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The Interdependence of Biodiversity and Human Well-Being in Sustainable Development

U. Srineetha

Associate Professor in Zoology, Government Degree College for Women, Pulivendla

Abstract

As society strives to transition towards more sustainable development pathways, it is important to properly conceptualize the link between biodiversity i.e. genes, traits, species and other dimensions and human well-being i.e. health, wealth, security and other dimensions. Human activities and their consequences, such as environmental pollution, the exploitation of resources or deforestation, are major causes of biodiversity loss. However, humans depend on a biologically diverse and healthy environment in many ways, as it provides access to clean water, air and food. Here, we explore how published conceptual frameworks consider the extent to which the biodiversity–HWB links are being integrated into public discourse and scientific research and the implications of our findings for sustainable development. We find that our understanding has gradually as fundamental to HWB. Analysis of the literature trends indicates increasing engagement with the evolved from seeing the value of biodiversity as an external commodity that may influence HWB to biodiversity terms *biodiversity*, *HWB* and *sustainable development* in the public, science and policy spheres, but largely as independent rather than linked terms. We suggest that a consensus framework for sustainable development should include biodiversity explicitly as a suite of internal variables that both influence and are influenced by HWB. Doing so will enhance clarity and help shape coherent research and policy priorities. We further suggest that the absence of this link in development can inadvertently lead to a ratcheting down of biodiversity by otherwise well-meaning policies. Such biotic impoverishment could lock HWB at minimum levels or lead to its decline and halt or reverse progress in achieving sustainable development. We will build on the expertise of an interdisciplinary team involving scholars from psychology, biodiversity research, human geography, and behavioral economics and combine this expertise with a variety of methods, with a focus on quantitative research, experimental and intervention designs, and investigate participants from different age groups to understand the causal effects of different environments with varying degrees of biological diversity on mental health, and to identify the physical, social, and psychological boundary conditions of these causal effect

Keywords: Biodiversity, nature, human health, sustainable development, well-being, ecosystem services

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Introduction

Biodiversity—the variety of life on Earth encompassing genes, species, and ecosystems—forms the foundation of human well-being and sustainable development. Healthy ecosystems provide essential services such as food, clean water, climate regulation, disease control, and cultural and recreational benefits that are vital for human survival and quality of life. From forests and oceans to agricultural landscapes, biodiversity supports livelihoods, enhances resilience to environmental change, and underpins economic development, particularly for communities that depend directly on natural resources [1]. However, biodiversity is declining at an unprecedented rate due to human activities including habitat destruction, pollution, and overexploitation of resources, climate change, and the introduction of invasive species. This loss threatens ecosystem stability and weakens the natural systems that sustain human health, food security, and economic prosperity. Vulnerable populations are especially affected, as they often rely most heavily on ecosystem services and have the least capacity to adapt to environmental degradation. Recognizing the intrinsic link between biodiversity and human well-being is essential for achieving sustainable development [2]. Protecting and restoring biodiversity not only conserves nature but also promotes social equity, economic resilience, and long-term environmental sustainability. Integrating biodiversity conservation into development planning and policy is therefore critical to ensuring a healthy planet that can support present and future generations.

Biodiversity facing threats

However, biodiversity is facing numerous threats that have the potential to cause significant harm to ecosystems and species, some of the main biodiversity threats include.

1. Habitat Loss and Fragmentation: Biodiversity habitat loss and fragmentation are among the most significant drivers of global biodiversity decline.

Habitat loss refers to the complete destruction or severe degradation of natural ecosystems, often caused by deforestation, agricultural expansion, urbanization, mining, infrastructure development, and climate change. When habitats are lost, species lose essential resources such as food, shelter, and breeding sites, leading to population declines and extinctions [3].

Habitat fragmentation occurs when large, continuous habitats are broken into smaller, isolated patches. Even if some habitat remains, fragmentation reduces habitat quality and connectivity. Isolated populations experience restricted movement, reduced gene flow, increased inbreeding, and higher vulnerability to environmental disturbances. Fragmentation also intensifies edge effects, such as increased predation, invasive species, and microclimatic changes.

