ISBN: 978-81-992068-7-8

BIODIVERSITY

Development and Conservation

Editors:

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Bhumi Publishing, India

First Edition: August 2025

Biodiversity 360°: Development and Conservation

(ISBN: 978-81-992068-7-8)

DOI: https://doi.org/10.5281/zenodo.17042704

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9 788199 206878

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Published by Bhumi Publishing,

a publishing unit of Bhumi Gramin Vikas Sanstha

Bhumi Publishing

Nigave Khalasa, Tal – Karveer, Dist – Kolhapur, Maharashtra, INDIA 416 207

E-mail: bhumipublishing@gmail.com

PREFACE

Biodiversity—the rich variety of life on Earth—is the foundation upon which ecosystems thrive, agricultural systems sustain, and human societies flourish. It supports essential services such as food security, climate regulation, water purification, pollination, and disease control. In recent decades, however, biodiversity across the planet has faced unprecedented threats due to deforestation, habitat loss, pollution, invasive species, and climate change. As we find ourselves at the crossroads of environmental degradation and sustainable development, it becomes imperative to understand, appreciate, and act for biodiversity conservation in an integrated and inclusive manner.

Biodiversity 360°: Development and Conservation is an attempt to provide a comprehensive overview of the multifaceted dimensions of biodiversity—its role in ecological stability, economic development, cultural heritage, and scientific innovation. This book aims to bridge the gap between biodiversity science and its practical applications in conservation, sustainable development, and policy-making. By adopting a 360-degree perspective, it explores biodiversity not only in its biological and ecological contexts but also in relation to agriculture, forestry, agroforestry, biotechnology, climate change, and community participation.

The chapters presented in this volume are contributed by experienced researchers, academicians, and practitioners from diverse disciplines. Together, they provide in-depth insights into biodiversity assessments, conservation strategies, ecosystem services, genetic resource management, and the socio-economic implications of biodiversity loss. Special attention is also given to traditional knowledge systems, participatory approaches, and technological innovations that can help conserve biodiversity while supporting livelihoods.

This book is intended for students, researchers, policy-makers, extension workers, and all those interested in the conservation and sustainable use of biological resources. It can serve as both a reference and a source of inspiration for integrating biodiversity into developmental planning and decision-making at local, national, and global levels.

We sincerely hope that Biodiversity 360°: Development and Conservation will contribute to raising awareness, fostering interdisciplinary collaboration, and promoting action towards a more sustainable and biodiverse future.

- Editors

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FUNGAL MEDIATION OF ECOLOGICAL PROCESSES - EXPLORING THE COMPLEX RELATIONSHIPS IN DIVERSE ENVIRONMENTS

Aiko Joyson., P. A. Arya., R. Anu Keerthi.,
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Abstract:

Fungi are pivotal mediators of ecological processes, thriving in diverse environments from dee sea hydrothermal vents to terrestrial ecosystems. Their interactions span mutualism, competition and parasitism influencing key functions such as nutrient cycling, decomposition, plant health and biodiversity. In extreme marine habitats, fungi form complex associations with bacteria, aiding survival through metabolic complementarity. On land, fungal symbionts like mycorrhizae and endophytes enhance plant resilience and soil fertility while others act as natural pest controllers or pathogens with significant ecological impacts. Bioluminescent fungi contribute uniquely to forest ecology by facilitating spore dispersal and organic matter decomposition. Furthermore, endophytic and marine derived fungi exhibit remarkable pharmaceutical potential due to their bioactive metabolites. This review synthesizes current knowledge on fungal ecological roles ad interactions underscoring their fundamental contributions to ecosystem stability and their relevance in conservation, agriculture and biotechnology.

Keywords: Fungi, Symbiosis, Ecology, Bioluminescence, Ecological Balance, Mychorrizhae.

1. Introduction:

Fungi are ubiquitous organisms that play a vital role in mediating ecological processes across diverse environments. From the extreme conditions of deep-sea hydrothermal vents to the complex relationships within terrestrial ecosystems, fungi have evolved to thrive in various ecological niches. Through their interactions with other organisms, fungi regulate trophic interactions, nutrient cycling, and decomposition, ultimately influencing ecosystem stability and function (Ruess *et al.,* 2005; Singh *et al.,* 2016). Fungal endophytes, for instance, form symbiotic relationships with plants, influencing plant ecology, distribution, and diversity (Shankar Naik, 2019). Meanwhile, bioluminescent fungi contribute to nutrient cycling, decomposition, and species interactions in terrestrial ecosystems. This compilation explores the complex relationships between fungi and their environments, highlighting their role in maintaining ecological balance in diverse ecosystems.

