well as economic performance (as opposed to single-objective optimization (maximize yield, maximize growth, minimize cost) [5].

Recent advances make this transition more feasible than it was even a decade ago. Monitoring and accountability have improved through Earth observation, sensor networks, biodiversity assessment technologies, and digital reporting systems. Decision-making is increasingly supported by integrated modeling, scenario analysis, and multi-criteria approaches that can compare options under uncertainty and incorporate distributional impacts. Policy toolkits have broadened beyond command-and-control regulation to include economic instruments (such as payments for ecosystem services and reforms to environmentally harmful subsidies), corporate and supply-chain commitments, and blended finance mechanisms that channel capital toward restoration and sustainable infrastructure. Community-based and rights-based approaches have gained visibility, emphasizing the importance of legitimacy, tenure security, and co-management in sustaining environmental outcomes over time. Meanwhile, "nature-based solutions" and restoration initiatives are being promoted as pathways to deliver climate, biodiversity, and livelihood benefits simultaneously—though evidence also highlights risks of over-claiming benefits, weak permanence, or social exclusion when projects are poorly designed [6].

Despite this momentum, the literature remains fragmented in ways that hinder cumulative learning. Evidence is often siloed by sector (water, land, forests, fisheries), by intervention type (protected areas, market instruments, infrastructure), or by outcome category (ecological indicators vs. economic indicators vs. social indicators). Studies frequently emphasize short-term or local outcomes while omitting leakage, rebound effects, governance durability, or long-run ecological thresholds [7]. Economic analyses can underrepresent non-market values and distributional justice; ecological analyses can underrepresent feasibility, costs, political economy, and the incentives that drive implementation. As a result, practitioners and policymakers face a practical question that is not consistently answered by any single discipline: Which management approaches reliably improve environmental conditions without sacrificing economic opportunity, under what conditions, and with what safeguards for equity and long-term resilience?

This review addresses that question through a sector-and-tool synthesis aligned with the SDGs, focusing on real-world management challenges and decision levers rather than idealized solutions. We organize the evidence around six resource domains that anchor the SDG implementation landscape: (i) water resources, (ii) land, soils, and food systems, (iii) forests and terrestrial carbon–biodiversity governance, (iv) oceans, coasts, and fisheries, (v) biodiversity conservation and ecological connectivity, and (vi) extractives and energy-transition resource systems, including circularity strategies. These domains are not independent; they interact through shared drivers (climate risk, demographic change, markets, governance capacity) and through physical linkages (watersheds, land–sea flows, habitat corridors, supply chains). Yet each domain also has characteristic decision points and failure modes that matter for policy design: allocation rules and environmental flows in water management; tenure and incentives in land and soil restoration; enforcement and demand-side leverage in forests and supply chains; spatial planning and compliance in marine systems; connectivity and coexistence in biodiversity governance; and siting, permitting, and mitigation hierarchies for mining and energy infrastructure. **Table 1** summarizes the six resource domains reviewed in this article, the dominant pressures acting on each system, their primary SDG linkages, and the management levers and failure modes most consistently reported across the literature [8–10].

Table 1. Scope map of resource domains, pressures, and levers.

Resource Domain (Section)	Core Ecological Assets	Dominant Pressures	Primary SDGs	Common Management Levers Emphasized in This Review	Typical "Failure Mode" If Misdesigned
Water (2)	River flows, aquifers, wetlands, water quality	Scarcity, drought/flood extremes, nutrient loads, groundwater overdraft	6, 2, 13	Allocation reform, environmental flows, demand management, reuse, hybrid green–gray portfolios, basin governance	Efficiency gains without depletion reduction; weak enforcement; ignored groundwater–surface water linkages
Land/Soils/Food (3)	Soil organic matter, nutrient cycling, landscape multifunctionality	Erosion, salinization, land conversion, input pollution, market-driven expansion	2, 12, 15, 13	Regenerative practices, restoration, spatial planning, tenure security, demand-side measures	Rebound/leakage; hectare-based "restoration" without functional recovery; exclusionary land governance
Forests (4)	Carbon stocks, habitat complexity, hydrological regulation	Commodity expansion, illegal logging, fire/disturbance, infrastructure	15, 13, 12	Protected areas/OECMs (other effective area-based conservation measures), community forestry, supply-chain controls, carbon/PES with safeguards, adaptive disturbance management	"Paper parks"; weak integrity in crediting; displacement; carbon-centric monocultures
Oceans/Coasts/Fisheries (5)	Fish stocks, coastal habitats, marine connectivity	Overfishing, habitat loss, pollution, warming/acidification, coastal hazards	14, 2, 13	Rights-based/co-management, MSP, habitat restoration for risk reduction, pollution prevention	Static rules under shifting stocks; MSP without enforcement; upstream pollution unaddressed
Biodiversity/Connectivity (6)	Species/populations, corridors, refugia	Fragmentation, cumulative impacts, conflict, climate-driven range shifts	15, 14, 13	Networked protection, connectivity planning, coexistence strategies, credible monitoring/finance	Coverage targets without outcomes; offsets substituting irreplaceable ecosystems; conflict undermining durability
Extractives/Transition (7)	Water/land/biodiversity in resource frontiers	Mining footprints, tailings risk, renewables/transmission siting, material demand	7, 8, 12, 13, 15	Strategic siting, cumulative impact governance, mitigation hierarchy, circularity, rights/benefit-sharing	Project-by-project approvals; long-term liabilities externalized; "green" supply chains reproducing injustice

A core premise of this review is that "balancing ecosystems and economies" cannot be reduced to a single metric or universal policy prescription. Instead, the balance is shaped by three recurring features of ERM decisions. The first is trade-offs across time. Many interventions produce near-term economic gains while creating long-term ecological debt (e.g., groundwater depletion, soil degradation, habitat fragmentation). Conversely, some conservation or restoration actions impose near-term costs but yield long-term benefits in productivity, risk reduction, and resilience. The second feature is trade-offs across space and scale, including displacement (leakage) of impacts to other regions, sectors, or communities. The third feature is trade-offs across groups, reflecting differences in power, rights, and vulnerability. Policies that appear efficient in aggregate can be regressive in distribution, undermining legitimacy and long-run effectiveness. A credible SDG-aligned ERM approach therefore requires both biophysical realism (thresholds, cumulative impacts, uncertainty) and social realism (institutions, incentives, equity, political economy) [11].

Within that framing, this review contributes in three ways. First, it synthesizes advances in ERM as they are applied within each major resource domain, emphasizing what is known about effectiveness, scalability, and common failure modes rather than cataloging interventions. Second, it draws cross-sector lessons about the enabling conditions that repeatedly determine whether "co-benefits" materialize—such as enforcement capacity, transparent monitoring, adaptive management, secure tenure and rights, stakeholder legitimacy, and financing that rewards long-run outcomes rather than short-run outputs. Third, it foregrounds the SDG lens by treating environmental and economic objectives as jointly relevant performance criteria and by highlighting where SDG interactions tend to be synergistic, conflictual, or highly context-dependent.

The rest of the article is presented in the following way. Section 2 is a literature survey of the progress in water resources management, the allocation in times of scarcity, water quality, basin-scale governance, and flood and drought resilience. Section 3 analyses land, soils, and food systems, including drivers of degradation, restoration, regenerative activities, and the social circumstances that inclusiveness and tenure contribute to the outcomes, namely, social conditions. Section 4 deals with forests and terrestrial carbon-biodiversity governance, which connects the dynamics of deforestation, community and protected area models, and market leverage, including certification and deforestation-free pledges. Section 5 considers oceans, coasts, and fisheries and reviews the management inventions, spatial planning in the marine environment, protection of the habitat, and new demands related to pollution and climate-related changes in fish stocks. Section 6 is centred on biodiversity and connectivity, paying attention to the effectiveness, monitoring issues, coexistence, and economic routes along which biodiversity protection is frequently legitimized or funded. Section 7 then brings together the fast-changing field of extractives and the energy transition, such as environmental footprints of minerals, permitting and siting trade-offs, social license and rights, and the promise and limits of circular economy strategies. Lastly, Section 8 incorporates cross-sector knowledge in an application of a set of decision principles and future research focus to enhance the outcome of SDG-aligned resource management. Building on this framing, **Figure 1** conceptualizes environmental resource management as a coupled social–ecological system in which pressures, governance instruments, and outcomes feedback across time and scale, shaping SDG coherence [12].

Ultimately, ERM under the SDGs is not a question of finding a perfect equilibrium between nature and growth. It is the ongoing task of designing institutions, incentives, and measurement systems that (i) respect ecological thresholds and cumulative impacts, (ii) create durable economic value compatible with those limits, and (iii) distribute benefits and risks in ways that are legitimate and just. The advances reviewed here suggest that achieving this is increasingly possible—but only if interventions are evaluated and governed as components of coupled social–ecological systems, rather than as isolated projects or single-sector reforms.

2. Water Resources: Allocation, Quality, and Basin-Scale Resilience (SDG 6, SDG 2, SDG 13)

Sustainable development revolves around water, as it connects human health, food systems, energy production, industrial growth, and ecosystem integrity through a shared biophysical medium [13]. However, in contrast to most other environmental resources, water is both a stock and a flow that traverses across jurisdictions and sectors as well as transformations in form, quality, and timing. This fluidity reverberates, such that coordination failure is particularly sensitive to water management, with each decision being made independently, like extending irrigation, locating industry near rivers, or even constructing upstream storage, to contribute to ecological degradation, increase flood risk, deplete groundwater, and cause conflict downstream. In the SDGs, however, water governance is not simply an increase in access to safe water and sanitation (SDG 6), but of ecological processes that make a reliable water supply, buffer the variability of the climate, and support agriculture and livelihoods available in a warming world (SDG 2) (SDG 13).

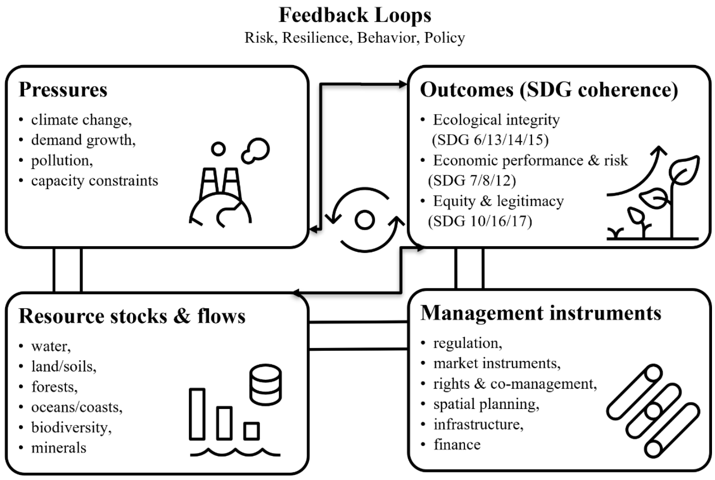

Figure 1. Conceptual framework linking ecosystems, economies, and SDG coherence.

2.1. Allocation under Scarcity and Variability

Modern water allocation is either on a chronic scarcity basis or a basis of extreme variability. Fueled by climate change, which alters the precipitation patterns, escalates evaporative demand, and alters the frequency of droughts and extreme rainfall events, as well as the growing population and increasing economic development, intensify low-level requirements. Central allocation dispute has ceased sharing water in abundance in normal years and fends off shortages in extended dry seasons, allowing no fewer than two basins to adequately carry out their functions without interrupting aquatic life itself or devastating the livelihood system its clients depend on. This has rekindled interest in the allocation regimes that are more explicitly focused on ecological demands, including environmental flows that sustain minimum habitat conditions, temperature regimes, sediment transport, and connectivity of aquatic species. Practically, the implementation of environmental flows must rely on the legalization of ecological water requirements and enforceability of rules that can withstand drought politics and operations flexibility so that managers can increase or decrease releases with changes in conditions [14].

Weaknesses in the legacy water rights systems are also revealed by scarcity, which was more suited to hydrology and less competitive. Every prior appropriation, riparian rights, customary entitlements, and administrative permitting entail some assumption regarding the priority, transferability, and execution ability. These systems can under stress lock in historical allocations that are not in touch with contemporary societal values, they are disproportionately protective of powerful users, or they can promote a use-it-or-lose-it behavior that is rewarding waste. Reforms allowing water to be reallocated using water markets, leasing, negotiated transfers, or drought-sharing arrangements can be effective in improving the economic efficiency of shifting water to high tier uses, however, they also carry the risk of inequity, third-party effects, and ecosystem harm when transporting transactions neglect the importance of return flows, interactions amidst groundwater and surface water, or cumulative withdrawals. In any markets that are encouraged, the critical design challenge is to seek an open accounting, environmental protection, and social protection that eliminates the transfer of harms to the marginalized populations or downstream ecology [15].