Impacts on biodiversity include: Decline in species richness and abundance. Disruption of ecological processes (pollination, seed dispersal, nutrient cycling).Loss of specialist and endemic species. Reduced ecosystem resilience to climate change. Together, habitat loss and fragmentation undermine ecosystem integrity and directly threaten biodiversity, ecosystem services, and human well-being [4].

2. Climate Change: Biodiversity loss. Climate change alters temperature, precipitation patterns, and the frequency of extreme and climate change are closely interconnected, with climate change acting as a major driver of biodiversity events such as droughts, floods, heat waves, and cyclones. These changes directly affect species' survival, reproduction, and distribution. Many species are forced to shift their ranges pole ward or to higher altitudes to track suitable climates, while others—especially endemic, specialist, and slow-moving species—are unable to adapt or migrate fast enough, leading to population declines and extinctions. Climate change also disrupts ecological interactions. Changes in seasonal timing (phonological shifts) can cause mismatches between species, such as plants flowering earlier than their pollinators emerge. Marine biodiversity is particularly vulnerable, as ocean warming, acidification, and deoxygenating lead to coral bleaching, loss of shell-forming organisms, and altered food webs.

Key impacts of climate change on biodiversity include: Shifts in species distribution and range contraction. Increased extinction risk and loss of genetic diversity. Altered species interactions and ecosystem functioning. Degradation of ecosystems such as coral reefs, wetlands, forests, and alpine systems. Conversely, biodiversity plays a critical role in climate change mitigation and adaptation. Diverse ecosystems store carbon (forests, mangroves, sea grasses), regulate climate, and enhance resilience to climate extremes. Protecting and restoring biodiversity is therefore essential for addressing climate change and sustaining ecosystem services and human well-being [5]

3. Overexploitation: Biodiversity and overexploitation are strongly linked, as overexploitation is one of the leading direct drivers of biodiversity loss worldwide. Overexploitation refers to the unsustainable use of biological resources through activities such as overfishing, excessive hunting and poaching, overharvesting of timber, fuel wood, and non-timber forest products, as well as illegal wildlife trade. When species are harvested faster than they can reproduce, populations decline rapidly and may collapse or become extinct.

Overexploitation affects not only target species but also entire ecosystems. The removal of key species—such as top predators, large herbivores, or commercially valuable fish—can disrupt food webs, alter species composition, and impair ecosystem functions. It also reduces genetic diversity, making populations less resilient to environmental change and disease.

Impacts of overexploitation on biodiversity include: Population declines and species extinctions. Loss of genetic diversity. Disruption of food webs and ecosystem balance. Degradation of ecosystem services (fisheries, forests, livelihoods) Sustainable use, effective governance, community-based resource management, and enforcement against illegal trade are essential to reduce overexploitation and conserve biodiversity while supporting human well-being.

4. Pollution: Biodiversity and pollution are closely connected, as pollution is a major driver of biodiversity loss across terrestrial, freshwater, and marine ecosystems. Pollution involves the introduction of harmful substances or energy into the environment, including chemicals (pesticides, fertilizers, and heavy metals), plastics, oil spills, sewage, industrial effluents, air pollutants, noise, and light. These pollutants degrade habitats, poison organisms, and disrupt ecological processes. For example, agricultural runoff rich in

nutrients causes eutrophication in water bodies, leading to algal blooms and oxygen depletion that kill aquatic life [6].

Pollution affects biodiversity at multiple levels. At the species level, it causes mortality, reduced reproduction, and physiological stress. At the ecosystem level, it alters species composition and food webs. Persistent pollutants can bio accumulate and bio magnify along food chains, severely impacting top predators and humans.

Major impacts of pollution on biodiversity include: Decline in species abundance and diversity. Habitat degradation and ecosystem imbalance. Bioaccumulation and bio magnification of toxic substances. Loss of ecosystem services such as clean water, soil fertility, and fisheries. Reducing pollution through stricter regulations, sustainable agricultural practices, waste management, and cleaner technologies is essential for biodiversity conservation and human well-being.