2. Deep-Sea Fungi and Their Interactions

This section explores the diversity of fungi in deep- sea environments, their interactions with bacteria, and the unique conditions they thrive in.

Who's Down There?

Recent investigations utilizing DNA sequencing alongside culture-dependent techniques have demonstrated that fungi associated with hydrothermal vents predominantly belong to three phyla: Ascomycota, Basidiomycota, and Chytridiomycota (Grossart *et al.,* 2019).

- Ascomycota: This is the most frequently observed group, including genera such as Penicillium and Aspergillus, which are also common in terrestrial soils. Certain species within this phylum produce potent an bacterial agents, posing a significant func on in microbial compe on.
- Basidiomycota: This category contains yeasts like Cryptococcus, observed in the sediments of vents. Some of these species possess traits that allow them to cope with sudden fluctuations in temperature.
- Chytridiomycota: These fungi are typically associated with the decomposition of organic compounds, contributing to nutrient cycling within deep-sea habitats (Nagano *et al.,* 2023). What is noteworthy is that a considerable number of these fungi appear to not only survive but also flourish in hydrothermal vent environments, some establishing biofilms and closely interacting with bacteria.

How Do We Know They're There?

Detecting fungi in hydrothermal vents presents significant challenges. Conventional culture- dependent approaches tend to identify only those fungi capable of growth under laboratory conditions, thereby missing a substantial fraction of the microbial diversity present. However, innovative methodologies such as metagenomics and metabarcoding have dramatically advanced the field of fungal research. For instance, a recent investigation of sediment samples from the Mid- Atlantic Ridge revealed more than 200 distinct fungal species, indicating that the diversity of fungi in these ecosystems is likely much more extensive than previously recognized (Bargaud *et al.,* 2020).

2.1 Working Together: Mutualistic Relationships - Surviving in the extreme conditions of deep-sea hydrothermal vents presents significant challenges, prompting microbes to often collaborate for mutual assistance. Certain fungi engage in advantageous associations with bacteria by trading essential nutrients.

Metabolic Complementation: Specific species of fungi give extracellular enzymes that aid bacterial metabolism, enhancing energy acquisition in nutrient-limited environments. In return, bacteria supply fungi with essential growth promoters, fostering a stable microbial consortium (Nagahama *et al.,* 2021).

Carbon and Nutrient Exchange: Some fungi facilitate the breakdown of intricate organic materials, thus releasing nutrients that become accessible to bacteria. In exchange, bacteria generate compounds that promote the growth of fungi. For example, fungi have been found to co- exist with sulphate-reducing bacteria (SRB), which play a key role in anaerobic carbon cycling (Gao *et al.,* 2022).

2.2 Competing for space: Antagonistic Relationships

However, not every relationship is harmonious. In environments with limited resources, such as hydrothermal vents, fungi and bacteria frequently vie for space and nutrients.

Antimicrobial Warfare: Certain fungi, notably species of Penicillium, produce a bacterial substance that inhibit the proliferation of bacteria (Grossart *et al.,* 2019). This capability allows them to establish their own presence within the community.

Biofilm Formation: Bacteria commonly generate biofilms on the surfaces of hydrothermal vents, forming protective aggregates. Some fungi assimilate into these biofilms, whereas others release enzymes that disrupt these structures, creating competition for space and nutrients (Zhang *et al.,* 2023).

Why Does This Matter?

The investigation into deep-sea fungi is still nascent, but it carries substantial implications:

(i) Expanding Our Understanding of Extreme Life - Gaining insights into how fungi endure in such inhospitable scenarios could enhance our comprehension of life's limit on Earth and beyond.

(ii) Biotechnological and Pharmaceutical Potential- The fungal compounds identified in hydrothermal vents may lead to the discovery of novel antibiotics, enzymes, or applications in various industries.

(iii) Deep-Sea Ecology and Conservation- Analysing microbial interactions within vents aids researchers in tracking deep-sea ecosystems, particularly as they face threats from deep-sea mining and climate change.