Governance of groundwater is the catch-all solution to the allocation outcome since aquifers are long-term buffers, as well as long-term liabilities [16]. The pumping of groundwater may provide stability to production and incomes and make everything steady when surface water supply is not reliable, yet prolonged overdraft leads to declines in resilience, high energy expenses, land subsidence, deterioration of water quality via salinization or freezing movement of contaminants, and diminished baseflows to sustain rivers and wetlands. Dispersed wells, inadequate control, and political opposition leave many aquifers poorly regulated. New governance strategies focus on metering, pumping caps and recharge, managed aquifer recharge, and collective management institutions that reconcile individual incentives of aquifer sustainability. These approaches are dependent on plausible measuring, enforceable regulations, and legitimacy of governance, especially in situations where smallholders use groundwater to have livelihood security.

As a key tenet of allocation strategy, demand management has become more central because expanding the supply is becoming more and more expensive, disruptive to the environment, or even vulnerable to climate change [17]. The withdrawals can be minimized by urban leakage, tiered pricing, appliance standardization, industrial water recycling, and agricultural efficiency improvement, although the practices are context-specific. The benefits of efficiency do not necessarily lead to water efficiency at the basin-wide level since the water conserved can be either re-allocated to increased production, or transferred to other consumers or decrease return flows, an effect that makes simple efficiency vs. sustainability narratives more complex. In agriculture, where the vast bulk of consumptive use is usually done, the critical difference is between decreasing withdrawals and decreasing consumptive use; merely switching the mode of conveyance or application can be followed by an increment in crop production without a decrease in depletion. The SDG-compatible allocation, therefore, demands a form of accounting that identifies consumptive use and ecological flow requirements and not just diversions.

2.2. Water Quality Management and Pollution Control

Although scarcity has received most attention in drought, water quality deterioration may place an equally binding developmental and ecosystem constraint [18]. The impact of pollution is that it lowers the supply that can be used, raises the cost of treatment, erodes fisheries and recreation, and creates chronic health impacts that are disproportionately experienced by poorer communities. The water quality problems have changed more so than before, where point source industrial and municipal discharges can be easily regulated and treated, to complex blends of nonpoint pollution such as agriculture, diffuse urban runoff, and past contaminants that are stored in the sediments and soils.

The case of nutrient pollution is an example of the complexity of governance of water quality in the SDGs [19]. Nitrogen and phosphorus runoffs are fueled by fertilization in the landscape, leading to eutrophication, harmful algae blooms and hypoxic regions that harm biodiversity and local economies. Since the sources are scattered and sporadic, a comprehensive management of the watershed (i.e., a portfolio of interventions) may be needed: fertilizer timing and placement, riparian buffers, wetland renovation, better manure management, and stormwater systems. However, the effectiveness of these interventions lies in the incentives to adopt them, the capability to enforce them, and the fact that the decision-making made at the farm level should be associated with the downstream outcomes. Voluntary-only programs can be used to achieve uneven outcomes, and those which require strict regulation may have political resistance and monitoring limitations. Increasing options to use standards, technical assistance, costs sharing and outcome-based incentives as hybrids are more and more discussed, but they require a strong monitoring process to check actual decreases and prevent the shift of pollution either spatially or temporally.

Urban water quality governance has also come to be known to extend the traditional wastewater treatment to stormwater management and to new contaminants. The increased rainfall may overload combined sewer systems; the impervious surfaces increase the rate of runoff of hydrocarbons, heavy metals, and pathogens. The response by many cities has been the provision of green storm water infrastructure which resembles natural hydrology including bioswales, permeable pavements, and urban wetlands [5]. These are measures that can enhance the local water quality and reduce the flood peaks with co-benefits like cooling and amenity value; however, the performance of these measures can vary due to their design, maintenance, and the degree of adoption. In the meantime, such contaminants as pharmaceuticals, microplastics, and industrial chemicals are challenging in terms of their detection and treatment, and they are often ahead of regulation systems. To deal with these pollutants, better treatment technologies are necessary, but in combination with upstream measures in product design or industrial practice and waste management, connecting water quality with SDG 12 of responsible consumption and production.

Equity, too, has an intersection with water quality that makes technical solutions challenging [20]. Those communities that have no political influence may have poor infrastructure investment, less effective enforcement on polluters, or be more at risk of receiving contaminated supplies. A water management that is SDG-sensitive, therefore, is placing more and more focus on distributional monitoring, transparent reporting, and governance mechanisms that help the affected community to prioritize, challenge risks, and obtain remediation.

2.3. Infrastructure Choices and the Rise of Hybrid Water Portfolios

Historically, one of the leading approaches to the security of water and the promotion of economic activity was large-scale water infrastructure, such as dams, canals, levees, treatment plants, desalination, and inter-basin transfers [21]. Such projects can provide considerable benefits yet they also create ecological and social effects in terms of changed flow regimes, interrupted sediment transport, obstructed migration corridors and displacement of communities. With increasing allocation of basins and increasing risks posed by climate, the query has moved out of development additional infrastructure and toward redesigning portfolios that are resilient and lower effect and adaptable to uncertainty.

Green infrastructure and nature-based solutions have become the focus of attention as an addition or alternative to the conventional gray infrastructure. Restoration of watersheds, reconnecting flood plains, wetland, and reforestation can be used to increase the infiltration and decrease the erosion, moderate flood levels, and improve the water quality [22]. The benefits of such interventions are frequently viewed as cost-effective and multi-benefit, particularly in the case of long-time horizons and multi-objectives. Nevertheless, their performance is relative and could be exaggerated in case the maintenance, land opportunity costs and governance limitations are not considered. Green infrastructure is most useful in certain environments in hybrid systems that incorporate engineered dependability and ecological buffering. Hybrid portfolios also have a reduction in single-point failures by spreading risk among various assets and levels.

Water reuse and recycling are also another significant development of sustainable portfolios especially when it comes to urban and industrial systems [23]. By having wastewater treated to appropriate levels and using it to irrigate agricultural lands, power industries or indirectly producing drinking water, the pressure on freshwater supply can be decreased and drought-resistance enhanced. The encumbering factors are usually the people acceptance, the energy needs, the financial ability, and the regulatory power to provide the safety. Desalination also offers a climate resistant supply alternative to the coastlines, yet poses issues in energy intensity, implications in greenhouse gases, disposal of the brine, and cost. According to SDG, these technologies should become a part of resiliency only when they are incorporated in decarbonization policies and when they are not costly in terms of creating disparities in access.

The management of flood risk is also changing as a concern with structural protection to more integrated methods that see value in residual risk and room-for-river strategies. Frequent floods can be mitigated with levees and floodwalls, but the catastrophe risk may be enhanced with the encouragement of floodplain developments or a collapse during extreme events. Flood management is also integrated to combine structural controls and land-use planning, early warning infrastructure, insurance, and restoration of the floodplain, which reduces flood volumes yet increases ecosystems [24]. The economic justification in such approaches can be based on damages avoided, but ecological and social co-benefits may be large, provided such benefits are famously measured and regulated.

2.4. Basin-Scale and Transboundary Governance

Since water flows shared among users and jurisdictions, the institutional support of sustainable management is basin-scale governance. It has been a long-held belief that integrated water resources management (IWRM) is a viewpoint that can be used to align the allocation, quality, and ecosystem goals, yet there has been uneven implementation because of institutional fragmentation, weak enforcement of the idea, and constraints of the political economy. Basin entities are able to enhance coordination through avenues of sharing of data, collective planning, and dispute resolution although their success relies on authority, consistent funding and validity. The governance of basins is in most cases limited by the lack of administrative match to hydrological reality and mismatch of sectoral requirements that favor agriculture, energy, or urbanized supply with the ecological costs not factored in [25,26].

These coordination problems are heightened by transboundary basins. Costs are downstream in the form of upstream infrastructure, withdrawals, and pollution and are upstream in the form of downstream dependence. Cooperation can be stabilized with formal treaties and river commissions which can clarify rights, responsibilities but they often find it difficult to respond to a climate-related hydrological change, changing demand, or a scientific change of ecological limits. Governance is increasingly shifting towards more benefit-sharing forms that do not rely on fixed and volumetric allocation but rather on sharing the fruits of collaboration, like mutual hydropower earnings, drought management or collaborated investment in watershed protection [26]. It is based on data transparency and shared monitoring because the lack of trusted information can cause cooperative regimes to degenerate into accusations and strategic behavior.

The basin governance is equally based on participation and rights [27]. Water decisions are regularly involved with indigenous people, the rural areas, and the urban neighborhoods that have little political influence. In the absence of these groups in the governance processes, a project might be resisted, non-compliant or even socially conflictual and thus not be durable. On the other hand, increase in legitimacy and long-term stewardship through co-management and acknowledgement of customary rights can work especially when accompanied by capacity building and significant benefit reimbursement. Basin governance is seen in the SDG context, therefore, as much of a social and institutional challenge as it is of a hydrological one.

2.5. Evidence Patterns, Persistent Gaps, and Directions for SDG-Aligned Water Management

When it comes to allocation, quality, infrastructure, and governance, one common theme that can be found in the literature is that technical solutions are hardly ever successful without institutional alignment and plausible accountability. The interventions are more likely to work well when they are entrenched in the governance structures capable of quantifying the variables of interest, applying the rules, adjusting to learning, and coordinating the distributional effects in a transparent way. On the other hand, typical problems of failure are underestimating cumulative effects, ignoring groundwater-surface water connections, using indicators that measure inputs, and believing that efficiency turns directly into sustainability. These failures may be increased by short planning horizons and divided power, especially in cases where political rewards encourage visible projects and less visible institutional reforms such as monitoring, maintenance, and enforcement [28].

An important infrasound of frontier of SDG-focused approaches to water management is elaborating decision structures with a clear sense of uncertainty and ecological frontiers [29]. The rising level of climate variability and extremes is augmenting the worth of adaptable rules, adaptive allocation, and portfolios that can act upon the shifting conditions without undermining the ecosystem integrity. The other boundary is to enhance accountability by creating scientifically plausible and socially believed monitoring including being transparent on trade-offs and distributional consequences. Lastly, funding and execution capacity are conclusive. Many basins do not have the fiscal space, technical know-how or institutional stability to maintain investments and impose regulations even when they know how to do so. To counter such limitations, water planning has to be supplemented with the wider strategies of development, incentives across the board have to be harmonized, and the ecological needs of water must not be seen as constraints, but as pre-requisites of an economically resilient future.

3. Land, Soil, and Food Systems: Degradation, Restoration, and Sustainable Intensification (SDG 2, SDG 12, SDG 15, SDG 13)

Land systems are found between the most significant interactions in the SDGs, as they are the point of food security, rural livelihoods, biosafety, and climate mitigation and adaptation [30]. Land use and land management modifications transform the hydrological regulations, the storage of carbon, the connectivity of habitats, and nutrient cycling, as well as productivity, employment, and allocation of economic opportunity. The complexity of governing land systems under the SDGs is magnified by the reality that land is a scarce resource that is subject to a variety of demands, and land outcomes are the result of choices by a heterogeneous group of actors that are constrained, motivated, and entitled by different things. Consequently, achievement of SDG 2 (food security and sustainable agriculture) may conflict with SDG 15 (terrestrial biodiversity and ecosystem integrity) in case growth or intensification destroys habitats, exhausts soils, or is more polluting. Simultaneously, effective interventions can produce synergies by enhancing productivity within the current agricultural land, rehabilitating degraded land, and enhancing climate shock resilience (SDG 13) and lessening supply chain waste and environmental footprints (SDG 12).

3.1. Patterns and Drivers of Land Degradation

Land degradation is neither an isolated process nor a single one that is independent, but rather a family of interacting dynamics that worsen the ability of land to confer ecosystem services and withstand production [31]. Water and wind erosion, loss of nutrients, salinization, acidification, compaction, and loss of soil organic matter all result in decreased productivity and exposure to drought and excessive rainfall. These are usually co-located and might be supported by land cover transformation, excessive grazing, improper tillage, inadequately controlled irrigation, and conversion of natural ecosystems to agricultural land and pastures. In most drylands and semi-arid areas, the process of degradation is highly linked with the variation of rain and heat, where climate change leads to an escalation of land systems to the level where recovery is slow and expensive.

Socioeconomic agents are often the ones that dictate where the degradation concentrates and how fast it occurs [32]. Poverty, insecure tenure, low access to credit, and poor extension services may result in short-term coping mechanisms that increase long-term land degradation such as cultivation of marginal lands and a decline in fallow. On the other hand, a short fuse approach to commercializing agriculture can lead to faster intensification and growth in areas that have failed to internalize the costs of the environment due to a lack of proper governance. Expanding the infrastructure and integrating the market can raise land values and encourage land conversion, and also allow the adoption of technologies to increase yields. These forces can develop complexity of routes where certain regions are in a state of degradation spirals and others an area of land recovery through investment, policy support, or abandonment through migration. Knowledge of these heterogeneous pathways is critical to SDG-oriented land management since interventions that can be successful in capitalized commercial systems might not be successful in the smallholder landscape, where the major constraints are institutional and financial, rather than technical.

