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BIODIVERSITY LOSS: A GLOBAL ISSUE THREATENING ECOLOGICAL BALANCE

ESMANUR ŞEREN[1], Prof.Dr.ABUZER ÇELEKLİ[2]

[1] Gaziantep University, Faculty of Art and Science, esmanurserenn@gmail.com - 0009-0006-9890-237X

[2] Gaziantep University, Faculty of Art and Science, celekli.a@gmail.com - 0000-0002-2448-4957

ABSTRACT

The accelerating loss of biodiversity globally presents an urgent challenge, threatening ecological balance, human well-being, and economic stability. This review synthesizes current knowledge on the multifaceted causes of biodiversity decline, including habitat destruction, climate change, pollution, overexploitation, and the spread of invasive species. It further explores the profound consequences of this loss on ecosystem services such as pollination, water purification, and carbon sequestration, which are indispensable for human survival. The paper emphasizes the critical role of conservation and sustainable use strategies, highlighting the importance of expanding protected areas, adopting sustainable management practices in agriculture, forestry, and fishing, and engaging local and indigenous communities in conservation efforts. Additionally, it underscores the significance of international cooperation and policy frameworks, such as the Convention on Biological Diversity, in mobilizing resources and coordinating global efforts to combat biodiversity loss. The review calls for an integrated research approach, combining biological, socioeconomic, and policy perspectives to fill existing knowledge gaps and address the challenges of biodiversity loss. It advocates for immediate, global, and coordinated action, supported by robust scientific research and adequate funding, to reverse the current trends of biodiversity decline. Through adaptive, innovative, and inclusive conservation approaches, the paper argues for preserving the planet's biological diversity for future generations, recognizing nature's intrinsic and practical values.

Keywords: Biodiversity Conservation, Climate Change, Ecosystem Services, Habitat Destruction, Invasive Species

1. INTRODUCTION

In the face of global challenges such as increasing human population and climate change, the preservation of wetland ecosystems and biodiversity has become increasingly paramount (Çelekli et al., 2023a, 2023b, 2023c; Çelekli and Zariç, 2024a). The degradation of wetlands not only threatens ecosystems but also undermines the sustainability of natural resources, which form the foundation for food security and efforts to combat climate change (Zariç et al., 2024;

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Zariç and Çelekli, 2023). In this context, understanding the significant relationship between wetland resources, particularly algae, and the nexus of nutrition security and biodiversity conservation is crucial for devising appropriate solutions towards a sustainable future (Çelekli et al., 2024; Çelekli and Zariç, 2023a, 2024b, 2024c, 2023b; Zariç et al., 2022). Unsustainable modern dietary habits have even been linked to jaw issues in humans (Zariç et al., 2023).

Biodiversity, or biological diversity, refers to the variety of life on Earth, encompassing the variability among all living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems and the ecological complexes they are part of (Thompson et al., 2004). This diversity is not only a matter of aesthetics or intrinsic value but also plays a crucial role in the functioning of ecosystems and the services they provide, which are essential for human survival and well-being (Haines-Young and Potschin, 2012). Biodiversity contributes to ecosystem resilience, productivity, stability, and availability of resources such as food, medicines, and clean water (Çelekli and Zariç, 2023c; Oliver et al., 2015).

Biodiversity holds immense importance beyond its practical benefits, serving as the cornerstone for crucial ecosystem services including air and water purification, climate regulation, pollination, and soil fertility (Sekercioglu et al., 2010). These services are indispensable for sustaining life, and a decrease in biodiversity can lead to ecosystems that are less resilient, productive, and supportive of various species, including humans (Perrings, 2011). Additionally, biodiversity serves as a vital indicator of ecosystem health, with its decline signaling environmental degradation and potential sustainability challenges (Perrings, 2011). Figure 1 depicts Earth's biodiversity hotspots, exemplified by regions like the Brazilian Cerrado and the Atlantic Forest (Mittermeier et al., 2011).