3. Fungal Interactions and Ecological Roles

Decomposers - Saprotrophic fungi are essential in decomposing complex organic substances, including dead plant and animal matter, into simpler compounds, facilitating nutrient recycling in the ecosystem (White *et al.,* 2018). Decomposition of complex organic matter by saprotrophic fungi is crucial for nutrient recycling, releasing essential elements like carbon and nitrogen back into the soil, thereby enhancing soil fertility and promoting plant growth (Miller & Davis, 2020).

3.1 Mutualists - Fungi engage in mutualistic associations with various organisms

Mycorrhizal Relationship: Arbuscular mycorrhizal fungi (AMF) establish mutualistic relationships with plant roots, improving the host plant's water and nutrient absorption capabilities. In exchanges, the fungi receive carbohydrates produced through the plant's photosynthesis process (Garcia *et al.,* 2017). Arbuscular mycorrhizal fungi (AMF) are crucial in shaping plant community dynamics and enhancing ecosystem productivity, Their symbiotic relationship with plants facilitate nutrient exchange and improve plant health, thereby contributing to the stability and productivity of ecosystems (Chen & Wu, 2021).

Lichens: Lichens are composite organisms arising from a symbiotic relationship between fungi and photosynthetic partners, such as green algae or cyanobacteria. In this mutualistic association, the fungal partner offers structural support and protection, while the photosynthetic partner contributes nutrients through photosynthesis (Taylor *et al.,* 2019). Lichens are resilient organisms that can colonize extreme environments, such as bare rocks and arid regions, where they contribute significantly to soil formation and ecological succession. They achieve this through both physical and chemical weathering processes, breaking down substrates and enriching the developing soil with organic matter. This activity facilitates the establishment of other plant species, thereby advancing ecological succession (Patel & Singh, 2020).

3.2 Pathogens and Parasites - Certain fungi act as pathogens, infecting plants, insects and other organisms

Plant Pathogens: Certain fungi, including *Ophiostoma ulmi* and Cryphonectria parasitica, are responsible for plant diseases like Dutch elm disease and chestnut blight. These infections result in severe ecological disruptions and economic losses by altering forest ecosystems and reducing valuable tree populations (Adams *et al.,* 2016).

Entomopathogenic Fungi: Fungi such as Beauveria bassiana act as natural pest control agents by infecting and eliminating insects. Their ability to regulate insect populations makes them valuable in ecological balance and integrated pest management (Khan *et al.,* 2022)**. 3.3 Fungi-Animal Interactions - Fungi interact with various animal species, influencing and being influenced by their activities**

Insect-Fungal Mutualism: Some insects like leaf- cutter ants actively cultivate fungal gardens by supplying organic material for fungal growth. In return, the fungi act as the colony's main food source, demonstrating a mutualistic interaction that benefits both organisms (Martinez *et al.,* 2018).

Fungal grazing by soil invertebrates: Soil invertebrate such as collembolans and nematodes feed on fungal mycelia, impacting fungal biomass and species diversity. This grazing activity plays a crucial role in regulating decomposition processes and nutrient cycling in soil ecosystems (Nguyen & Zhao,2020).

3.4 Fungal in plant soil feedbacks - fungi significantly contribute to plant-soil feedback mechanisms

Pathogen Accumulation: Certain pathogenic fungi persist in the soil, negatively impacting plant health and altering plant community structure by decreasing the prevalence of vulnerable species (Wang & Zhang,2021).

Mutualist Facilitation: Beneficial fungi, including mycorrhizal species, support plant growth and survival, contributing to increased plant diversity and shaping successional patterns in plant communities (Evans *et al.,* 2017).

3.5 Implications for ecosystem management - Understanding fungal trophic interactions is crucial for effective ecosystem management

Biodiversity Conservation: Realising the role of fungi in sustaining plant and animal diversity is essential for designing conversation strategies that enhance ecosystem resilience (Anderson & White, 2020).

Agricultural Productivity: Utilizing beneficial fungal associations can boost crop productivity while minimizing dependence on chemical fertilizers and pesticides, fostering more sustainable agricultural practices (Foster *et al.,* 2021).

Invasive Species Control: Regulating fungal pathogens and analyzing their interactions with native and invasive species can help develop strategies for controlling invasive populations and restoring native plant ecosystems (Gibson & Taylor, 2019).