Measurement and monitoring continue to pose a point of concern since degradation is sometimes slow, spatial, and cannot be outlined with just one gauge [32]. Recent progress in remote sensing has enhanced the possibility of identifying land cover change, vegetation dynamics and certain proxies of soil condition, but numerous important properties, such as soil organic carbon, salinity and compaction remain ground trusted and situation-dependent. This measurement gap is important as it influences targeting, evaluation and accountability. When indicators like greenness are monitored, they might be on more easily visible indicators, then potentially overlook greater soil degradation or they could classify seasonal changes as recovery. Implementation of SDGs more and more involves integrated monitoring, which makes use of both Earth observation and field measurements in combination with socio-economic data, so that ecological change, as well as livelihood outcomes and distributional effects, can be measured.

3.2. Sustainable Intensification and the Productivity–Environment Frontier

It has been suggested that sustainable intensification is a way forward to the reconciliation of food production and environmental objectives, that is, through higher yields and efficiency in the use of available agricultural land, instead of opening up to natural ecosystems. Conceptually, the reduction of pressure on land conversion can be done through the closure of yield gaps, which preserve habitats, whereas pollution can be minimized and resilience can be restored through better nutrient and water management. As a matter of fact, results are relative, and they depend on the interactions of productivity gains with markets and policies, and land governance [33].

Precise nutrient management, enhanced varieties, combined pest management, conservation agriculture, agroforestry, and rotated diversification are part of the agronomic advancements that stabilize production and enhance the soil structure[34]. Most of these methods have the potential to boost soil organic content and water retention and, thus, minimize exposure to heat and drought. They are also capable of reducing the cost of inputs and enhancing the profitability of the farmers in case the barriers to adoption are overcome. The environmental advantages of intensification, however, are contingent on whether or not it leads to a reduction in land expansion and consumptive water use or whether it leads to an increase in profitability and an expansion, an increase in stocking rate, or an increase in the intensity of input utilization. This bounce back phenomenon is especially relevant in situations where land is plentiful, the state is weak, and the demand on the commodities is on its way up. In these contexts, the intensification may co-exist with deforestation not preclude it, meaning that sustainable intensification should be accompanied by land-use regulation, implementation, and supply-chain responsibility in case it should provide SDG 15 co-benefits.

The other recurrent problem is the fact that efficiency at field scale does not necessarily translate into a decrease in environmental pressure at the landscape scale. An increase in irrigation efficiency can lead to higher yields, though it can decrease flow back to the downstream ecosystem. Nutrient-use efficiency can reduce losses per unit production, as well as total nutrient loading, which increases because of increased production. These scale discrepancies demand basin- and landscape-scale accounting concerning the absolute pressures on a system, including total nutrient loading and groundwater depletion, and land conversion, instead of scales that rely on metrics of intensity. Other uses of such accounting, as per SDG 12, may also concern consumption-side strategies and plans, such as dietary changes, food loss reduction, and waste reduction, which can reduce pressure on land systems by decreasing demands on resource-intensive commodities[35].

3.3. Restoration Pathways and the Politics of "Net Gain"

Land restoration has become a cornerstone of SDG narratives, ranging from reforestation and afforestation initiatives to rangeland rehabilitation, wetland restoration, and regenerative soil practices. Restoration is attractive because it promises multiple benefits: improved soil fertility, enhanced biodiversity, increased carbon sequestration, reduced erosion, and improved water regulation[36]. Yet restoration outcomes vary widely, and the concept itself is contested when it is used to justify ongoing degradation elsewhere under "net gain" or "offset" logic.

Ecologically, restoration success depends on baseline conditions, species selection, hydrological context, disturbance regimes, and the time horizon of evaluation. Reforestation in water-limited environments can reduce streamflow and groundwater recharge, illustrating that carbon-oriented restoration can conflict with water objectives if not carefully designed. Similarly, afforestation with monoculture plantations can increase biomass while providing limited biodiversity value and sometimes increasing fire risk. In contrast, restoration that prioritizes native species, connectivity, and ecosystem function tends to deliver broader ecological benefits, but may require longer time horizons and higher upfront costs. The SDG challenge is to design restoration portfolios that recognize ecological heterogeneity and prioritize areas where restoration is both feasible and socially legitimate[37].

Socially, restoration interacts with land rights and livelihoods in ways that can determine durability. Projects that restrict access to land without credible compensation or alternative livelihoods can produce conflict and undermine outcomes through non-compliance or sabotage. Conversely, restoration that improves tenure security, supports local institutions, and provides tangible benefits—such as improved grazing conditions, diversified income from agroforestry, or reduced flood risk—tends to be more resilient. Financing is also a key determinant. Where restoration is linked to carbon finance or ecosystem service payments, questions of additionality, permanence, and benefit-sharing become central, as does the risk that external capital reshapes land governance in ways that marginalize local users. These concerns are particularly salient where customary rights are weakly recognized or where land governance is characterized by contested claims[38].

The growing emphasis on "land degradation neutrality" and restoration targets can create incentives to prioritize easily measured activities over meaningful outcomes. For example, hectares "restored" may be reported even when ecological function does not recover, or when interventions merely shift pressures to adjacent lands. This points to the need for outcome-based monitoring that tracks soil health, biodiversity, hydrological function, and livelihood impacts over time, rather than focusing on implementation metrics. It also underscores the importance of distinguishing between restoration as ecological recovery and restoration as land-use change that may create new trade-offs.

3.4. Multifunctional Landscapes and Spatial Planning for SDG Coherence

The fact that land provides several services at the same time means that the concept of land management that is managed under the SDGs is progressively focusing on a multifunctional landscape, instead of single-use zoning. This practice acknowledges that the pursuit of the maximization of a single goal, say the production of commodities, may undermine other services, which eventually contribute to long-term welfare, such as pollination, water control, and climate creation. The multifunctionality is sought by the spatial planning that should match the land use to the ecological appropriateness and connectiveness accompanied by taking into consideration the social needs, infrastructure, and markets [39].

Landscape strategies are usually a mixture of core areas that are either protected or conserved and sustainable production zones, and buffers that are restored to minimize edge effects, erosion and pollution [40]. Agricultural mosaics have the potential to increase the connectivity and heterogeneity of habitats, which in turn benefits the biodiversity without reducing production in agro forestry and diversified farming systems. Adaptive grazing management can be used in the rangelands to ensure vegetation cover and soil carbon are preserved whilst supporting pastoral livelihoods. Such strategies need governance arrangements that are able to coordinate the property boundaries and are able to reconcile the competing interests, which is usually achieved through community-based institutions, watershed councils, or jurisdictional programs that are connected to the supply chains.

Spatial planning is also at the heart of controlling the leakage and displacement. Conversion pressures might be redistributed elsewhere and that might have a nattier impact with the net effect of conservation in one location offsetting demand elsewhere. To manage leakage, it is necessary to align land-use governance with market incentives, i.e., deforestation-free procurement, traceability systems, and jurisdictional certification models that compensate regions based on their performance towards environmental performance standards. These systems do not however, work without the involvement of credible monitoring and enforcement, and can ostracize smaller producers in the event that compliance becomes very expensive. Spatial planning that supports SDGs must consequently be formulated in a way that does not strengthen inequality, that is, such that smallholders and indigenous people can take part and gain advantages instead of being replaced by large players with more potential to comply [41].

3.5. Tenure, Inclusion, and the Distribution of Costs and Benefits

The questions of rights, legitimacy and distribution determine whether land interventions are successful or not. The security of tenure affects the long-term soil health and renewal of land and soil users, their access to credit or payment programs, and security against eviction. Unsecured tenure may provide incentives to extract short-term and may facilitate the elite capture of benefits of conservation finance, agricultural modernization projects or infrastructure projects. On the other hand, the incentives of stewardship can be enhanced, conflicts alleviated, and more acceptable development outcomes promoted by clarifying and recognizing customary and indigenous rights [42].

Inclusion is not only a functional requirement but also normative. A land policy that is formulated without significant involvement is prone to misdiagnosing the constraints, putting strains on those least able to tolerate, and undermining trust in the policy that is necessary to compel adherence to it. The gender relations are of special concern in most agrarian settings where females can be the key actors in the production and resource allocation, but have no official right to the land and authority. When aggregate productivity is increased, programs that do not deal with these asymmetries may increase inequality. Distributional analysis and safeguards under the SDGs are thus part of the plausibility of land-based interventions, particularly those that focus on land use limitations or the commercialization of ecosystem services [43].

In rural areas, economic transitions make distributional outcomes even more difficult. Maybe some incomes can grow due to the processes of mechanization, commercialization, and entering into global value chains, and others might be deprived of labor or land concentration may grow. Land policies play along in these transitions; this way, access to markets, inputs, and finance is determined. The land management will be SDG-friendly with a specific focus on the matters of distribution of benefits among the land users, workers, and communities, and the policies that can be provided to achieve indicative progression, such as cooperative models, easy access to extension services, and finance tools implemented to address the needs of smallholders [43].

In the literature, one of the common understandings is that land-based solutions cannot be measured in terms of biophysical performance or their short-term effects on yield. They should be evaluated as joint social-ecological interventions, the results of which rely on governance capacity, market dynamics, and rights. The most effective interventions are those that include both on-farm or local practice enhancement and landscape-level planning to conserve and safeguard ecosystems of great value and ensure displacement is avoided [40]. They further fare better when implementation proxies are not used, but instead absolute pressures and outcomes are tracked by monitoring systems, i.e., the conversion of land, the carbon paths of soil, and the nutrient loading.

The other theme that is repeated is that climate change elevates the importance of soil health and landscape heterogeneity as sources of resilience [44]. Practices that enhance soil organic matter and a structure can withstand drought and cause erosion in case of extreme rainfall, whereas diversified systems can make systems less susceptible to pests and climate shocks. However, access to knowledge, money and safe rights determines the possibility of the adoption of such practices, which means institutional changes and capacity building are frequently a precondition of ecological benefits.

Lastly, the SDG framing emphasizes the fact that the demand side policies are not secondary concerns but are central to the sustainability of land. Food loss and waste, supply-chain efficiency, and consumption patterns can be reduced to reduce pressure to expand, and to make the trade-offs between food and biodiversity difficult. Such measures, together with fair governance and effective oversight, can be used to reverse land systems into paths on which productivity, livelihoods, and ecosystem integrity can thrive without oppressing each other. Many widely promoted land interventions underperform not because the practices are ineffective, but because rebound, leakage, and governance fragmentation shift pressures across space and time; **Figure 2** summarizes these common pathways and the institutional 'break points' that can interrupt them [45].

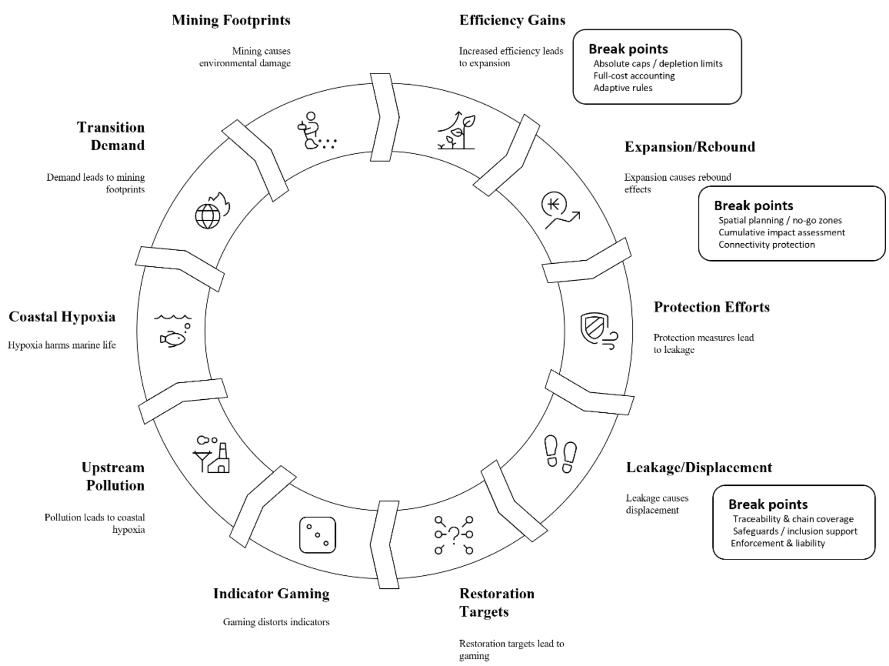

Figure 2. Common trade-offs, rebound and leakage pathways across sectors with break points.

4. Forests and Terrestrial Carbon–Biodiversity Governance (SDG 15, SDG 13, SDG 12)

Forests are a unique environmental resource management because they are where several global public goods are consolidated in one type of land cover [46]. They are sites of high carbon storage, regional hydrology, biodiversity maintenance, and livelihoods, which include timber and non-timber products, and culture. The loss and degradation of forests consequently echo through SDG 15 (life on land) and SDG 13 (climate action), as well as create contradictions with SDG 12, as the consumption and production systems fuel land use change by creating demand and supply chains. However, forests are not managed as an individual resource. They are incorporated into various tenure regimes, institutional structures, and market regimes and are more and more influenced by climate-induced disruptions like wildfire, mortality through drought, and outbreaks of pests. Forest governance has become, under the SDGs, both a conservation-versus-development story with a more complex agenda incorporating protection, sustainable management, restoration, as well as demand-side interventions, while seeking to respond to the equity and legitimacy, and integrity of climate and biodiversity claims.