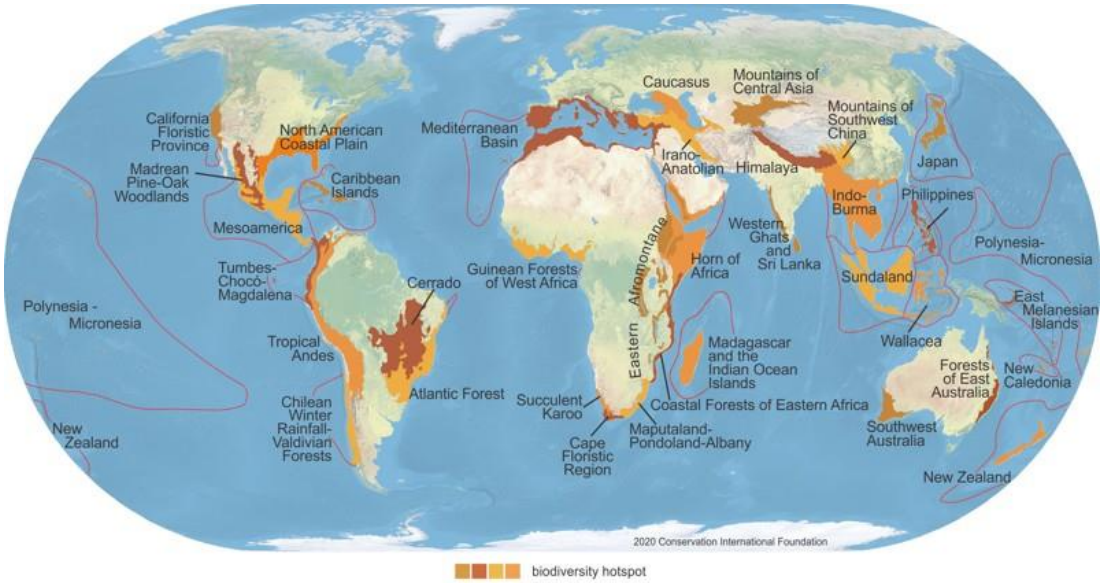

Figure 1. Map of the Earth's biodiversity hotsposts (Mittermeier et al., 2011)

The role of biodiversity in maintaining global ecological balance is immense (Huston, 1999). Diverse ecosystems are more robust and can adapt to changes and shocks, such as climate change and natural disasters (Renaud et al., 2010). This resilience is vital in the face of increasing environmental pressures and challenges. Biodiversity also plays a critical role in mitigating climate change by contributing to carbon sequestration, controlling pests and

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diseases, and helping ecosystems recover from disturbances (Çelekli and Zariç, 2023d; Thompson et al., 2009). Table 1 indicated Overview of Biodiversity Loss.

Table 1. Overview of Biodiversity Loss

Indicator	Data	Period	REF
Global vertebrate populations	68% decline	1970-2020	(Almond et al., 2020)
Forested area loss	420 million hectares	1990-2020	(Mather, 2003)
Freshwater species populations	83% decline	1970-2020	(Almond et al., 2020)
Species at risk of extinction (IUCN)	Over 37,400 species	As of 2023	(Betts et al., 2020)
Decline in pollinator diversity	Significant declines noted	Various	(Mayberry and Elle, 2010)
Economic value of ecosystem services loss	Estimated at US$4-20 trillion per year	Annually	(Max Finlayson, 2018)

2. THE GLOBAL STATUS OF BIODIVERSITY LOSS

2.1 Assessment of Current Biodiversity Conditions

Global biodiversity is in a worrying state, marked by significant declines in species populations and ecosystem integrity worldwide. The Living Planet Report by the World Wildlife Fund reveals an average 68% decline in vertebrate species populations since 1970 (Green et al., 2020), indicating loss of species, ecosystem degradation, and reduced genetic diversity within populations (Schaberg et al., 2008). Habitats like forests, wetlands, and coral reefs, abundant in biodiversity, face threats from human activities such as deforestation, pollution, and overfishing, hastening their degradation and the loss of their services (Prakash and Verma, 2022).