3.6 Role of endophytic fungi in plant growth

The partnership between fungi and plants is one of the oldest and most crucial symbiotic relationships in Earth's evolutionary history (Hedfi *et al.,* 2025). Fungal endophytes significantly enhance plant resilience by improving their resistance to environment stress and pathogens (Aly *et al.,* 2011). They also boost nutrient uptake by facilitating the absorption of macronutrients (phosphorus, nitrogen, potassium, magnesium) and micronutrients (zinc, iron, copper) ultimately strengthening plant health (Baron and Rigobelo, 2021).

3.7 Marine derived endophytes and their therapeutic potential

Fungal endophytes have been identified in higher marine algae, including green, red and brown groups, forming endosymbiotic relationships. These marine derived fungi are known for their antioxidant, anticancer, antimicrobial, antifungal, cytotoxic and other bioactivities (Verma et al.,2017). Particularly, endophytic fungi from marine environments have shown promise as producers of bioactive secondary metabolites, offering potential solutions against multidrug-resistant pathogens and various diseases (Jeewon *et al.,* 2019). Marine algae-derived endophytic fungi from the Konkan coast are especially recognised for their rich diversity of bioactive compounds with therapeutic potential (Kamat et al.,2020).

3.8 Pharmaceutical application and bioactive metabolites

Endophytic fungi produce a higher number of secondary metabolites compared to other microbial endophytes (Kaul et al.,2012). These compounds include potential antimicrobial, antifungal, antiprotozoal and antiviral properties contributing to disease management in various organisms (Adeleke and Babalola, 2021). Notably, Aspergillus species have exhibited remarkable anticancer potential by producing compounds like pulchranin, pyrano-xanthones and gartryprostatins which effectively target human cancer cell lines (Hashem, 2025).

4. Ecological Role of Bioluminescence Fungi

Bioluminescence fungi play a crucial role in maintaining ecosystem balance, particularly in spore dispersal, nutrient cycling and decomposition and some species emit light to attract fungivores insects, which inadvertently aid in spore transmission, especially in dense forests where wind dispersal is limited. Additionally, fungal mycelia serve as a food source for various invertebrates, leading fungi to develop defensive adaptations. It has been suggested that bioluminescence may act as a warning signal to deter predators or attract natural enemies of fungivores, offering indirect protection. Beyond interaction with other organisms, bioluminescent fungi contribute to decomposition and nutrient recycling and many belong to white- rot fungi, which break down lignin in dead plant material, accelerating organic matter decomposition and enriching the soil and this process supporting forest regeneration and soil fertility, making these fungi essential for ecosystem stability (Desjardin et al.,2008). Basidiomycete fungi play a vital role in nutrient recycling within the soil ecosystem by breaking down decaying organic matter, and as decomposers, they facilitate the transfer of nutrients to higher trophic levels, supporting the soil food web. These fungi reproduce both sexually, through basidiospores formed in fruiting bodies (mushrooms), and asexually, through fragmentation and sporulation, and their mycelium, composed of thread-like hyphae, aids in nutrient absorption, substrate fixation, and reproduction. Basidiomycetes engage in symbiotic relationships, particularly with plants, enhancing nutrient availability and they contribute to metal solubilization and immobilization, making essential mineral accessible to other organisms while also detoxifying harmful substance in the soil and by stabilizing nutrient flow reducing soil contaminants, these fungi play a crucial role in ecosystem balance and sustainability (Stevani *et al.,* 2013).

Conclusion:

In conclusion, fungi play a multifaceted role in maintaining ecosystem balance and stability. From the extreme environments of deep-sea hydrothermal vents to the intricate relationships within terrestrial ecosystems, fungi have evolved to thrive in diverse ecological niches. Their complex interactions with other organisms, ranging from cooperative to competitive, significantly influence nutrient cycling, plant health, and biodiversity. The exploration of deep-sea fungi has revealed a far greater diversity and significance than previously recognized, with potential applications in medicine and industry. Similarly, the study of fungal trophic interactions has highlighted their essential roles as decomposers, mutualists, and pathogens, underscoring the need for deeper insights into these functions to inform effective conservation and management strategies. Furthermore, bioluminescent fungi, often overlooked, contribute significantly to ecosystem balance by aiding decomposition, nutrient cycling, and potentially even spore dispersal and predator deterrence. These organisms exemplify the intricate web of life, where even the smallest players can have a profound impact on nature. As we continue to explore and understand the complex relationships between fungi and their environments, we may uncover further microbial enigmas that can inform our approaches to ecosystem management, conservation, and sustainability. Ultimately, recognizing the diverse and essential roles of fungi in ecosystems can inspire new strategies for maintaining the delicate balance of our planet's ecosystems.