4.1. Deforestation and Degradation Dynamics in a Globalized Economy

The modern-day deforestation is a result of both the proximate land-use choices and structural forces of economics. In most areas, agricultural growth continues to be one of the most active proximate forces, whereas commercial crop production, cattle ranching, and smallholder frontier relations interact differently depending on the region and conditions of government. Development of infrastructure, such as roads, rail, hydropower, and mining, may stimulate deforestation via the lowering of the costs of access and reorganizing land values, as well as fragmenting habitats and altering fire regimes. Degradation that entails selective logging, fuelwood harvesting, understory fires, and edge effects, in most cases, is a precursor to outright conversion and may be more difficult to control and manage. Since degradation may greatly deplete carbon stocks and degraded biodiversity, and still be classified as a forest, it provides governance blind areas, which are of concern in SDG reporting and the credibility of carbon and conservation finance [47].

The forces increase with globalization because the results of forests are connected to consumption patterns and capital flows elsewhere. The profitability of forest conversion can quickly vary due to commodity price cycles, concurrent currency changes, and trade policies. Corporate supply chains are becoming intermediaries to land-use incentives in terms of procurement standards, trader consolidation, and financing terms. It is these structural driving forces that allow one to understand how local conservation achievement can be undercut either by regional spill or by moving the lineage of deforestation. They also emphasize that forest governance cannot be limited to protected areas only; it should also incorporate the demand side of incentives and the politics of land development [46].

The interplay of climate change and deforestation also makes governance rather tricky. Forests play the role of regulating the climate and are climate sensitive. The growing temperatures and changes in the rainfall patterns may augment drought stress, diminish growth, and augment the fire vulnerability, thus turning forests from a carbon sink to carbon source in certain settings. The disturbance regimes may develop a feedback loop where degraded forests are more easily burned, resulting in further degradation and subsequent conversion. These processes question governance patterns based on constant baselines and predictability in recovery patterns, and they raise the antecedents of adaptive management and of monitoring systems that can identify not only land cover dynamics but also dynamics in forest condition and disturbance frequency [48].

4.2. Protected Areas, OECMs, and the Question of Effectiveness

Protected areas have continued to be a key tool of conservation of forests under SDG 15, and the growing focus on 30 by 30 has reinvigorated interest in being representative and connected [49]. Nevertheless, it is the capacity to implement and enforce, as opposed to the designation of legal status, that defines the effectiveness of the protected areas, as well as the clarity of boundaries, legitimacy of governance, and socioeconomic context of the landscape being placed under protection. This can be demonstrated to be of little effect on deforestation and degradation in what can be termed as paper parks; the resources do not correspond to legal status and power. On the other hand, well-fenced secure regions have the capacity to overcome the conversion strain, preserve the biodiversity as well, and aid ecological services to neighboring communities, however, when combined with sustainable livelihood opportunities and conflict control.

Other effective area-based conservation measures (OECMs) expand the governance arena to identify conservation results realized by non-conventional governance models such as native territories, community conserved spaces, and some types of sustainably regulated product forests [50]. They are also relevant in the fact that conservation results are frequently produced by local institutions and customary governance as opposed to designation by the state. In most settings, the integrity of the forests and the robustness of community governance have a close association with the security of indigenous land rights and their control, as well as in situations where outside pressure is palpable and the capacity of a state is weak. Nonetheless, OECMs also present measurement, accountability, and consent issues, particularly in recognition where the goal is to achieve targets at the expense of the long-term support and protection of the rights holders.

The debate of effectiveness has been increasingly moving towards how the interaction between the areas of protection and conservation with the landscape around them. When there is displacement pressure leading to encroachment of deforestation in these adjacent areas, or when the protected areas are depressed into islands in a degraded matrix, forest conservation outcomes can be compromised. It has made landscape-scale planning and connectivity, and the relationship between the strategies of protected areas and the broader land-use governance and market incentives more important. In SDG, not the ecological perspective is the sole measure of effectiveness, but rather the distributional outcome and distributional justice, as the exclusionary models might bring a level of social conflict that is not sustainable and will not conserve the long-term results [40].

4.3. Community Forestry, Co-Management, and Rights-Based Governance

The community forestry and co-management models represent an institutionally-based change in centralized control to shared authority and local care. These have both normative reasons based on a commitment to rights, and practical reasons based on the finding that enforcement and monitoring are often easier when local communities have a substantial level of authority and benefit. Community forests can contribute to biodiversity and carbon performance as well as improve lives by harvesting timber, non-timber products, and the payment of ecosystem services [51]. In areas where the government is effective, societies can enforce regulations, control harvest times, and control access more efficiently than remote organizations.

Nevertheless, the performance is non-homogeneous, and it is a matter of the interplay of tenure security, institutional capacity, market access, and external pressure. Insecurity of tenure has the effect of deterring long-term stewardship investments and exposing communities to dispossession in the event of an increase in land values. Weak institutions may support elite capture, which ensures the lack of fair benefit-sharing and adherence. Market integration may augment incomes, but it may also enhance extraction incentives if regulation frameworks are slack. It has been suggested in the literature that community forestry is strongest where rights are well identified, the governance rules are locally legitimate, and the benefits are shared transparently, and external support whereby the support offers technical assistance and conflict-resolution services without compromising autonomy [52].

The concept of rights-based governance is also interconnected with the biodiversity conservation policies that promote coexistence, as opposed to exclusion. The communities that rely on forests are usually well informed in their ecology and are culturally connected to landscapes, but often have to rely on hunting or mining activities that need to be carefully governed to stay sustainable to changing population pressures and market realities. Governance aligned to SDGs thus includes the balancing of cultural activities and livelihood, with the environmental limits usually by adaptive regulations and participatory surveillance, which may adapt to a new situation. Notably, the rights-based approaches do not eliminate the necessity of the state capacity, but reform it to recognition, support, and enforcement against external illegal actors.

4.4. Market-Based Instruments, Supply Chains, and Demand-Side Leverage

Market and supply-chain approaches have become prominent because they can influence deforestation incentives beyond the boundaries of protected areas and national jurisdictions [53]. Certification schemes, sustainability standards, and corporate zero-deforestation commitments aim to reshape production systems by requiring traceability, compliance with land-use regulations, and improved management practices. These approaches reflect SDG 12's emphasis on responsible production and consumption, translating environmental goals into procurement decisions and financing conditions.

The effectiveness of supply-chain interventions hinges on traceability, coverage, enforcement, and incentives [53]. Traceability systems can map commodity flows and identify high-risk sourcing areas, but they can be circumvented through laundering, mixing, and shifting sourcing to less monitored regions. Commitments may focus on direct suppliers while ignoring indirect suppliers or embedded deforestation in complex commodity chains. Moreover, standards can impose compliance costs that disproportionately burden smallholders, potentially excluding them from markets or pushing them into informal channels with weaker environmental oversight. The distributional implications are central for SDG coherence: interventions that reduce deforestation at the cost of greater rural inequality may be politically unstable and ethically problematic.

Economic instruments and finance mechanisms also include payments for ecosystem services (PES), jurisdictional REDD+ programs, and emerging biodiversity and carbon credit markets [54]. These mechanisms aim to internalize global benefits by creating financial returns for conservation and restoration. Yet integrity challenges are persistent. Additionality is difficult to demonstrate where baselines are uncertain or where deforestation pressures fluctuate with markets. Permanence is threatened by climate-driven disturbances, political change, and long time horizons. Leakage can shift deforestation elsewhere. Benefit-sharing can be contested, especially where tenure is unclear or where intermediaries capture value. These concerns have led to a stronger emphasis on high-quality monitoring, transparent baselines, robust social safeguards, and governance systems that can enforce commitments over time.

A critical insight from the forest governance literature is that market mechanisms cannot substitute for public policy but can complement it when aligned with regulatory frameworks. Subsidies and fiscal policies can either reinforce conservation outcomes or undermine them by making conversion profitable. Enforcement against illegal logging and land grabbing remains foundational, especially where deforestation is driven by illicit or quasi-legal activities. Where state capacity is weak, supply-chain pressure can create incentives for reform, but it can also create perverse outcomes if it pushes production into less regulated markets. SDG-aligned governance therefore requires attention to market structure, policy alignment, and the institutional conditions that determine whether private commitments translate into public environmental outcomes [55].

4.5. Restoration, Climate Mitigation, and the Risks of Carbon-Centric Approaches

Restoration of forests is commonly introduced as one of the climate mitigation opportunities, which could also promote biodiversity and livelihoods [56]. Nevertheless, carbon-based restoration may endanger trade-offs in its application outside the ecological and social context. Restoration enhances ecosystem operation or may simply increase biomass depending on the choice of species, the place of planting, and the management regime. Natural regeneration or aided natural regeneration is often capable in a wide range of environments of providing robust biodiversity results, long-lasting carbon benefits at reduced cost compared to planting, but demands regulation to avoid fire, grazing, and opportunistic harvesting of the regenerating forests.

The afforestation and reforestation may also be incompatible with the water goals and biodiversity by substituting the natural grasslands, savannas, or wetlands, or by using monocultures that lower the complexity of the habitat. This can result in changes in albedo, hydrology, and fire regimes and makes the benefits of climate quite complicated. Such risks are especially acute when restoration initiatives are being motivated by short-term goals or the credit schemes that have incentives based on hectares that are readily quantified, or biomass builds up quickly. The SDG framework implies the transition from simplistic carbon accounting to multi-functional evaluation that should entail biodiversity, water regulation, and social outcomes [57].

The climate dislocation source brings an extra place of uncertainty over restoration and the carbon fund. The carbon gains are reversible, and depleting biodiversity can be brought about by increased risk of wildfires, drought, and pest outbreaks, not to mention provoking permanence assumptions. This has elicited the desire to have climate-resilient restoration approaches that focus on diverse species assemblage, structural heterogeneity, and landscape mosaics that suppress fire propagation. It also magnifies the significance of adaptive management and risk buffers in carbon accounting and governance measures that can be responsive to disturbance without losing long-term stewardship.

4.6. Monitoring, Enforcement, and the Credibility of Outcomes

The capacity to monitor change and give causes, and impose rules has become a more important assumption in forest governance [58]. The development of remote sensing has revolutionized the process of deforestation monitoring, as it is now possible to not only detect loss of forest cover in near-real time, but also the lack of transparency, which can be used to enforce compliance and create accountability. However, it is more difficult to track the degradation, biodiversity results, and social effects. The change in biodiversity may not be traced by the canopy cover; the degradation can be subtle and episodic and social outcomes demand participatory and context-sensitive actions that cannot be easily recorded using satellites.

The effectiveness of forest interventions under the SDGs therefore depends on the integrated monitoring systems which include the combination of Earth observation with the field measurements, ecological surveys, and social indicators [59]. These systems need to deal with uncertainty directly and not with incentives that lead to the so-called indicator gaming and the maximization of what is measured rather than what matters. Open disclosure may enhance accountability, but it may also bring into the limelight political sensitivities, particularly in cases where deforestation is associated with strong political interests. Monitoring in these situations is only required where there is an absence of enforcement capability and institutional safeguards that can be used on the evidence generated.

The very process of enforcement is complex, and it involves legal deterrence, administrative capacity, judicial effectiveness, and political will to deal with illegal activities and land grabbing. In places where the strength of enforcement is low, conservation outcomes are frequently dependent on social legitimacy and local governance, once more underscoring the importance of the rights-based approach and benefit-sharing. In case of high levels of enforcement and low levels of legitimacy, conflict may compromise results. Forest governance, in line with SDGs, therefore necessitates the creation of a balance between deterrence and inclusion, regulation, and incentives, and acknowledgment of forests as spaces of struggle between power and rights, as well as environmental paths [60].

According to the literature on forest governance, sustainable developments within the SDG 15 and SDG 13 are most probable when the interventions work on three complementing dimensions: place-based protection and management, rights and institutions that support the local stewardship, and when the interventions are on the demand-side and market mechanisms that restructure incentives across the forest frontier [61]. Protected areas and OECMs are good, but they serve well when incorporated in landscape plans that deal with leakage and connectivity. Improving legitimacy and compliance, Community forestry and rights-based governance can be enhanced with secure tenure, institutional capacity, and elite capture protection, but they must include these. Supply-chain commitments and finance mechanisms can change incentives; however, in cases where the integrity is credible and when they do not replace public policy, but only complement it.

One of the key trends that is likely to affect the climate issue is the explicit inclusion of climate risk in forest planning and finance [62]. Disturbance regimes question permanence and need governance regimes that can do adaptive management and diversified approaches to restoration, and substantiate risk buffers. The other way is to reinforce the practice of outcome-based monitoring to detect degradation and biodiversity and canopy loss and to incorporate social equity as performance outcomes. Lastly, SDG coherence requires the consumption and production systems that contribute to deforestation to be given more attention. Unless incentives to conversion are minimized by subsidy reform, open supply chains and coordination of trade and investment policy, local conservation success will remain in competition with strong structural forces.