2.2 Changes and Trends over Time

In recent decades, biodiversity loss has accelerated due to the growing human population and its demand for natural resources; this has resulted in habitat loss, overexploitation, climate change, pollution, and the introduction of invasive species, worsening the decline in biodiversity (Vijeta et al., 2021). The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) warns that up to one million species are currently facing extinction, many within the next few decades, a rate tens to hundreds of times higher than the average over the past 10 million years; these alarming trends signify a crisis for the natural world and pose a direct threat to human well-being, underscoring the urgent need for global conservation efforts (Baste et al., 2024).

2.3 Measurement and Monitoring of Biodiversity Loss

Measuring and monitoring biodiversity loss pose significant challenges due to Earth's immense variety of life and the multitude of factors impacting it. Various indicators, such as species richness, population abundance, habitat extent, and ecosystem health, are employed to gauge biodiversity's status (Mollot et al., 2017). Tools like the Red List of Threatened Species, provided by the International Union for Conservation of Nature, furnish crucial data on species' extinction risk, habitat needs, and population trends (Betts et al., 2020). Remote sensing

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technology and geographic information systems are pivotal for tracking habitat changes and loss on a global scale (Menon and Bawa, 1997). Moreover, citizen science initiatives play a vital role in biodiversity monitoring by gathering data on species occurrences and distributions (Chandler et al., 2017). The global community depends on these assessments to steer conservation efforts and policy decisions (Berkes, 2007). Despite the complexities in measurement and monitoring, the collected data is invaluable for comprehending the magnitude of biodiversity loss and devising strategies to alleviate it (Pettorelli et al., 2014). The persistent decline in biodiversity emphasizes the necessity for reinforced conservation measures and sustainable management of natural resources to safeguard the health and resilience of ecosystems for future generations (Reid et al., 2019).

3. CAUSES OF BIODIVERSITY LOSS

3.1 Habitat Destruction and Fragmentation

Expanding agriculture, forestry, and urban development have resulted in substantial habitat destruction and fragmentation, a key contributor to biodiversity loss (Liu et al., 2019). For example, the FAO reports that around 420 million hectares of forest have been converted to other land uses since 1990, mainly due to agricultural expansion. This conversion not only diminishes the total area accessible for native wildlife but also divides habitats into disconnected patches, compromising species populations' viability by restricting their movement and resource access (Hobbs et al., 2008).

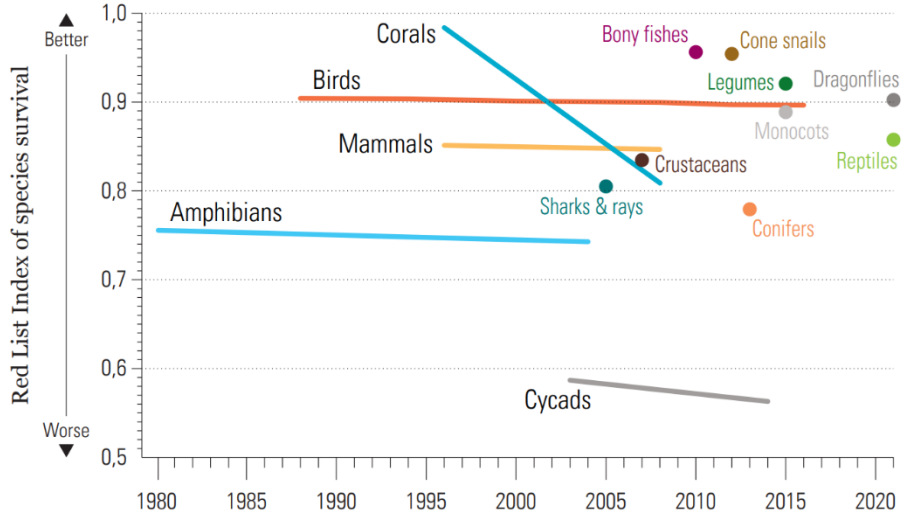

Figure 2. The Red List Index shows trends over time in species' survival probability, with a decline representing a species being driven to extinction (Almond et al., 2020).

3.2 Use of Water Resources and Transformation of Aquatic Ecosystems

The modification of water bodies for human purposes—through actions like dam construction for hydroelectric power, water diversion for irrigation, and pollution discharge—has significantly affected aquatic ecosystems (Carpenter et al., 2011). The World Water Development Report by UNESCO underscores that water resource overuse and pollution have degraded freshwater systems, impacting the quantity and quality of water accessible to species reliant on these environments. These changes contribute to the decline of freshwater biodiversity, with the Living Planet Index indicating an alarming 83% decrease in freshwater species populations since 1970 (Marques, 2020).