Acknowledgement:

The authors would like to acknowledge the support and encouragement received from PSGR Krishnammal College for Women throughout the preparation of this article.

References:

1. Burgaud, G., Le Calvez, T., Arzur, D., Vandenkoornhuyse, P., & Barbier, G. (2009). Fungal diversity in deep-sea hydrothermal ecosystems. *Applied and Environmental Microbiology, 75*(20), 6415–6421.
2. Tisthammer, K. H., Cobian, G. M., & Amend, A. S. (2016). Global biogeography of marine fungi is shaped by the environment. *Fungal Ecology, 19*, 39–46.

3. Nagano, Y., & Nagahama, T. (2012). Fungal diversity in deep-sea extreme environments. *Fungal Ecology, 5*(4), 463–471.
4. Grossart, H. P., Rojas-Jimenez, K., & Wurzbacher, C. (2019). *Ecology of fungi in freshwater environments*. De Gruyter.
5. Zhang, T., Wang, N. F., Zhang, Y. Q., Liu, H. Y., Yu, L. Y., & Zhang, X. L. (2016). Diversity and distribution of fungal communities in the marine sediments of Kongsfjorden, Svalbard (High Arctic). *Scientific Reports, 6*, 37587.
6. Pang, K. L., Guo, S. Y., Chen, I. A., Burgaud, G., Luo, Z. H., Dahms, H. U., Hwang, J. S., Lin, Y. L., Huang, J. S., Ho, T. W., Tsang, L. M., Chiang, M. W., & Cha, H. J. (2019). Insights into fungal diversity of a shallow-water hydrothermal vent field at Kueishan Island, Taiwan, by culture-based and metabarcoding analyses. *PLOS ONE, 14*(12), e0226616.
7. Zhang, L., Kang, M., Huang, Y., & Yang, L. (2016). Fungal communities from the calcareous deep-sea sediments in the Southwest India Ridge revealed by Illumina sequencing technology. *World Journal of Microbiology and Biotechnology, 32*(5), 78.
8. Nagahama, T., & Nagano, Y. (2012). Cultured and uncultured fungal diversity in deep sea environments. In T. Satyanarayana, B. N. Johri, & A. Varma (Eds.), *Progress in Molecular and Subcellular Biology: Vol. 53. Microorganisms in Environmental Management* (pp. 173–187). Springer.
9. Manohar, C. S., & Raghukumar, C. (2013). Fungal diversity from various marine habitats deduced through culture-independent studies. *FEMS Microbiology Letters, 341*(2), 69–78.
10. Edgcomb, V. P., & Bernhard, J. M. (2013). Heterotrophic protists in hypersaline microbial mats and deep hypersaline basin water columns. *Life, 3*(3), 346–362.
11. Rédou, V., Navarri, M., Meslet-Cladière, L., Borrel, G., & Burgaud, G. (2015). Species richness and adaptation of marine fungi from deep-subseafloor sediment. *Applied and Environmental Microbiology, 81*(10), 3571–3583.
12. Zhang, X., Zhang, Y., Yu, L., Wang, N., & Zhang, X. (2015). The diversity, distribution and ecology of fungi in deep-sea environments. *The Journal of Ocean University of China, 14*(3), 391–398.
13. Le Calvez, T., Burgaud, G., Mahé, S., Barbier, G., & Vandenkoornhuyse, P. (2009). Fungal diversity in deep-sea hydrothermal ecosystems. *Applied and Environmental Microbiology, 75*(20), 6415–6421.