5. Invasive species: Biodiversity and invasive species are closely linked, as invasive alien species are a major driver of global biodiversity loss. Invasive species are non-native organisms introduced intentionally or unintentionally into new ecosystems where they establish, spread rapidly, and cause harm to native species and ecosystems. They often outcompete native species for resources, prey on them, introduce diseases, or alter habitats. Because invasive species usually lack natural predators or controls in the new environment, their populations can grow unchecked.

Invasive species reduce biodiversity by causing declines or extinctions of native species, especially endemic and island species. They disrupt ecological interactions, change nutrient cycles, and alter ecosystem structure and functioning. For example, invasive plants can replace native vegetation, while invasive predators can decimate native wildlife populations.

Impacts of invasive species on biodiversity include: Decline and extinction of native species. Reduced genetic and species diversity. Disruption of food webs and ecosystem processes. Economic losses and reduced ecosystem services Preventing introductions, early detection, rapid response, and long-term management are essential strategies to control invasive species and protect biodiversity.

6. Disease: Biodiversity and disease are closely interconnected, with disease emerging as an important driver of biodiversity loss and ecosystem change. Diseases affect biodiversity when pathogens (viruses, bacteria, fungi, parasites) cause population declines or extinctions of wild species. Disease outbreaks can be natural, but their impacts are often intensified by human activities such as habitat loss, climate change, pollution, wildlife trade, and the introduction of invasive species. For example, climate change can expand the range of disease vectors, while habitat fragmentation increases stress and susceptibility in wildlife populations [7]

Loss of biodiversity can also increase disease risk through the dilution effect, where reduced species diversity allows disease-carrying hosts to dominate, and increasing pathogen transmission. Conversely, healthy and diverse ecosystems can regulate diseases by limiting host density and interrupting transmission pathways.

Impacts of disease on biodiversity include: Population declines and species extinctions. Reduced genetic diversity and resilience. Disruption of food webs and ecosystem functioning. Increased zoonotic disease

risks affecting human health. Maintaining biodiversity, regulating wildlife trade, monitoring emerging diseases, and protecting ecosystems are essential for reducing disease risks and supporting ecosystem and human well-being. These threats are interconnected and often exacerbate each other, posing significant challenges to biodiversity conservation efforts. Addressing these thetas require a combination of conservation measures, sustainable resource management, policy interventions, and global collaborative efforts to protect and restore ecosystems and species,

The requirements for mainting biodiversity include

1. Habitats: Requirements for maintaining biodiversity and habitats include ecological, management, and policy measures that ensure the long-term survival of species and healthy ecosystems [8].

Habitat protection and restoration

Conservation of natural habitats such as forests, wetlands, grasslands, and marine ecosystems. Restoration of degraded ecosystems to improve habitat quality.

Habitat connectivity

Maintenance of wildlife corridors and ecological networks to reduce fragmentation. Ensuring gene flow and species movement.

Sustainable resource use

Regulated harvesting of forests, fisheries, and wildlife. Promotion of sustainable agriculture and forestry practices.

Control of threats

Prevention and management of invasive species. Reduction of pollution and habitat degradation. Mitigation of climate change impacts.

Legal and institutional frameworks

Effective implementation of biodiversity laws and protected area networks. Community participation and indigenous knowledge integration.

Monitoring and research

Regular biodiversity assessment and habitat monitoring. Adaptive management based on scientific evidence.

Public awareness and education

Environmental education and stakeholder involvement. Support for conservation-friendly livelihoods. Together, these requirements help maintain biodiversity, ecosystem functions, and the services ecosystems provide to human well-being.

2. Species interaction: Reqementuirs for through healthy maintaining biodiversity species interactions focus on preserving the ecological relationships that sustain ecosystems.

Conservation of diverse species assemblages

Protection of native species, including keystone, umbrella, and endemic species. Maintenance of balanced predator–prey relationships.

Habitat integrity and connectivity

Preservation of natural habitats that support feeding, breeding, and migration. Maintenance of ecological corridors to enable interactions such as pollination and seed dispersal.

Protection of mutualistic interactions

Conservation of pollinators, seed dispersers, and symbiotic organisms. Reduction of pesticide use and habitat degradation affecting mutualists.

Control of invasive species and diseases

Prevention of invasive species that disrupt native interactions. Monitoring and management of wildlife diseases.