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3.3 Effects of Climate Change

Climate change, fueled by anthropogenic greenhouse gas emissions, disrupts global and local climates, significantly impacting biodiversity (Kannan and James, 2009). The Intergovernmental Panel on Climate Change (IPCC) documents shifts in species distribution, phenology, and the structural and functional dynamics of ecosystems due to rising temperatures and altering precipitation patterns (Iler et al., 2021). Additionally, sea-level rise and ocean acidification, stemming from increased atmospheric CO2 levels, present further threats. Ocean acidification, for instance, affects calcifying organisms by diminishing their ability to form and sustain shells or skeletons, endangering marine biodiversity at its foundational levels (Lu et al., 2018).

3.4 Pollution

Pollution originating from industrial, agricultural, and urban sources introduces harmful substances into natural environments. Notably, nitrogen and phosphorus runoff from agriculture contribute to eutrophication in aquatic systems, resulting in dead zones where aquatic life cannot thrive (Tiwari and Pal, 2022). The widespread presence of plastic pollutants, extensively documented in marine environments, poses physical and chemical hazards to wildlife, with millions of marine animals suffering from ingestion or entanglement annually; the accumulation of heavy metals and persistent organic pollutants in ecosystems has long-term detrimental effects on species survival and reproduction (Thushari and Senevirathna, 2020).

3.5 Overexploitation

Overexploitation of natural resources, such as overfishing and excessive harvesting of forest resources, directly diminishes species populations and degrades ecosystems (Prakash and Verma, 2022). The United Nations reports that over 30% of the world's fish stocks are overexploited, endangering marine biodiversity and the livelihoods of communities dependent on fisheries. Similarly, unsustainable logging practices contribute to deforestation, impacting terrestrial biodiversity and ecosystem services (Friedman et al., 2018).

3.6 Invasive Species

Introducing non-native species to new environments, whether accidentally or intentionally, can result in the establishment of invasive species that profoundly affect local ecosystems (Manchester and Bullock, 2000). Invasive species often outcompete native species for resources, prey on them, or introduce novel diseases (Lawson Handley et al., 2011). The Global Invasive Species Database highlights numerous cases where invasive species have led to the decline or extinction of native species, altered ecosystem composition and function, and diminished native biodiversity (Mollot et al., 2017).In conclusion, the causes of biodiversity loss are multifaceted, stemming from a combination of anthropogenic activities that alter habitats, climate, and species interactions. The scientific data underscores the urgent need for comprehensive conservation strategies to mitigate these impacts and preserve global biodiversity.

4. CONSEQUENCES OF DIVERSITY LOSS IN ECOSYSTEMS

4.1 Reduction in Ecosystem Services

The loss of biodiversity carries profound implications for the ecosystem services vital to human societies (Haines-Young and Potschin, 2012). Pollination, primarily carried out by bees and

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other insects, is essential for the production of approximately 35% of global food crops, as reported by the Food and Agriculture Organization (FAO) (van der Sluijs and Vaage, 2016). Water purification processes, facilitated by wetlands and forests, suffer as these ecosystems diminish, leading to heightened costs for artificial water treatment and decreased water quality (UN, 2015). Additionally, forests play a crucial role in carbon sequestration, mitigating climate change by absorbing CO2 from the atmosphere (Nunes et al., 2020). The Global Forest Resources Assessment by the FAO highlights that the world's forests store more carbon than is present in the atmosphere, emphasizing the importance of forest conservation for climate regulation (Kormos et al., 2017).