5. Oceans, Coasts, and Fisheries: Blue Economy with Ecological Limits (SDG 14, SDG 2, SDG 13)

The development opportunities and environmental risks are both concentrated over a small interface in the coastal systems as well as in oceans where the ecological processes and economic activity are closely bound. The coastal areas bear large cities, ports, tourism, aquaculture and fisheries, and harbor habitats, including coral reefs, mangroves, seagrasses, salt marshes and kelp forests, which control coastal protection, carbon sequestration, and marine life nursery activities. Marine governance under SDG 14 has the mandate of maintaining biodiversity and ecosystem integrity where SDG 2 imposes pressure on food supply via fisheries and aquaculture, and SDG 13 changes ocean temperature, chemistry, and circulation. This framing of the blue economy is what embodies this coupling of both marine ecosystems as productive natural resources; nonetheless, it has a danger of relegating ecological constraints to secondary positions with respect to growth ambitions. The governance dilemma of the central question to address is how to balance economic exploitation of marine resources with non-negotiable biophysical limits of stock dynamics, habitat dependency, assimilation capacity of pollution, and climate-induced change [63].

5.1. Fisheries Management Innovations and the Problem of Incentives

Examples of the typical challenge of managing renewable resources include fisheries, which are mobile, variable, and whose behavior is strategic. Overfishing occurs when incentives to harvest surpass the ability of the institutions to provide sustainable catches and even when the rivalry promotes short-term harvesting instead of long-term custodianship. There is a growing focus towards rights-based management, co-management and enhanced monitoring in contemporary fisheries governance as an effort to align incentives with sustainability [64]. Catch shares, and territorial use rights in fisheries, and other allocation schemes can help decrease the race to the top in fisheries and help sustain stock rebuilding by providing fishers with a long-term interest in long-term productivity. However, such systems may equally produce distributional crises in situations where small-scale fishers are disfavored in the beginning, whereby consolidation gathers access, or when cultural and subsistence practices are poorly valued.

The strategies of co-management to share power between governments and fishing communities have become a response to the challenges of centralized enforcement and the significance of local knowledge [65]. In numerous small-scale fisheries, community institutions have the potential to offer fine-scale surveillance and social enforcement so that adaptive regulations can be created regarding the equipment, time of year, and entry. How long co-management can survive will also be determined by whether benefits are visible, whether rules are perceived as having legitimacy, and whether external pressures, like the industrial fleets, market demand, or loss of habitat, will exceed local capacity. The combination of co-management and formal legal frameworks is usually final, as local power without legal support from outsiders may be compromised.

Enforcement is also now feasible due to advances in monitoring, control, and surveillance. Compliance and transparency can be enhanced through vessel monitoring systems, electronic logbooks, onboard cameras, and satellite-based detection of illegal fishing but costs, privacy and unfair treatment of small operators are posed [65]. In data-poor systems, estimates of stock continue to be a significant impediment to data-driven catch limits and a range of methods that employ empirical measures, precautionary regulations, and adaptive management instead of entirely characterized population models continue to develop. These methods can minimize the chances of collapsing in cases where uncertainty is high, but involve institutions that can change rules fast as the evidence evolves.

Climate change makes it difficult to govern fisheries as it changes the stock distributions, productivity, and recruitment patterns [66]. With species moving northwards or to greater depths, current allocation zones and national jurisdictions might no longer be consistent with ecological facts, putting pressure on future conflict and overexploitation. The variability caused by climate also counters the belief that historical levels of catch are sustainable levels. Governance of fisheries under SDG 13, thus, demands more dynamic management in the sense that it envisions changing distributions of species, inclusion of environmental indicators, and development of frameworks of cooperation in redistributing access when stocks cross boundaries.

5.2. Marine Spatial Planning, Zoning, and Multi-Sector Conflict

As a governing instrument on crowded seascapes, marine spatial planning (MSP) has developed as a key instrument in managing fisheries, conservation, shipping, tourism, aquaculture, and offshore energy competing in space [67]. The purpose of MSP is to minimize conflict and enhance ecological results, and offer regulatory certainty through assigning areas to various uses and setting regulations that factor in cumulative effects. With the rapid growth of offshore renewable energy, whose potential can be harnessed to achieve decarbonization, its relevance has only risen because of the new spatial demands and any ecological effect posed by noise and seabed disturbance, the risk of collision, and changed habitat patterns.

The success of MSP is based on the quality of the ecological information, the level of involvement of the different stakeholders, and the governing power to implement the zoning decisions [68]. In situations with limited data, planning can be based on crude proxies that cannot be used to represent important habitats, migration routes, and seasonal processes. In areas of poor participation, MSP might be seen as top-down, particularly in the case of the small fishers who lose access without being compensated or having any other livelihood source. On the other hand, in case MSP is constructed as a participatory process and trade-off analysis is open, it can lead to better legitimacy, less conflict, and better compliance.

The main problem of MSP is cumulative impact management. Single projects might seem bearable when considered separately, but when summed up, they cause greater impacts than the river merits. It becomes especially significant in coastal areas where the interaction of land-based pollution, dredging, habitat conversion, and climate stress takes place. Strategic environmental evaluation and ecosystem-based management strategies are trying to solve this through multiple activities as opposed to single permits. Nevertheless, the methods require the coordination among agencies and sectors that, in most cases, have varying mandates and timeframes. MSP, under SDGs, becomes a governance experiment of the productively interactive to institutionalize: it is only able to produce sustainable results when it conjoins zoning to enforceable criteria of lessening pollution reduction and zoning coffee-protected reexamination [69].

5.3. Coastal Habitats and Nature-Based Protection in a Changing Climate

The coastal ecosystems play a vital role in the provision of ecosystem services that are directly applicable to the economic resilience [67]. Mangroves, reefs, seagrasses, marshes, and dunes are used to mitigate wave energy, erosion, and storm surge, as well as toaster fisheries production and tourism. When climate changes, the economic value of such services increases due to the increased intensity of storms and rising sea levels. This has increased the desire to find solutions that are based on nature and hybrid infrastructure to offer a combination of engineered structures and habitat restoration to mitigate risk.

There are indicators that nature-based protection may be very effective in specific environments; however, the performance depends on geomorphology, sediment supply, ecological condition, and the time required by habitats to mature. Restoration may fail due to a lack of attack on stressors, including pollution, altered hydrology, or destructive fishing, or to the location of the project where sea-level rise exceeds that of habitat accretion and migration. Habitat resilience can also be compromised by hard infrastructure, by obstructing landward migration of marshes and mangroves, leading to a so-called coastal squeeze. Hybrid strategies are intended to minimize these trade-offs by applying engineered measures to establish the conditions under which habitats will be able to persist and protect in the long term.

Governance and finance play a decisive role in the protection of coastline habitat since the benefits usually favor larger publics, but the costs are well-known in the locality or in the short term. Rewarding investments that minimize expected losses on a large scale can theoretically be done through insurance markets, the disaster risk reduction budget, and financing public infrastructure, but institutional arrangements to translate avoided damages into consistent funding to make it after a disaster are not in place. In addition, the protection projects of the coasts can transform access and land value, and equity issues must include who will benefit, who will lose, and who will receive the new development. The ecological design is therefore not the sole method of

SDG-compatible coastal adaptation, but social protection and land-use policies that do not support maladaptive development behind new protective features [70].

5.4. Pollution Pressures: Nutrients, Plastics, and Chemical Contaminants

A characteristic issue of SDG 14 is marine pollution since it connects land-based production and consumption systems to the well-being of the ocean. Nutrient erosion and wastewater releases contribute to the occurrence of eutrophication, harmful algae blooms, and hypoxia in coastal waters, contributing to the degradation of fisheries and tourism as well as causing the modification of marine food webs. These issues mirror the challenge of managing diffuse sources and long-term delays between the policy action and recovery of the ecology. The watershed-based governance is the key to addressing marine pollution control, where agricultural policy, urban infrastructure development, and coastal management institutions are to be coordinated [71].

Plastic pollution has come to embody the role of the ocean as a sink for poorly managed waste [72]. Its government demonstrates how downstream cleanup is limited in relation to upstream prevention. Limiting the amount of plastic in the ocean is based on product design, garbage collection, recycling capability, and behavioral modifications, in which costs and duties are spread among producers, consumers, and municipalities. Leakage can be mitigated through policies like long producer responsibility, prohibition of some single-use products, and better waste management infrastructure, although they need enforcement, as well as substitutes that are more affordable.

The chemical pollutants, such as persistent organic pollutants and emerging substances, are complex because they have unpredictable ecological and health impacts, inadequate monitoring, and transboundary ocean currents and atmospheric deposition [73]. The solutions to these contaminants may demand international action and preemptive strategies that may be ahead of scientific certainty. The SDG framing supports the idea that marine pollution is an environmental problem and also a system governance problem connected with SDG 12, which focuses on sustainable production and consumption, and SDG 6, which focuses on wastewater and water quality management.

5.5. Aquaculture Expansion and the Sustainability of Marine Food Production

Aquaculture can take its place as a remedy to overfishing and increasing protein demand, but with its own environmental impact and control issues. Examples of impacts are nutrient loading, transmission of diseases, interactions with wild stocks genetically, conversion of habitats, and dependence on feed inputs, which can bring about land and fishery footprints in other areas. Sustainable aquaculture thus relies on species selection, location, technology, and regulatory controls, and is also reliant on the innovation of feeds that eliminate the use of wild fish or crops that are environmentally intensive [74].

Spatial planning once more takes centre-stage since siting choices dictate whether aquaculture will have a pernicious association with delicate habitats, fisheries migration routes, or current fisheries. Strong environmental policies and regulations can lessen risks, yet regulators' capabilities are highly diverse. Aquaculture can help diversify livelihoods and make coastal economies more stable, which in some cases pursue SDG 2 and SDG 8, and in others can result in enclosing coastal commons and increasing inequality [74]. Governance along SDGs, therefore, needs clear consideration of how access, rights, and benefit-sharing packages, and a life-cycle analysis assessing the externalizations in the larger food system.

5.6. Climate-Driven Change, Shifting Baselines, and Governance under Uncertainty

Climate change increases the oceans with conditions of warming, acidity, deoxygenation, and sea-level rise that become a moving goal in terms of management [75]. Coral bleaching and reef degradation decrease the complexity of habitats and abundance of fish, which compromises fisheries and tourism. Acidification poses a threat to the shell-forming organisms and rearranges the food webs. Unexpected ecosystem perturbations can be caused by deoxygenation and marine heatwaves. Such shifts establish shifting baselines where any reference point of history is not a possible or desirable state, and governance systems must reconsider the aim, standards, and trade-offs.

Anticipatory governance is frequently needed in marine systems as a means to adapt. The coverage of marine heatwaves, agile fisheries regulations that react to environmental indicators, and active spatial covers can increase preparedness [76]. However, such strategies require data, organizational flexibility, and interjurisdictional collaboration. They also bring concerns in distributive justice, as those communities that are reliant on specific species or coastal resources might suffer losses that cannot be completely compensated through adaptation. Cases like these demand the application of the SDG coherence through incorporating ecological management and ordinary stability, diversification of livelihoods, and designed shifts that alleviate precariousness.

The existing body of literature on oceans, coasts, and fisheries comes to one major conclusion: sustainable blue economy strategies work when they regard ecological limits not as externalities, but as constraints that are binding. Fisheries management through rights and co-management can enhance sustainability, although they need to be constructed in such a way that they avoid inequitable outcomes of access and respond to climate-driven changes. The only way that marine spatial planning can decrease the conflict and deal with cumulative impacts is by having credible data, stakeholder legitimacy, and enforceable authority across sectors. Coastal protection based on nature can offer a variety of benefits, but must be maintained over the long term, consistent with land-use governance, and must have structures that incentivize avoidance of risk instead of temporary construction outputs. The key to controlling pollution rests in the upstream intervention in the agricultural sector, urban infrastructure, and product systems, which connect the SDG 14 outcomes with the SDG 6 and SDG 12 policies [77].

In these areas, an important trend in the future is enhancing the governance of dynamic situations. Stagnant zoning, set allocations, and past benchmarks become more and more disconnected from climate change ecology. The adaptive strategies, which are reinforced by open monitoring, scenario planning, and collaborative institutions, are becoming necessary in ensuring that the ecosystems operate and stay economically viable. The other priority is the inclusion of equity in marine governance, since how the rights of access, exposure to risks, and benefits of development are divided determines legitimacy and obedience. Lastly, the growing rate of offshore energy, inland infrastructure expansion, and aquaculture implies that cumulative impact assessment and cross-sector coordination will either be decisive factors in whether the blue economy is an instrument of sustainable development or follows the same pattern of overuse and inequity that the resource governance of terrestrial systems has been [78].