Sustainable human activities

Regulation of hunting, fishing, and harvesting to avoid trophic imbalance. Promotion of biodiversity-friendly land-use practices.

Climate change mitigation and adaptation

Reducing climate stress that causes phonological mismatches. Protecting climate refugia to sustain long-term interactions.

Monitoring and ecological research

Long-term study of food webs and species interactions. Adaptive management based on ecosystem responses. Maintaining species interactions is essential for ecosystem stability, resilience, and the continued provision of ecosystem services.

3. International cooperation: Requirements for maintaining biodiversity through international cooperation focus on collective action, shared responsibility, and coordinated policies across countries [9].

International biodiversity agreements

Effective implementation of global conventions such as the Convention on Biological Diversity (CBD), CITES, Ramsar Convention, and Convention on Migratory Species (CMS).Alignment of national biodiversity strategies with international targets.

Tran's boundary conservation

Establishment and management of Tran's boundary protected areas and wildlife corridors. Cooperative management of shared ecosystems (rivers, seas, forests, mountains).

4. Control of illegal wildlife trade

International collaboration to prevent poaching and trafficking. Information sharing, joint enforcement, and capacity building [10].

Financial and technical support

Funding mechanisms for biodiversity conservation in developing countries. Transfer of technology and scientific expertise.

Research, data sharing, and monitoring

Global biodiversity assessments and shared databases. Early warning systems for invasive species and emerging diseases.

Climate change cooperation

Joint actions to mitigate climate change and support ecosystem-based adaptation. Protection of globally important carbon-rich ecosystems.

Capacity building and knowledge exchange

Training programs and sharing best practices. Inclusion of indigenous and local knowledge at international levels International cooperation is essential because biodiversity and ecological processes cross political boundaries, and global challenges require collective solutions. Addressing biodiversity loss requires Global collaboration and cooperation. Government organizations, and communities need to work together to develop and implement Strategies for biodiversity conservation and sustainable development [11].

5. Awareness and Education: Requirements for maintaining biodiversity through awareness and education emphasize building knowledge, positive attitudes, and responsible actions toward nature.

Environmental education at all levels

Integrating biodiversity conservation into school, college, and university curricula. Promoting experiential learning such as field visits and nature-based activities.

Public awareness programs

Awareness campaigns through media, workshops, and community outreach. Use of local languages and culturally relevant communication.

Community participation

Involving local communities and indigenous people in conservation activities. Promoting stewardship and ownership of natural resources.

Capacity building and training

Training for farmers, fishers, forest users, and policymakers on sustainable practices. Skill development for conservation professionals and educators.

Access to information and knowledge sharing

Dissemination of scientific research and traditional ecological knowledge. Open access to biodiversity data and best practices.

Behavioral change and sustainable lifestyles

Encouraging responsible consumption and waste reduction. Promoting biodiversity-friendly products and practices [12].

Institutional and policy support

Support for environmental education institutions and NGOs.Integration of awareness programs into national biodiversity strategies.

Awareness and education are essential for long-term biodiversity conservation by fostering informed decision-making and sustainable human–nature relationships.

6. Sustainable Uses: Requirements for maintaining biodiversity through sustainable use focus on meeting human needs while ensuring the long-term conservation of biological resources.

Sustainable harvesting and resource management

Regulated use of forests, fisheries, wildlife, and non-timber forest products. Harvesting within ecological limits to allow natural regeneration.

Biodiversity-friendly agriculture, forestry, and fisheries

Adoption of agro ecology, organic farming, and integrated pest management. Sustainable forest management and responsible fishing practices.

Legal and policy frameworks

Enforcement of laws regulating resource use and access. Implementation of biodiversity action plans and sustainability standards.

Community-based management and livelihoods

Involvement of local communities in decision-making. Promotion of alternative and sustainable livelihoods to reduce pressure on biodiversity [13].

Monitoring and adaptive management

Regular assessment of resource use impacts on ecosystems. Adjusting management practices based on scientific evidence [14].

Fair and equitable benefit-sharing

Sharing benefits from the use of biological resources and traditional knowledge. Compliance with Access and Benefit-Sharing (ABS) mechanisms [15].