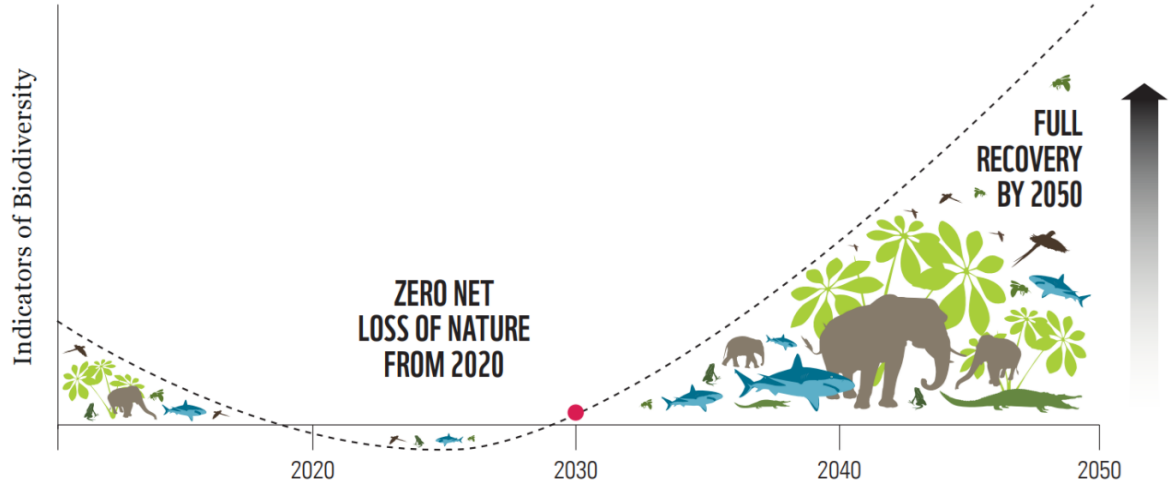

Figure 3. Nature Positive by 2030 A measurable global goal for nature (Almond et al., 2020).

4.2 Disruption of Ecological Balance

Biodiversity loss disrupts ecological balance, impacting interspecies relationships and the stability of food chains (Pimm, 1994). The extinction of a single predator or keystone species can trigger cascading effects throughout the ecosystem, a phenomenon observed in various studies. For instance, the removal of wolves from Yellowstone National Park resulted in overgrazing by elk and subsequent degradation of vegetation and river ecosystems (Barrios-O'Neill et al., 2017). The reintroduction of wolves helped restore balance, highlighting the intricate connections within ecosystems (Manning et al., 2009). Similarly, the decline in top predators in marine environments, often due to overfishing, has been associated with the overabundance of herbivorous species, leading to coral reef degradation (McClanahan et al., 2002).

4.3 Impacts on Human Health and Economic Activities

The loss of biodiversity also directly and indirectly impacts human health and economic activities (Chivian, 2002). A diverse genetic pool is crucial for food security, as crop diversity helps safeguard against pests and diseases while ensuring nutritional needs are met (Frison et al., 2011). The World Health Organization (WHO) underscores that 75% of the world's population relies on plant-based medicine for primary healthcare, with many pharmaceuticals derived from natural compounds. The loss of species may limit future discoveries of medicinal resources (Moyo et al., 2015). Furthermore, biodiversity is a cornerstone of the tourism industry, particularly in regions where wildlife and pristine natural environments attract visitors. Therefore, the decline in biodiversity can have significant economic repercussions, impacting livelihoods and economies, especially in biodiversity-rich but economically poor

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regions (Adetola, 2023). In summary, the ramifications of biodiversity loss transcend the environmental sphere, impacting the pillars of human well-being, economy, and health. Preserving biodiversity is not just a moral imperative but a critical step for sustainable development and the perpetuation of life on Earth as we understand it. The imperative for coordinated global action to halt and reverse biodiversity loss has never been more pressing, underscored by scientific evidence and international reports on the state of the planet's ecosystems.

5. CONSERVATION AND SUSTAINABLE USE STRATEGIES

5.1 Expansion and Management of Protected Areas

Protected areas serve as a cornerstone of biodiversity conservation strategies, offering sanctuary for species and safeguarding critical habitats (Vimal et al., 2021). The World Database on Protected Areas (WDPA) indicates that protected areas span approximately 15% of the land surface and 7% of the ocean. However, the efficacy of these protected areas often hinges on adequate management, funding, and enforcement. Research published in the journal Science underscores the necessity for a global expansion of protected areas to meet the Aichi Biodiversity Targets, particularly Target 11, which stipulates conserving at least 17% of terrestrial and 10% of marine areas. Effective management entails tackling challenges such as poaching, illegal logging, and the impacts of climate change within these zones (Afriyie et al., 2021).