6. Biodiversity, Protected Area Networks, and Ecological Connectivity (SDG 15, SDG 14, SDG 13)

The SDGs on biodiversity are faced with a scale and urgency paradox that has been observed. The ecological processes that maintain biodiversity are maintained across both landscapes and seascapes by migration, dispersal, genetic exchange, and disturbance regimes, but the organizational tools of biodiversity management tend to be restricted to administrative boundaries, property bounds, and sector requirements [79]. Simultaneously, the loss of biodiversity is being considered as a material threat to economic systems as well as an ethical and conservation issue (SDG 15 and SDG 14) because it is leading to the degradation of ecosystem services, including pollination, pest control, water filtration, and risk mitigation. The problem is exacerbated by climate change, which is changing species distributions and the regimes of disturbance and habitat suitability (SDG 13). In this respect, biodiversity conservation cannot be perceived as a local attempt to preserve rare species in remote reserves. It is a problem of resource management integration that needs to be successful in area management, connectivity planning, coexistence strategies, and monitoring systems that can be credible in tracking the results and dealing with equity and governance legitimacy.

6.1. Protected Areas, OECMs, and the Effectiveness Gap

The use of protected areas as the most common tool of biodiversity protection has not abated, and the latest commitments worldwide have made them even more prominent in the organization of national policies. One issue that continues to emerge in the literature, however, is the disparity between nominal coverage and ecological effectiveness. Designation is achieved, which is not achieved by proper funding, manpower, boundary control, or management planning, and results in conservation areas that are more on paper than in ecological activity. Even well-controlled protected areas may not work when they are located badly in relation to biodiversity priorities, with respect to underrepresentation of some ecosystems, or even failure to safeguard some life-cycle habitats and migration paths. The framing of SDG strengthens the idea that effectiveness should be measured based on the ecological outcomes, including the trends in population, quality of the habitat, and integrity of the ecosystem, but not only on the amount of land or sea allocated [80].

Other effective area-based conservation measures in which the conservation toolkit is expanded to acknowledge long-term two-way protection, which accrue through governance arrangements that do not necessarily have conservation as their objective, such as indigenous and community-controlled territories, locally managed marine zones, and some sustainable-use landscapes. OECMs are both important since they preempt the diversity of governance and the place of rights and local institutions. Yet, they also introduce the issues of criteria, permanence, and responsibility. When recognition is sought on the basis that it is required to satisfy numeric targets, then there is a possibility of OECMs being again labelled as re-labeled land uses with no identified biodiversity deliverables, or that recognition is a degradation of customary governance where external reporting becomes mandatory. The key here is effective implementation, and this is based on clear and outcome-oriented standards, consent and participation, as well as sustained support that reinforces and does not overtake local governance capacity [67].

Leakage and displacement also determine the effectiveness gap. Creating preserved zones may resettle resource exploitation and land transformation elsewhere in case the leading factors, like resource demand, infrastructure construction, or poor enforcement, are the same. This risk of leakage is particularly applicable to species-rich regions defined as a protection in the areas of low pressure, as the high-biodiversity and high-threat areas are still under political guidance. Strategies to address displacement consist of combining the use of preserved area as part of the larger land- and sea-use management, activating supply chain and development strategies, which lead to fewer incentives towards conversion and overexploitation [67].

6.2. Connectivity, Corridors, and Climate-Smart Conservation Planning

Connectivity has also become a central feature of current biodiversity management due to the fact that fragmentation is one of the main causes of biodiversity loss, and due to the fact that climate change necessitates species and ecological communities to travel across space. Permeable landscapes, deep water horizons, stepping-stone habitats and corridors aid in dispersal and migration, genetic exchange and help species to follow the changing climate envelopes. Connectivity planning is thus more and more being placed as the interface between the conservation goals that are area-based and ecological functionality, which is the conversion of the protected areas to networks that maintain persistence in the long term [81].

It is not just a case of drawing lines on maps when designing connectivity, but recognizing functional trails about species motion and habitat sustainability as well as the resistance of the landscape, bearing in mind land tenure, development demands, and governability viability. Multi-scale planning is emphasized as important in the literature, since connectivity requirements differ among taxa and life stages, and since interventions at a local scale are unable to succeed, more generally, unless connected to the larger network structures. Practically, connectivity is sought by an amalgamation of tools: land acquisition or easement, degraded linkage restoration, road crossing structures, riparian buffer protections, and spatial planning that is non-hypocritical to channel further erosion in high-value routes.

Climate-smart conservation makes it more complicated as it focuses on refugia and adaptive aptitude [82]. Regions that are historically favored by some species may no longer be viable with warming, and wetlands that receive north-facing and riparian processes; deep reefs may come to be of a disproportionately high importance to persistence. This view changes conservation planning to be a representation of stable forms to a view of adaptive networks of conservation planning, expecting range shifts and evolving disturbance regimes. It also increases uncertainty as a governance issue. Since the suitability of future habitats is not determinable with accuracy, conservation planning is turning to portfolios that show reasonable performance in a wide variety of possible futures as opposed to maximizing a single scenario.

6.3. Human–Wildlife Coexistence and the Social Foundations of Durability

The conservation touching not only isolated reserves but also intertwined landscapes, the contact between wildlife and people is becoming more rampant and more significant [83]. Human-wildlife conflict, crop raid, predation on livestock, property damage, and threats to human lives may create significant resistance towards conservation and may result in retaliatory killing, which compromises biodiversity objectives. On the other hand, the support of conservation and better results may be enhanced by the coexistence strategies, reducing the risk and offering the real benefits.

Literature on coexistence points out that technical solutions, such as protection, exclusion fencing, guard dogs, and better husbandry, are frequently needed but seldom effective [84]. The effectiveness will be determined by the affordability, cultural acceptance, and support of interventions in the long run. Compensation plans may lessen incentives against retaliation, although they may also produce moral hazard; they can be seized by elites, or be unsuccessful when compensation is not received in time or is seen as inequitable. Reliability can be enhanced by performance-based or insurance-like means, but demands plausible validation and administrative ability. Where wildlife brings earnings in the form of tourism or controlled wildlife hunting, then benefit-sharing schemes can be used to create greater local support, yet they may also serve to widen the disparity should the benefits be delivered to a small group of players.

The issue of coexistence has grown to be closely linked to land-use transformation and climate pressure. Ecosystem destruction and population reduction can also lead to wildlife being concentrated in smaller areas, therefore increasing exposure, and drought can cause wildlife to move towards farms and settlements. Such dynamics indicate that coexistence does not merely exist as a conflict events management process, but a landscape management process to sustain habitat and decrease forcible closeness. In SDG coherence, the strategies of coexistence should also consider equity: communities that have to endure the costs of coexistence with wildlife are quite often underrepresented in an act of governance and are not likely to receive many benefits. Procedural justice of conservation, transparency of decisions, and equitable sharing of costs and benefits are therefore important to sustainable conservation [85].

6.4. Biodiversity Monitoring, Indicators, and the Integrity of Claims

The credible measurement can be listed among the persistent bottlenecks in the governance of biodiversity [86]. Biodiversity is multi-dimensional because it involves genes, species, populations, communities, and ecosystem processes, and none of them serve comprehensively. The data obtained through traditional monitoring that relies on field surveys can be of high quality; however, the area covered is usually restricted in spatial terms and expensive to operate. Models So-called falling-object methods cannot identify cryptic in species: newer techniques and methods, like environmental-DNA, bioacoustics, machine-learning camera traps, and more vigorous far-off sensing, provide prospects to scale investigations, identify cryptic species, and trace natural habitat structure. However, these approaches also create new problems in calibration and data management, as well as proxy interpretation.

Policy incentives are very dependent on the choice of indicators [87]. When monitoring emphasizes more on area-based measures, actors can maximize the area of identified hectares instead of ecological results. When characteristics work on charismatic species, then ecosystem well-being will not be considered on a higher level. Provided that measures deal with the short-run changes in abundance, the long-term balance and support might be overlooked. There is a growing argument in the literature in favor of indicator portfolios that relate pressures, states, and responses, which integrate measures of habitat extent and condition with indicators of population trend and measures of functional diversity where possible. The consideration of social indicators is also essential, especially to OECMs and community control systems, since normative authority and equity may be a determinant of ecological viability.

The credibility of the finance systems relating to biodiversity matters also increases the necessity of plausible monitoring. Biodiversity credits, offsets, and no net loss policies require that they can show additionality, equivalence, and durability, which is frequently challenging in ecologically complex ecosystems with a long recovery period. Ineffective monitoring may allow over-crediting and greenwashing, which undermines trust and may even lead to a rapid loss of biodiversity by sanctioning destructive development. Governance consistent with SDGs must thus comprise conservative conditions, open assumptions, prolonged regulation dedication, and solid safeguards to represent coercion of non-renewable environments by the possibility of dubious restoration assertions. Considering the dangers of indicator substitution and over-claiming benefits, **Table 2** suggests the minimal ecological, economic, and equity outcome-based indicator portfolio specific to each sector to facilitate plausible monitoring, reporting, verifying, and management [88].

Table 2. Suggested outcome indicator portfolio (MRV) by sector.

Sector	Ecological Outcome Indicators	Economic Performance Indicators	Equity/Legitimacy Indicators	Typical Data Sources
Water	Environmental flow compliance; groundwater storage trend; nutrient loads; habitat condition	Reliability of supply; avoided flood/drought damages; cost per unit service	Affordability; exposure to contamination; stakeholder participation	Gauges, remote sensing, groundwater monitoring, utilities, basin reports
Land/Soils/Food	Soil organic carbon trajectory; erosion rate; land conversion; nutrient surplus	Yield stability; input efficiency; farm profitability; food loss/waste	Tenure security; smallholder inclusion; gender participation	Field sampling, EO, farm surveys, value-chain datasets
Forests	Net forest loss + degradation; carbon stock change; fire/drought disturbance metrics	Sustainable forest income; avoided damages; finance mobilized with integrity	Rights recognition; benefit-sharing; conflict incidence	EO + field plots, fire products, MRV systems, community monitoring
Oceans/Coasts	Stock status; bycatch rates; habitat extent/condition; hypoxia events	Catch value stability; tourism revenue; avoided coastal damages	Access rights distribution; compliance burden; community risk exposure	VMS/e-logbooks, surveys, EO, water-quality monitoring
Biodiversity	Population trends; connectivity indices; habitat condition; functional diversity proxies	Nature-based tourism value; risk reduction value; cost-effectiveness	Conflict reports; compensation fairness; consent processes	eDNA, camera traps, acoustics, EO, ranger/community data
Extractives/ Transition	Water withdrawals/quality impacts; tailings risk indicators; footprint/fragmentation	Jobs quality; local procurement; lifecycle cost and delay risk	Grievance resolution; FPIC/consultation quality; benefit-sharing	Company reports, regulators, independent audits, EO footprint mapping

6.5. Financing Biodiversity and Aligning Incentives across Sectors

Financing is often put forward as the constraining factor to biodiversity conservation, yet the literature indicates that the underlying key problem is the problem of incentive alignment. Public budgets, philanthropy, and tourism revenues and private finance instruments can all be used to raise the amount of conservation funding, but biodiversity losses will still occur unless the economic system is changed to reward habitat conversion and overexploitation. Consequently, biodiversity governance in the SDGs gives greater consideration to mobilizing finance alongside restructuring incentives that incentivize degradation [88].

Ecosystem services and conservation incentives can be used to finance stewardship provided that they are constructed in a clear conditionality framework, with equal benefit sharing, and credible monitoring. Nevertheless, they may also corrupt local governance in the case when it is elitist-captured or in the case when it is only open to bigger landowners. The purpose of biodiversity offsets and credits is to direct the development finance towards conservation, but these tools are controversial as they tend to sanction ecological loss and ecological equivalence is frequently difficult to determine. Long-term financing and conservation trust funds can enhance more sustained levels of funding by stabilizing the funding against short project cycles, but the structure needs to provide accountability and be in line with local priorities [89].

In agriculture, infrastructure, and extractives, cross-sector alignment is deemed especially crucial because a decision can be made to quickly restructure habitats [90]. At source, effects can be mitigated through incorporating biodiversity criteria into land-use planning, allowing, and supply chain procurements. The mitigation hierarchy has developed into a standardized way of incorporating biodiversity in development (avoid, minimize, restore, offset), although it only works effectively when avoidance becomes a constraint and when offsets are made sparingly and only in instances where the impacts are truly residual. Weak governance may turn the hierarchy into a paper game; strong governance may significantly redirect development into softer developmental channels.

Page after page on the strategies to protect areas, connectivity planning, coexistence strategies, and modes of finance, the same message is clear: biodiversity outcomes are driven by networks, ecological networks of habitat and population, institutional networks of rights, incentives, and accountability [91]. It should be expanded area-based coverage, which is wanting but insufficient; it must be effective through representativeness, quality of management, enforcement, and integration into more comprehensive land- and sea-use regulation to deal with displacement and its root causes. The focus of connectivity and climate-smart planning is getting more and more central due to their ability to operationalize resiliency in changing conditions, but it needs multi-level coordination and long-lasting tools that can endure the political cycles.

Coexistence is also predetermined as beliefs in social legitimacy eventually provide conservation. In the case of concentrated costs and diffuse benefits, the governance of biodiversity will be weak unless the policies are specifically focused on equity and benefit-sharing. The cross-cutting constraint is measurement and monitoring, especially in the context of an expanding and growing biodiversity finance and an increasing number of claims to a net gain. To avoid greenwashing, credible sets of indicators, a transparent baseline, and long-term commitments to monitoring are all that should be in place in the context of adaptive management.