Awareness and capacity building

Educating users and stakeholders on sustainable use practices. Training in conservation-compatible technologies. Sustainable use ensures biodiversity conservation while supporting economic development, food security, and human well-being. By full filling these requirement, we can help protect and preserve Earth's biodiversity allowing ecosystem to thrive, species to survive and future generation to continue benefiting from the inherent value and serious and services provided by diverse life form. If it is said that the biggest threat to biodiversity is from the human race and due to the loss or decrease of biodiversity, the human species suffers the most. So it wouldn't be wrong at all. We can know the relationship between humans and biodiversity from their historical, mythological, cultural and social relationship or their interdependence at present time [16].

Historical relationship of Human with Biodiversity

The history of humans' relationship with nature dates back thousands of years. In the early stages of human development, our ancestors were primarily hunter-gatherers, relying on the natural environment for food, shelter, and other basic needs. They lived in close proximity to nature and had a deep understanding and appreciation for the natural world [17]. As humans transitioned from hunter-gatherer societies to settled agricultural communities, they started to manipulate and shape the environment to suit their needs. The domestication of plants and animals marked a significant shift in our relationship with nature, as humans began to cultivate crops and raise livestock for sustenance. This intimate connection with the land and nature became central to civilizations such as the ancient Egyptians, Mesopotamians, and Mayans, who relied on agriculture for their survival and development [18].

Mythological connection of humans with biodiversity

In various for environmental stewardship, encouraging the protection and conservation of biodiversity for future generations. Exploring and understanding the mythological connection with biodiversity can help to foster a greater appreciation for the natural world and inspire efforts to safeguards its diversity. Plants of spiritual significance are worshipped in various cultures across the world: Sacred Fig (Ficus religiosa): In Hinduism, the sacred fig tree is considered a symbol of enlightenment and is worshipped as the Bodhi tree, under which the Buddha attained enlightenment. Lotus (Nelumbo nucifera): The lotus is revered in Hinduism, Buddhism, and other religions as a symbol of purity, enlightenment, and rebirth. Olive tree (Olea europaea): In Greek mythology, the olive tree is associated with goddess Athena and is considered a symbol of peace and wisdom [19].

Ash tree (Fraxinus excelsior): In Norse mythology, the ash tree is considered sacred and is associated with the world tree Yggdrasil, which connects the different realms of existence. Ayahuasca vine (Banisteriopsis caapi): Among indigenous Amazonian cultures, the ayahuasca vine is worshipped for its psychoactive properties and is used in spiritual ceremonies for healing and insight. These examples illustrate the diverse ways in which plants are venerated and worshipped across different cultures for their spiritual and symbolic significance.

Culture connection of humans with biodiversity

Humans have a deep and enduring cultural connection with biodiversity, shaped through beliefs, traditions, livelihoods, and everyday practices. This connection goes far beyond biological dependence and forms the foundation of many societies and identities. Biodiversity is closely linked to cultural identity and heritage. Many communities associate specific plants, animals, and landscapes with their ancestry, myths, and history. Sacred groves, holy rivers, totem animals, and culturally important species reflect how nature is woven into spiritual beliefs and religious practices [20].

Traditional knowledge systems are another strong expression of this connection. Indigenous and local communities have developed rich knowledge about ecosystems, medicinal plants, crop diversity, and wildlife management over generations. This traditional ecological knowledge supports sustainable resource use and biodiversity conservation. Biodiversity also shapes languages, art, and cultural expressions. Local species and landscapes influence folklore, songs, dances, symbols, and festivals. In many cultures, seasonal changes in biodiversity guide agricultural rituals, food habits, and social events [21].

Livelihoods and cultural practices are intertwined with biodiversity. Fishing communities, pastoralists, forest dwellers, and farming societies depend on diverse ecosystems for food, materials, and income. These interactions often foster stewardship values and a sense of responsibility toward nature. Overall, the cultural connection between humans and biodiversity reinforces conservation by promoting respect, identity, and well-being. Protecting biodiversity therefore also means safeguarding cultural diversity, knowledge systems, and the social values that sustain harmonious relationships between people and nature.