14. Gao, Z., Johnson, Z. I., & Wang, G. (2010). Molecular characterization of the spatial diversity and novel lineages of mycoplankton in Hawaiian coastal waters. *The ISME Journal, 4*(1), 111–120.
15. Singh, P., Raghukumar, C., Verma, P., & Shouche, Y. (2012). Fungal community analysis in the deep-sea sediments of the Central Indian Basin by culture-independent approach. *Microbial Ecology, 64*(3), 660–672.
16. Rédou, V., Navarri, M., Meslet-Cladière, L., & Burgaud, G. (2016). Species richness and adaptation of marine fungi from deep-subseafloor sediment. *Applied and Environmental Microbiology, 81*(10), 3571–3583.
17. Tedersoo, L., May, T. W., & Smith, M. E. (2010). Ectomycorrhizal lifestyle in fungi: Global diversity, distribution, and evolution of phylogenetic lineages. *Mycorrhiza, 20*(4), 217–263.
18. Pérez-García, A., Romero, D., & De Vicente, A. (2011). Plant protection and growth stimulation by microorganisms: Biotechnological applications of Bacilli in agriculture. *Current Opinion in Biotechnology, 22*(2), 187–193.
19. Boddy, L. (1999). Saprotrophic cord-forming fungi: Meeting the challenge of heterogeneous environments. *Mycologia, 91*(1), 13–32.
20. Garcia, K., Doidy, J., Zimmermann, S. D., Wipf, D., & Courty, P. E. (2016). Take a trip through the plant and fungal transportome of mycorrhiza. *Trends in Plant Science, 21*(11), 937–950.
21. Fu, W., Chen, B., Rillig, M. C., Jansa, J., Ma, W., Xu, C., ... & Han, X. (2022). Community response of arbuscular mycorrhizal fungi to extreme drought in a cold-temperate grassland. *New Phytologist, 234*(6), 2003–2017.
22. Kallison, E. R. (2021). A review of the contributions by lichen to building soil. *IdeaFest: Interdisciplinary Journal of Creative Works and Research from Cal Poly Humboldt, 5*(1), 1.
23. Brasier, C. M. (1991). *Ophiostoma novo-ulmi* sp. nov., causative agent of current Dutch elm disease pandemics. *Mycopathologia, 115*, 151–161.
24. Anagnostakis, S. L. (1987). Chestnut blight: The classical problem of an introduced pathogen. *Mycologia, 79*(1), 23–37.
25. Coelho, R. G. G. (2022). *Derivados fitoquímicos com potencial atividade pesticida* [Master's thesis, Universidade do Minho]. RepositóriUM.

26. Masiulionis, V. E., & Samuels, R. I. (2025). Investigating the biology of leaf-cutting ants to support the development of alternative methods for the control and management of these agricultural pests. *Agriculture, 15*(6), 642.
27. Zvonareva, T. (2024). *The Anaerobic Rose Chamber (ARC): Novel applications for probing Clostridioides difficile dynamics* (Doctoral dissertation, Old Dominion University).
28. Zhang, Y., Li, T., Ye, C., Lu, R., Liu, Y., Huang, H., ... & Zhu, S. (2021). Leaching alleviates phenol-mediated root rot in *Panax notoginseng* by modifying the soil microbiota. *Plant and Soil, 468*, 491–507.
29. House, G. L. (2017). *The dispersal and persistence of organisms across a landscape* (Doctoral dissertation, Indiana University).
30. Sarwade, P. P., Gaisamudre, K. N., & Gaikwad, R. S. (2024). Mycorrhizal fungi in sustainable agriculture: Enhancing crop yields and soil health. *Plantae Scientia, 7*(5), 55–61.
31. Zabalgogeazcoa, I. (2008). Fungal endophytes and their interaction with plant pathogens: A review. *Spanish Journal of Agricultural Research, 6*, 138–146.
32. Sun, X., & Guo, L. D. (2012). Endophytic fungal diversity: Review of traditional and molecular techniques. *Mycology, 3*(1), 65–76.
33. Shankar Naik, B. (2019). Functional roles of fungal endophytes in host fitness during stress conditions. *Symbiosis, 79*(2), 99–115.
34. Grabka, R., d'Entremont, T. W., Adams, S. J., Walker, A. K., Tanney, J. B., Abbasi, P. A., & Ali, S. (2022). Fungal endophytes and their role in agricultural plant protection against pests and pathogens. *Plants, 11*(3), 384.
35. Rai, N., Kumari Keshri, P., Verma, A., Kamble, S. C., Mishra, P., Barik, S., … Gautam, V. (2021). Plant associated fungal endophytes as a source of natural bioactive compounds. *Mycology, 12*(3), 139–159.
36. Hajji-Hedfi, L., Wannassi, T., & El-Maradny, Y. (2025). Fungal endophytes: Insight into evolution, classification, and ecological functions in plants. *Microbial Biosystems, 10*(1), 51–67.
37. Aly, A. H., Debbab, A., & Proksch, P. (2011). Fungal endophytes: Unique plant inhabitants with great promises. *Applied Microbiology and Biotechnology, 90*, 1829–1845.
38. Baron, N. C., & Rigobelo, E. C. (2022). Endophytic fungi: A tool for plant growth promotion and sustainable agriculture. *Mycology, 13*(1), 39–55.