5.2 Sustainable Practices in Agriculture, Forestry, and Fishing

Adopting sustainable practices in agriculture, forestry, and fishing is paramount to alleviating pressure on biodiversity (Thrupp, 2000). Agroecology, integrating biodiversity as a fundamental farming element, has improved productivity, resilience, and sustainability while lessening environmental impacts (Wezel et al., 2020). The Food and Agriculture Organization (FAO) endorses sustainable forest management practices that harmonize economic, social, and ecological goals. Similarly, the Marine Stewardship Council (MSC) advocates for sustainable fishing practices to maintain the health and productivity of fish populations and ecosystems for future generations.

Table 3: Successful Conservation Case Study

Case Study	Location	Strategies Used	Challenges Faced	Outcomes Achieved	Reference
Gorilla Conservation	Central Africa	Anti-poaching patrols, habitat restoration, community engagement	Poaching, habitat loss, disease	Increase in mountain gorilla population	IUCN (2020)
Great Barrier Reef Protection	Australia	Marine protected areas, water quality improvements,	Coral bleaching, water pollution, invasive species	Stabilization of certain coral populations, improved water quality	Great Barrier Reef Marine Park Authority (2021)

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Case Study	Location	Strategies Used	Challenges Faced	Outcomes Achieved	Reference
		climate change mitigation			
Amazon Rainforest Sustainable Use	Brazil	Protected areas, sustainable land use practices, indigenous rights enforcement	Deforestation, illegal mining, agriculture expansion	Reduction in deforestation rates, empowerment of indigenous communities	National Institute for Space Research (INPE) Brazil (2020)
Tigers in India	India	Anti-poaching units, habitat corridors, community-based tourism	Poaching, human-wildlife conflict, habitat fragmentation	Doubling of wild tiger population since 2006	(Almond et al., 2020)
Bald Eagle Recovery	United States	DDT ban, habitat protection, reintroduction programs	Pesticide pollution, habitat destruction, hunting	Recovery from near extinction to over 10,000 breeding pairs	U.S. Fish & Wildlife Service (2019)

5.3 Participation of Local and Indigenous Communities

Local and Indigenous communities are integral to biodiversity conservation, often holding traditional knowledge and sustainable management practices that have preserved biodiversity for generations (Chamley et al., 2008). The Convention on Biological Diversity (CBD) acknowledges the significance of engaging these communities in conservation initiatives, emphasizing the importance of respecting their rights and knowledge. Research indicates that lands managed by Indigenous peoples typically exhibit higher levels of biodiversity, highlighting the effectiveness of their stewardship practices.

5.4 Biodiversity in Combating Climate Change

Biodiversity plays a crucial role in mitigating climate change, with ecosystems like forests, peatlands, and mangroves serving as substantial carbon sinks (Secretariat of the Convention on Biological Diversity (CBD), 2016). The Intergovernmental Panel on Climate Change (IPCC) highlights that safeguarding and restoring these ecosystems can help mitigate climate change by absorbing CO2 from the atmosphere. Additionally, preserving healthy ecosystems enhances resilience to the impacts of climate change, decreasing vulnerability for both human and natural communities (Côté and Darling, 2010).

5.5 Innovations in Technology and Science

Technological and scientific advancements offer new avenues for biodiversity conservation and sustainable practices (Stephenson, 2020). Remote sensing and satellite technology furnish data for monitoring habitat alterations, species distributions, and biodiversity threats on a global

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scale (Pettorelli et al., 2014). Genetic technologies like DNA barcoding facilitate species identification and the detection of illegal wildlife trade (Smart et al., 2021). Furthermore, progress in renewable energy technologies diminishes reliance on fossil fuels, thereby reducing habitat destruction linked to energy extraction and mitigating climate change (Gasparatos et al., 2017). In conclusion, a comprehensive strategy that integrates protected area expansion, sustainable resource utilization, community engagement, climate change mitigation, and technological innovation is imperative for conserving biodiversity and securing its sustainability. These approaches, underpinned by scientific research and global collaboration, are pivotal for reversing the prevailing trends of biodiversity decline and preserving the natural world for posterity.