How Loss of Biodiversity Effects Human Well Being and Mental Health

The loss of biodiversity has wide-ranging impacts on human well-being and mental health, affecting physical survival, emotional stability, cultural identity, and quality of life.

1. Impacts on physical well-being

Biodiversity loss reduces ecosystem services essential for human health, such as clean air and water, fertile soils, pollination, and climate regulation. Declining food diversity can lead to malnutrition and food insecurity, while ecosystem degradation increases vulnerability to natural disasters and the spread of infectious diseases [22].

2. Effects on mental health and emotional well-being

Healthy, bio diverse environments support psychological restoration, stress reduction, and emotional balance. Loss of green spaces, wildlife, and natural landscapes is linked to increased stress, anxiety, depression, and feelings of isolation. The disappearance of familiar species and landscapes can cause **ecological grief**, a form of distress associated with environmental loss.

3. Reduced cultural and social well-being

Many cultures derive identity, spiritual meaning, and social cohesion from biodiversity. Its loss disrupts cultural practices, traditional knowledge, and community relationships with nature, particularly among Indigenous and local communities, leading to loss of belonging and psychological distress [23].

4. Decline in recreational and aesthetic benefits

Bio diverse ecosystems provide opportunities for recreation, nature-based tourism, and relaxation. Their degradation limits access to restorative environments, reducing life satisfaction and opportunities for physical activity and social interaction.

5. Increased inequality and vulnerability

Biodiversity loss disproportionately affects communities that depend directly on natural resources for livelihoods. Economic stress, displacement, and loss of security can contribute to mental health challenges, including anxiety and depression.

In summary, biodiversity loss undermines both material foundations of human well-being and non-material benefits such as mental health, cultural identity, and emotional resilience. Conserving biodiversity is therefore essential not only for ecological sustainability but also for maintaining healthy, resilient human societies. Recognizing the link between biodiversity loss, Eco anxiety and mental health is crucial. it highlights the need for Holistic approaches that addresses both ecological and psychological well-being. Promoting nature- based therapy, engaging with nature, advocated for policy changes and prioritized environmental conservation and fostering education and awareness.

Conceptual Approaches Linking Biodiversity and Human Well-Being

Biodiversity and human well-being are closely interconnected, and existing conceptual frameworks highlight these linkages by emphasizing how biological diversity underpins ecosystem functions and services essential for human life. Frameworks such as the Millennium Ecosystem Assessment and the IPBES conceptual framework illustrate that biodiversity supports provisioning services (food, fuel, medicine), regulating services (climate regulation, disease control, water purification), cultural services

(recreation, spiritual values), and supporting services (nutrient cycling, soil formation). These ecosystem services directly and indirectly contribute to key dimensions of human well-being, including health, livelihoods, security, and social relations. At the same time, these frameworks recognize feedback loops, where human activities, governance systems, and socio-economic drivers influence biodiversity, which in turn affects the resilience of ecosystems and the sustainability of well-being benefits[24]. By integrating ecological, social, and institutional dimensions, existing conceptual frameworks provide a holistic understanding of how conserving biodiversity is not only an environmental concern but also a fundamental requirement for sustaining and enhancing human well-being.

Conclusion

Human well-being and sustainable development are fundamentally interdependent with biodiversity. Biodiversity underpins essential ecosystem services—such as food security, clean water, climate regulation, and disease control—that form the material foundation of human survival and economic development. At the same time, it contributes to non-material dimensions of well-being, including mental health, cultural identity, social cohesion, and spiritual fulfillment. Sustainable development cannot be achieved if biodiversity continues to decline. Environmental degradation erodes livelihoods, increases vulnerability to climate change and disasters, and deepens social and economic inequalities, particularly for communities that depend directly on natural ecosystems. Conversely, development pathways that respect ecological limits and promote biodiversity conservation enhance resilience, long-term prosperity, and quality of life. Recognizing the interdependence between biodiversity and human well-being highlights the need for integrated policies that balance environmental protection with social and economic goals. Protecting biodiversity is not a constraint on development but a prerequisite for truly sustainable development that ensures the well-being of present and future generations.

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