Subsequent steps towards a framework-supported biodiversity administration thus involve reinventing protected area and OECM requirements around the objectives instead of labels, investing in connectivity as a fundamental method of planning, conveying climate threat into the pattern of conservation networks, and enforcing equity insurance in the structure of coexistence and finance. Above all, the biodiversity governance needs to be viewed as a mainstream development issue and be part of the economic sectors that are shaping the land and sea utilization, instead of being an independent conservation agenda [92].

7. Extractives and the Energy Transition: Minerals, Renewables, and Circularity Trade-Offs (SDG 7, SDG 8, SDG 12, SDG 13, SDG 15)

The energy transition of the world is transforming the longstanding management of environmental resources due to the rapid growth of the demand for minerals, materials, and infrastructure relating to renewable power production, electricity networks, batteries, and electrified transport. This shift lies at the heart of the SDG 13 (climate action) and SDG 7 (affordable and clean energy), and it is commonly positioned as an unquestionable environmental good in comparison with the reliance on fossil fuels. However, the material demands of the decarbonization process impose new burdens on land, water, and biodiversity, generating governance issues that involve SDG 15 (life on land), SDG 6 (water, in most cases), SDG 12 (responsible consumption and production), and SDG 8 (decent work and economic growth). Mining growth, processing and refining, massive renewable sitings, and infrastructure may divide ecosystems, create hazards of wastes and pollution, pressure on water, and social conflict in situations of poor rights and benefit-distribution. The dilemma of SDG-oriented management must thus not be on whether or not the transition should take place, but how to shape mineral supply and energy infrastructure trajectories that have the least ecological impacts, rights and benefits, and risks should be equally distributed, and benefits realized promptly without causing rapid emissions reductions [93].

7.1. The Material Footprint of Decarbonization and the Geography of Impacts

Energy systems are physical systems. Wind power, solar power, grid storage, and transmission can only be scaled using large amounts of steel, aluminum, copper, cement, and a combination of minerals that have since become strategic in terms of batteries and electronics [94]. Although the transition decreases the operational emissions with regard to energy consumption, it may escalate the upstream environmental impact in terms of extraction, processing, and waste disposal. These effects are geographically concentrated, usually in areas that are both ecologically sensitive and politically disputed, resulting in a spatial discrepancy between the areas where low-carbon benefits are potentially gained and the locations where environmental and social costs are suffered.

It is the geography of extraction that is influenced by the location of ore deposits rather than the preparedness of the government. Most of the critical mineral areas have a weak regulatory capacity, inadequate infrastructure, and competing land rights, which increases the possibility that their growth rate will exceed that of institutions. Whereas good governance implies the existence of strong governance, the collective effects of various projects such as roads, power lines, water withdrawals, and worker settlements may be greater than the area covered by individual mines. Refining and processing add more loads on high power requirements, two elements of chemicals use and waste discharges, and are commonly concentrated in industrial belts in which the loads of pollution may be non-homogeneous. These trends underscore the argument that the supply chains of green technology have the potential to recreate the long-term environmental justice issues unless the governance is designed to address distribution, cumulative factors, as well as long-term liabilities [95].

7.2. Environmental Risks of Mining and Processing: Water, Waste, and Biodiversity

Mining effects are also extremely context-dependent in terms of mineral type, ore grade, extraction method and local ecology, though three categories of risk are shared across situations: water stress and contamination, waste and tailings, and biodiversity loss by land disturbance and fragmentation. The effect of water is usually determinant in social license and environmental impacts. Mines may be in competition with agriculture and population over limited water resources, change the water table or drain acid mine wastes or heavy metals. Such dangers do not end at the closure of a mine, and it is essential to monitor and treat them over long periods of time. Mining may become a major water user in dry areas or water-stressed basins, directly connecting extraction governance to basin allocation regimes and also establishing the priority, compensation, and ecological flows question [96].

Waste management is core since a majority of mined material is converted to waste rock or tailings, and such an amount of tailings can grow with a fall in ore grades. Tailings storage facilities have low probability but high-consequence risks, such as disastrous failures that have devastating downstream effects. Chronic seepage and dust can destroy ecologies and human health even in the absence of fiendish tragedies. The responses of governance are becoming more focused on more rigid requirements on tailings design, independent scrutiny, transparency, emergency preparedness, and financial assurance measures that enable liabilities to be capped. Standards, however, are not a guarantee when implementation is lax, or the benefits are to promote cost reduction. The tailings risks of the tailings also reveal the vulnerabilities of the permitting systems, which concentrate on the approval of the projects instead of on the lifecycle responsibility [97].

The effects of biodiversity are both direct, through habitat destruction, fragmentation, and indirectly by facilitating access and settlement [98]. Disturbance of a given ecosystem through such mining ventures may result in a disproportionate harmful impact on biodiversity due to the high prominence of the base integrity and an obscure recovery period. The mitigation activities are usually based on the mitigation hierarchy, which is avoid, minimize, restore, offset; however, in the case of location-specific deposits, avoidance may be challenging politically. The restoration is unpredictable in areas where soils are strongly disturbed and when hydrology is disturbed. The use of offsets is especially disputed in terms of mining since the effects can be huge, ecosystems might be non-renewable, and the time lag can be extensive. These limitations drive governance in the direction of strategic siting and landscape-scale planning that aims to avoid high-value and high-sensitivity locations, as opposed to basing it on downstream compensation.

7.3. Siting and Permitting: From Project-by-Project Approval to Cumulative Impact Governance

One of the biggest weaknesses of traditional permitting is that it does not regard the projects as parts of the changing regional systems but rather as discrete events. With the rapid growth that is characterized by transition, the overall effects of numerous mines, processing plants, and renewable installations can generate landscape change [98]. The strategic environmental assessment and regional planning are thus increasingly becoming more popular as methods of analyzing portfolios of projects, determining areas of no-go and order development to cause the minimum ecological and social disturbance. Such strategies also have the potential to minimize investor uncertainty as the limitations become clear at an early stage, as opposed to the conflicts that drag on since the inception of the proposed projects.

In the case of renewables, the issue of siting and permitting has less direct impact but is equally severely repercussive [99]. The operational emissions and pollution of the wind and solar projects may be comparatively lower than fossil fuels, but land space, aesthetics, and wildlife interaction may be high. Turbine, habitat fragmentation, and opposition to pastoral or agricultural land uses can cause birds and bats to die, which can be catalyzed by opposition. The access pressures and further fragmentation can be caused by transmission infrastructure. Successful governance still depends more on spatial planning to find the presence of lower conflict zones, biodiversity data, and take into consideration co-location with degraded lands, the built environment, and existing infrastructure corridors. The objective is not to avoid impacts, which is often impossible, but to reduce them by avoiding and carefully designing with underwriting by both monitoring and adaptive mitigation.

Equity and rights also play a role in permitting systems [100]. It is through indigenous consent, community consultation, and agreement on benefits to the community that the legitimacy and potential conflict are addressed. In the face of procedural but not substantive consultation, the opposition may put projects on hold and undermine trust, generating a governance paradox where weak social processes slack off decarbonization, and indeed fail to secure communities at the same time. On the other hand, good rights-based processes could enhance performance by enlightening the acceptable development paths and by making sure that the benefits of jobs, revenue, and infrastructure are distributed in a form that captures the local priorities.

7.4. Social License, Labor, and Distributional Outcomes in Resource Frontiers

Extractive and energy-transition projects can provide a significant level of local economic impact in terms of employment, procurement, infrastructure, and fiscal revenues to SDG 8 [101]. However, such advantages tend to be unequal and can be short-lived in case economies get addicted to boom-bust cycles or when gains are stolen away. The concept of social license to operate has grown central as a result and represents the fact that legal permits are not adequate in situations where communities feel that the projects are unfair, risky, or forceful.

The concerns of distribution occur at various dimensions. The benefits can be received by the landowners, contractors or skilled people, whereas the costs can be imposed on pastoralists, subsistence users or the downstream communities. In-migration has the potential to put pressure on housing and social services, change local labor markets, and raise social tensions. They are gendered and in most situations the women are disproportionately affected by social disruption as well as environmental risks and offered fewer job opportunities. These trends highlight the fact that SDG-consistent governance should be viewed as the inclusion of social impact assessment as a substantive tool of planning and not as a compliance measure whereby project approval will be linked to enforceable agreements on employment quality, local purchases, grievance systems, and benefits sharing.

Governing revenues is also decisive. Public goods can be financed by Royalties and taxes, but according to the literature on the resource curse, poor institutions may transform resource fortune into corruption, conflict, and failure to invest in long-term development. Transparency programs and fiscal governance reforms are meant to enhance accountability, but they have to be accompanied by local protocols that would mean that revenues are converted into visible improvements in services and strength. The risk, in terms of transition context, whereby the demand growth rate could be fast, is that the governance capacity could be overwhelmed and leave long-term liabilities that will still be in existence even after the construction of infrastructure during the transition [102].

7.5. Circular Economy Strategies: Promise, Limits, and Rebound Dynamics

There are often suggested solutions that can help alleviate pressure on primary extraction through approaches to the circular economy by improving recycling, reuse, remanufacturing, as well as material efficiency [103]. In the case of batteries and electronics, advanced collection and recycling technologies are able to salvage useful metals as well as lessen the necessity of new mining, instead of creating end-of-life processing using design-to-disassemble. Efficiency in construction materials and grid infrastructure can equally mitigate the need to use virgin materials. These measures are very much aligned with SDG 12 and indirect improvements on SDG 13, as less energy is used in the materials production.

The success of circularity in compensating primary demand is limited, however, due to the processes of growth and the physical world. The speed of clean energy infrastructure development generates a mismatch between the deployment of products and the availability of finished materials, i.e., recycling supply could be lower when the demand is the greatest. The system of collection may be disjointed and the economics of recycling are based on price and the policy incentives of commodities. Certain materials cannot be easily obtained in high purities and there are losses accruing with each cycle. Rebound effects may also arise in case efficiency decreases costs and consumption. Due to this fact, circularity can be better considered as a critical complement, but not a near-term alternative to primary extraction.

Circular governance means balancing incentives, both in product and consumer behavior design, waste management infrastructure, and industrial policy [104]. Prolonged producer responsibility, deposit programs, and procurement specifications are capable of enhancing storage and boosting recyclability, with spending on household processing facilities having the ability to lessen the dependency on considerably environmentally intensive or opaque supply chains. However, there are also distributional effects of circularity policies (including redistributing waste to informal workers or weaker environments). Coherent SDGs must thus be concerned with labor conditions and fairness in recycling and waste industries.

7.6. Integrating Transition Goals with Biodiversity and Water Constraints: Toward Least-Harm Pathways

One fundamental observation that can be made regarding the literature is that there is a range of decarbonization pathways and that all present some differences in their results in terms of emissions, land, water, and biodiversity. Narrow-minded decision-making that is based on carbon may have unintended consequences of putting a lot of pressure on the delicate ecosystems or water-stressed basins. SDG-consistent governance thus requires the least-harm planning, which considers biodiversity and water limitation to be part of the transition plan, not additions that are addressed by mitigation [105].

Integrated assessment at various scales allows least-harm pathways to be taken. At the strategic level, there are possible comparisons made of alternative technology combinations, infrastructure patterns, and material demand paths, which include land and water restrictions and emissions. Conscientious use of the mitigation hierarchy and cumulative impact assessment at the project level can be used to minimize damages in situations where the siting is not on high-value ecosystems and where water use is constrained by the sustainability of the basin. On the governance level, the conflict can be minimized and better results achieved by aligning the permitting with spatial planning, rights-based consultation, and transparent monitoring. According to the literature, such integration becomes more and more possible, since better data and planning tools can be used, and institutionally hard, as energy, mining, environment, and land agencies may be working separately and have divergent mandates and political incentives [106].

The transition will not go green per se; it will need active regulation so that climate gains will not be obtained at the cost of ecological destruction and social injustice [107]. Three priorities run across the mining, processing, renewables siting strategies, and circularity strategies. To begin with, the planning needs to be upstream taking strategic evaluation and spatial governance to prevent the most sensitive ecosystems and to address cumulative effects, instead of depending on project-by-project mitigation. Second, responsibility should be enhanced by having a plausible monitoring system, enforceable laws of waste and water management, and financial guarantee systems that internalize long-term liability. Third, legitimacy needs to be established via rights-respecting procedures, equitable exchange of benefits, and a powerful grievance system that helps in disseminating distributional effects and alleviating conflict. In the domains, there are replicated intervention families that are only successful under certain institutional and measurement conditions. **Table 3** is an aggregate of the cross-sector success conditions and the minimum verification requirement to prevent symbolic compliance.

Table 3. Cross-sector comparison of intervention families and what success requires.