6. INTERNATIONAL COOPERATION AND POLICIES

6.1 CBD (Convention on Biological Diversity) and Other International Agreements

The Convention on Biological Diversity (CBD), established at the Earth Summit in Rio de Janeiro in 1992, stands as a comprehensive global accord aimed at conserving biological diversity, promoting the sustainable use of its components, and ensuring the fair and equitable sharing of benefits from genetic resources. With 196 parties, the CBD boasts three primary objectives that serve as a framework for international biodiversity endeavors. Additionally, the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization of the CBD further underscores the importance of benefit-sharing in conservation (Chandra and Idrisova, 2011). Other pivotal international agreements include the Ramsar Convention on Wetlands, which centers on wetland conservation and sustainable use, and the CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora), designed to ensure that international trade does not imperil species survival (Gardner and Davidson, 2011). The United Nations Framework Convention on Climate Change (UNFCCC) and its Paris Agreement also wield significant influence on biodiversity, given that climate change stands as a significant driver of biodiversity loss (Warren et al., 2018).

6.2 Recommendations for Global, Regional, and Local Policies

Global, regional, and local policies must be integrated and aligned to combat biodiversity loss effectively (Xu et al., 2021). Globally, there is a need for more robust implementation and enforcement of international agreements (Weiss and Jacobson, 1999). Regionally, policies should address specific biodiversity challenges, considering ecological, social, and economic contexts (Wittmer and Gundimeda, 2012). Locally, community involvement and integrating traditional knowledge are vital for successfully managing and conserving biodiversity (Chamley et al., 2008).

6.3 Policy Recommendations Include:

Strengthening the integration of biodiversity considerations into other sectors, such as agriculture, forestry, and urban development, to address indirect drivers of biodiversity loss. It enhances the effectiveness of protected areas through better management, adequate funding, and community involvement (Simkin et al., 2022). They are implementing measures to reduce pollution, including stricter regulations on pesticides and plastic waste (Rajmohan et al., 2019).

6.4 Mobilization of Funding and Resources

Adequate funding is essential for the successful implementation of biodiversity conservation efforts (Adenle et al., 2015). The Global Environment Facility (GEF), acting as a financial

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mechanism for the CBD, has contributed significant funding to biodiversity projects worldwide (Menzel, 2005). Nevertheless, the current level of economic resources falls short of addressing the magnitude of biodiversity loss. Innovative financing solutions such as green bonds, biodiversity offsets, and payment for ecosystem services (PES) schemes have the potential to mobilize additional resources (Seidl et al., 2024). Increased international cooperation is paramount for mobilizing the necessary funding and resources (Chandra and Idrisova, 2011). Wealthier nations can support biodiversity conservation in developing countries through financial aid, technology transfer, and capacity-building initiatives (Adenle et al., 2015).

7. CONCLUSION

This comprehensive review on biodiversity loss highlights the intricate interplay of various drivers, including habitat destruction, climate change, pollution, overexploitation, and invasive species, and their significant impacts on essential ecosystem services vital for human survival, such as pollination, water purification, and carbon sequestration. These impacts extend to disrupting ecological equilibriums and posing threats to food security, public health, and economic stability. Additionally, it underscores the importance of leveraging technological advancements and scientific research for effective biodiversity monitoring and the creation of innovative conservation financing mechanisms. International cooperation and policy frameworks, notably the Convention on Biological Diversity, play a crucial role in mobilizing resources and implementing efficient conservation strategies globally. This approach should prioritize filling knowledge gaps, particularly concerning the impacts of climate change on biodiversity and the effectiveness of conservation strategies across various ecosystems. In summary, the synthesis of these findings emphasizes the urgent need for coordinated global action to reverse biodiversity decline, necessitating robust research, adequate funding, and inclusive, innovative conservation approaches that acknowledge both the intrinsic and practical values of nature, thus ensuring the preservation of our planet's biological diversity for future generations.

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