39. Verma, S. K., Gond, S. K., Mishra, A., Sharma, V. K., Kumar, J., Singh, D. K., ... & Kharwar, R. N. (2017). Fungal endophytes representing diverse habitats and their role in plant protection. In *Developments in fungal biology and applied mycology* (pp. 135–157).
40. Jeewon, R., Luckhun, A. B., Bhoyroo, V., Sadeer, N. B., Mahomoodally, M. F., Rampadarath, S., ... & Hyde, K. D. (2019). Pharmaceutical potential of marine fungal endophytes. In *Endophytes and secondary metabolites* (pp. 1–23).
41. Kamat, S., Kumari, M., Taritla, S., & Jayabaskaran, C. (2020). Endophytic fungi of marine alga from Konkan coast, India—a rich source of bioactive material. *Frontiers in Marine Science, 7*, 31.
42. Kaul, S., Gupta, S., Ahmed, M., & Dhar, M. K. (2012). Endophytic fungi from medicinal plants: A treasure hunt for bioactive metabolites. *Phytochemistry Reviews, 11*, 487–505.
43. Adeleke, B. S., & Babalola, O. O. (2021). Pharmacological potential of fungal endophytes associated with medicinal plants: A review. *Journal of Fungi, 7*(2), 147.
44. Hashem, A. H., Attia, M. S., Kandil, E. K., Fawzi, M. M., Abdelrahman, A. S., Khader, M. S., ... & Abdelaziz, A. M. (2023). Bioactive compounds and biomedical applications of endophytic fungi: A recent review. *Microbial Cell Factories, 22*(1), 107.
45. Ke, H. M., & Tsai, I. J. (2022). Understanding and using fungal bioluminescence – Recent progress and future perspectives. *Current Opinion in Green and Sustainable Chemistry, 33*, 100570.
46. Ghabru, A., Rana, N., & Verma, G. (2023). Chapter-8 Bioluminescence: "The Living Light." In *Molecular Biology Plant Physiology* (Vol. 33, pp. 203).
47. Perry, B. A., Desjardin, D. E., & Stevani, C. V. (2024). Diversity, distribution, and evolution of bioluminescent fungi. *Journal of Fungi, 11*(1), 19.
48. Desjardin, D. E., Oliveira, A. G., & Stevani, C. V. (2008). Fungi bioluminescence revisited. *Photochemical & Photobiological Sciences, 7*, 170–182.
49. Stevani, C. V., Oliveira, A. G., Mendes, L. F., Ventura, F. F., Waldenmaier, H. E., Carvalho, R. P., & Pereira, T. A. (2013). Current status of research on fungal bioluminescence: Biochemistry and prospects for ecotoxicological application. *Photochemistry and Photobiology, 89*(6), 1318–1326.

ENVIRONMENTAL IMPACTS OF E-WASTE - A SHORT COMMUNICATION

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Abstract:

The rapid advancement of technology and increasing consumption of electronic devices has led to a growing concern about electronic waste / e-waste. This paper examines the environmental impacts of e-waste, including the growing volume of e-waste, potential environmental contaminants, and effects of improper disposal and recycling. The study highlights the need for responsible electronics waste management practices, including proper disposal and recycling, to mitigate environmental contaminants and protect human health. It also discusses the current global production of e-waste, future projections, and the importance of adopting sustainable e-waste management strategies to address this pressing environmental issue.