Intervention Family	Where It Appears Most	Main Mechanism	What Robust Success Typically Requires	What to Verify (Minimum)
Spatial protection (PAs, OECMs, no-go zones)	Forests; biodiversity; marine	Limits conversion/extraction; preserves core habitat	Adequate funding and enforcement; representativeness; connectivity; legitimacy and rights safeguards	Avoided loss (counterfactual), management effectiveness, leakage/displacement

Table 3. *Cont.*

Intervention Family	Where It Appears Most	Main Mechanism	What Robust Success Typically Requires	What to Verify (Minimum)
Rights-based co-management	Fisheries; forests; rangelands; OECMs	Aligns stewardship incentives with local authority	Secure tenure/access rights; equitable benefit-sharing; conflict resolution mechanisms; legal recognition	Compliance, distribution of benefits/costs, institutional durability
Economic instruments (PES, credits, subsidy reform)	Forests; restoration; water; biodiversity finance	Internalizes externalities through payments/prices	Credible baselines, additionality, permanence; transparent MRV; safeguards against elite capture	Net ecological outcomes, social safeguards, leakage and reversal risk buffers
Nature-based/restoration solutions	Coasts; land; watersheds; forests	Restores function; buffers hazards; sequesters carbon	Correct ecological targeting; maintenance; stressor removal (pollution, hydrology); long horizons	Functional indicators (not hectares), climate-risk robustness, co-benefits realized
Demand-side & supply-chain governance	Forest commodities; plastics; minerals	Shifts incentives upstream via procurement/traceability	High traceability coverage; enforcement; inclusion of smallholders; alignment with public regulation	Deforestation/pollution reductions across full chain; exclusion risk; laundering controls
Hybrid infrastructure portfolios	Water; coasts; cities	Combines engineered reliability and ecosystem buffering	Lifecycle finance; adaptive operations; land-use coordination to prevent maladaptation	Reduced risk and ecological harm vs baseline; maintenance and performance stability

The policies of the circular economy are able to smooth out the demand peaks on primary extraction in the long term, but not in the short term, with intensive growth. Thus, SDG coherence would be based on the need to scale clean energy and, at the same time, to enhance environmental and social governance in the resource frontiers. The success of the energy transition in the long run will be accordingly evaluated not only by the volume of emission reductions but also by the ability of the transition to set the pathways of development that will not overstep the ecological threshold and provide long-term and sustainable, equitable economic advantages[108].

8. Conclusion: Cross-Sector Synthesis, Decision Principles, and Future Directions

Striking a balance between ecosystems and economies under the SDGs is not an issue of maintaining a stable middle ground as much as an issue of managing dynamic, coupled social-ecological systems where pressures, incentives, and risks change more quickly than institutions generally do. Nature-wide, in waters, onshore and offshore, in forests, oceans and coasts, biodiversity networks, and extractives to the energy transition, the literature is brought together into a single realization: environmental resource management provides long-lasting development solutions only when ecological boundaries are addressed as an existing constraint and social legitimacy as a fundamental design necessity, rather than an afterthought. Policies focused on the short-term increase in output—be it crop output, hydropower output, coastal development, timber revenues, or mineral supply—tend to externalize the long-term costs in forms of impaired ecosystem functioning, increased climate susceptibility, and social conflict that eventually undermine economic value. On the other hand, more ecological thresholds and distributional results can be internalized in interventions that transform trade-offs into the stabilized synergies of the natural processes that mediate productivity, risk buffering, and resilience.

In order to convert these results into a practical decision, **Figure 3** outlines an SDG-compatible decision pathway that brings ecological thresholds, distributional protection, outcome-based MRV, and adaptive learning into one cycle of management.

The first cross-sector finding is the critical role played by measurement, monitoring, and accountability. The coming of age of Earth observation, digital MRV, and new biodiversity assessment tools has broadened the scope of what can be measured, but the results indicate that what is measured is what is also governed. Where the monitoring systems are used to monitor inputs and activities instead of the ecological conditions and human consequences, governance is pushed towards symbolic compliance and indicator optimization. This is a high-stakes risk in the case of restoration targets, biodiversity credit, carbon financing, and corporate supply-chain commitments, where incentives can reward apple hectares enrolled or credits issued as opposed to long-term restoration of ecosystem functioning. In all sectors, the most plausible methods involve portfolios of indicators reflecting pressures, states, and responses, incorporating explicitly the issue of uncertainty, and with institutions able to act on the information that they generate. Surveillance enhances performance only in cases where it is associated with binding rules, transparency in reporting, and management procedures that alter decisions where circumstances vary.

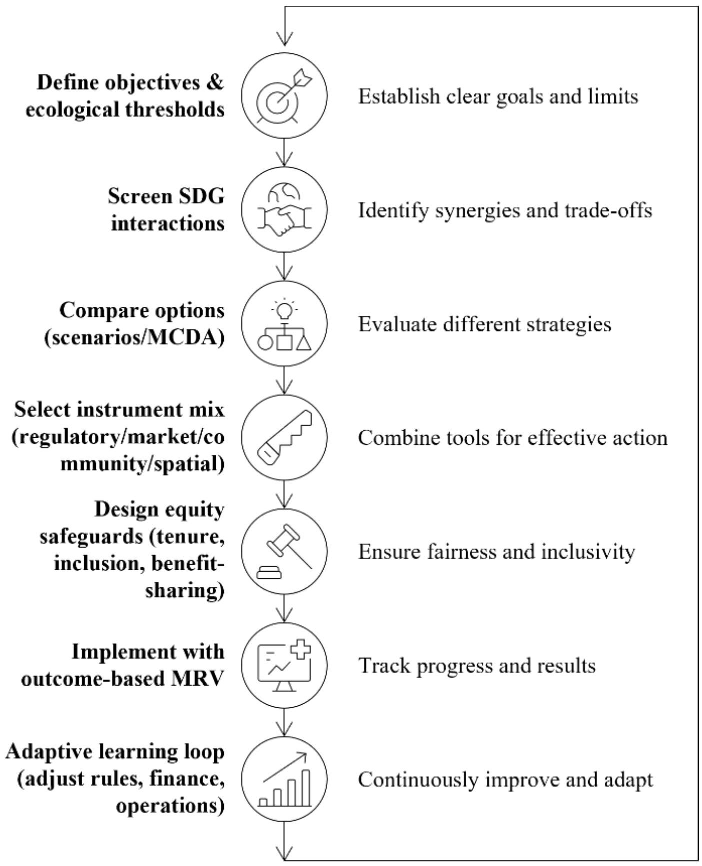

Figure 3. SDG-aligned decision pathway for implementation of ERM under uncertainty.

The second cross-sector observation is that the effectiveness of governance is dependent on the matching of incentives on different scales. Local stewardship is up to the protection of forests, to the management of fisheries, and even to the continuation of land restoration, when rights are solid and benefits real, but local action is time after time frustrated when upstream drivers are not addressed. Place-based conservation is often crushed by the forces of demand-side forces such as commodity markets, supply-chain structures, subsidy regimes, and infrastructure investment, provided they remain rewarding conversion and overuse. This misalignment can be brought to the fore with the SDG lens: SDG 15 or SDG 14 cannot be maintained if SDG 12 is only rhetorically followed. This means that the most effective strategies should be the ones that integrate place-based (protected areas, co-management, restoration) and structural (subsidy reform, procurement standards, traceability, pollution controls, and integrated planning) interventions to redesign incentives. Significantly, this kind of incentive alignment should be created in a manner that does not lead to the formation of exclusionary results that would place the compliance burden on smallholders or small-scale fishers and allow bigger actors to adjust with relative simplicity.

The third cross-sector finding is that equity cannot be separated from effectiveness. The distributional effects: who is constrained, who benefits as a result of finance, who is subject to risk of pollution or hazard, who is the owner of land or of resource rights—influence the legitimacy and the obedience, and consequently the sustainability of environmental results. Rights-based approaches, meaningful participation, and benefit-sharing arrangements are continually found as enabling conditions in any number of sectors, in community forestry, fisheries co-management, conservation areas, restoration initiatives, mining, and renewables siting. In situations where there is poor social protection, intervention may lead to conflict, resistance, or displacement, which will compromise ecological integrity as well as economic stability. Equity as a normative endpoint under SDG coherence implies that, in addition to the reduction of fragility, it is a governance tool aimed at enhancing the chances of resource management rules surviving political periods and disasters.

The fourth cross-sectoral finding is the increased significance of adaptive governance in the context of climate change. Permanent ground posts and unchanging allocations are becoming more and more in line with ecological realities. Distribution of water is becoming increasingly erratic; species are changing their locations; forests are getting more disturbed; and, under rising sea levels and intensifying storms, the coastal risks are rising. These dynamics optimize the importance of the flexible use of rules, the shifting spatial planning, the risk-conscious finance, and the collection of interventions that work reasonably across various futures. Simultaneously, adaptation also brings about difficult decisions on losses that cannot be entirely averted, necessitating the combination of environmental management and diversification of livelihoods with social protection and premeditated changes in vulnerable areas. According to the literature, adaptive management would be the most viable in circumstances where monitoring is ongoing, the authority to make decisions is adequately incorporated, and institutional incentives are rewarding learning and not punishing revision.

When combined, these findings imply a viable decision rule of SDG-compatible environmental resource management. To start with, decision-making should be designed in terms of clear ecological limits and accumulating effects, as opposed to incremental mitigation that can destroy ecosystems by cumulative effects. Second, trade-offs must be considered to be judged over time, space, and social groups, and protective measures against the shirking of harms onto the marginalized communities or downstream ecosystems. Third, sustainable governance structures, such as safeguarded rights, enforceable rules, clear assertiveness, and responsive learning cycles, should be prioritized instead of limited project outputs. Fourth, the demand-side and structural drivers should be considered as the main part of the resource management, rather than the outside scenario. Lastly, financial instruments ought to be structured to compensate verified results and long-term custodianship with sparse presuppositions regarding additionality and eternalization, especially where climate shocks largely impact steadiness. Since the interactions of SDGs often happen through design decisions. Because SDG interactions are frequently mediated by design choices, **Table 4** summarizes common ERM decisions, the synergies they can unlock, the trade-offs they tend to trigger, and the design features that consistently reduce those trade-offs.

Table 4. SDG interaction matrix for common ERM decisions.

ERM Decision/Policy Lever	Likely SDG Synergies	Common Trade-Offs	Design Features That Reduce Trade-Offs
Environmental flows + demand management	6 with 2 and 13 via resilience	Short-term water reallocation conflicts	Transparent accounting; drought-sharing rules; protections for vulnerable users
Regenerative soil + diversified systems	2 with 13 and 15 via resilience and habitat	Transition costs; adoption barriers	Tenure security; extension/finance; monitoring of absolute pressures (conversion, nutrient loading)
Protected areas/OECMs networks	15/14 with 13 via carbon and resilience	Displacement; access restrictions	Connectivity planning; rights safeguards; benefit-sharing; leakage controls
Supply-chain deforestation controls	12 with 15/13 via incentive shifts	Exclusion of smallholders; leakage to unmanaged markets	High coverage traceability; inclusion support; alignment with public regulation
Marine spatial planning + co-management	14 with 2 via stock recovery	Perceived enclosure; enforcement gaps	Participatory design; dynamic rules; compliance support for small-scale fleets
Mining + renewables buildout	7/13 with 8 via energy access/jobs	Water stress, tailings risk, biodiversity loss	Strategic siting/no-go zones; cumulative impact assessment; strong liability and rights frameworks
Circular economy policy	12 with 13 via reduced material intensity	Limited near-term offset; rebound effects	EPR, design standards, collection infrastructure, labor safeguards

Another forward research agenda with apparent implications for practice is also mentioned in the review. Similarly, cross-sector outcome measures are still scarce, which limits synthesis and prevents the assessment of interventions across different contexts. There is a need to have stronger causal evidence to differentiate between correlation and impact, especially when it comes to popular instruments like nature-based solutions, certification, ecosystem services payments and offset, and similar. More focus is needed on the experiments of governance that experiment with institutional designs in the conditions of the real political economy, such as the means of scaling participatory approaches without losing their legitimacy and getting more and more excluded. The nexus of the energy transition and biodiversity and water constraints is a particularly urgent border, and needs to be planned with both an eye towards cumulative effects of mining, processing, renewable location, and transmission growth, and realistic evaluations of what circular economy policies can offer on different timeframes.

Overall, the SDGs concept of balancing ecosystems and economies is only possible when the governance of the two perceives ecosystems as central economic infrastructure and not as secondary amenities. The improvements discussed here—enhanced monitoring, enhanced decision support, the increasing variety of policy instruments, and the increase in the popularity of rights-based and participatory models broaden the range of solutions that are practical. However, progress will be weak where it seeks interventions as solitary endeavors, where the realization of targets entails nominal coverage instead of functional results, or the decarbonization process is undertaken without a consideration of its material and spatial imprints. The SDGs offer a lingua franca of integration; to accomplish its pledge, we need to translate that lingua franca into enforceable, adaptive, and equitable administrative to the resource management regimes that support not only ecological integrity but economic well-being in the time of accelerating change.

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The data is all presented in the article.

Conflicts of Interest

The authors declare no conflict of interest.

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