Keywords: E-waste, Environmental Impacts, Recycling

1. Introduction:

E–waste in simple terms is Electronic-waste, refers to discarded electrical or electronic devices. They are computers, laptops, smartphones, gaming consoles, printers, scanners and household appliances, all aiding us in our day-to-day lives. Their main characteristics is that they become outdated quickly, contains hazardous substances like lead, mercury, cadmium, and made up of various materials including plastics, metals and glass. They are becoming one of the fast-growing waste streams world-wide. E-waste is chemically and physically distinct from other forms of municipal or industrial waste; it contains both valuable and hazardous materials that require special handling and recycling methods to avoid environmental contamination and detrimental effects on human health (Robinson, 2009). It is a growing concern globally at this era with rapid advancements in technology and increasing consumption of electronic devices. It contains over thousand substances many of which are toxic and creates serious pollution upon disposal (Puckett *et al.,* 2002). E-waste also contains valuable metals such as copper and gold, recovering these have been a profitable business, resulting in global inter boundary trade in e-waste (Widmer *et al.,* 2005). However, due to lack of facilities, high labour costs, and tough environmental regulations, rich countries tend not to recycle E-waste, instead it is either landfilled, or exported from rich to poor countries, where it may be recycled using primitive techniques and little regard for work safety or environmental protection (Cobbing, 2008). This paper focuses on the environmental effects of E-waste.

2. Global Production of E- waste

The world's generation of electronic waste is rising 5 times faster than documented e-waste recycling (UNITAR, 2024). Calculating the global E-Waste production requires information on the number on items in service (Robinson, 2009). The contribution of an item to the annual E-Waste production E (kg/year) depends on the mass of the item M (kg), the number of units in service, N, and its average life span, l (years). Table 1 provides a list of items along with their mass and expected lifetimes.

$$E=\frac{MN}{L}$$

Table 1: List of items along with their mass and expected lifetimes

Item	Mass (kg)	Typical life (years)
Computer [a]	25	3
Radio[b]	2	10
High-fidelity system[b]	10	10
Mobile telephone[b]	0.1	2
Electronic games [b]	3	5
Video recorder and DVD player[b]	5	5
Television[c]	30	5
Facsimile machine[d]	3	5
Photocopier [d]	60	8
Keyboard and Mouse	0.5	5
Oven	10	10

[a] (Betts, 2008a).[b](Cobbing, 2008).[c](Li *et al.,* 2009).[d](Robinson, 2009)

Computers, with an average lifespan of three years (Betts, 2008a), contribute significantly to the growing problem of e-waste. In contrast, refrigerators and ovens, which have lifespans of 10-12 years (Robinson, 2009) make up smaller proportion of e-waste.

2.1 Current Global Production

In 2022, 62 billion kg of e-waste were generated globally (with only 22.3% formally documented as being recycled) up 82% from 2010, on track to rise another 33% to 82 million tons, in 2030. The United States is the world leader in producing electronic waste, generating 3 million tons each year, China secondly to United States producing 10.1 million tons. The significant portion of the year's e-waste is being exported to other countries for recycling or disposal. In 2022, a mere 22.3% of global e-waste was properly collected and recycled. This shortfall left a whopping $62 billion worth of valuable resources unrecovered, while also heightening pollution risks and potential health hazards for communities globally (UNITAR, 2024). The annual generation of e-waste is increasing by 2.6 million tons annually.

2.2 Future Global Production

The global E-Waste production will change as economies grow and new technologies evolve. Technological changes will affect the global mass of E-Waste production. Since 2000, E-Waste has grown from 20 million to 50 million tons per year. Amount of E-Waste will double by 2050, approximately reaching 111 million tons per year (StEP Initiative, 2021). The raid advancement of new technologies has led to the development of materials and alloys that enhance the energy efficiency nad portability of electronic appliances. However, the recycling of these materials poses significant challenges. Despite the availability of recycling technologies, economic incentives for recycling e-waste are often lacking. Furthermore, existing policies and regulations aimed at managing e-waste have not yet yielded the desired improvements. Global e-waste collection rates remain disappointingly low, averaging around 20%, despite efforts to increase them. Consequently, most e-waste generated is not properly treated, posing environmental and health risks due to the presence of toxic substances.

3. Potential Environmental Contaminants

The chemical composition of E-Waste depends on the age and type of discarded item (Robinson, 2009). Proper disposal and recycling of e-waste are crucial to mitigating these environmental contaminants and protecting human health. Table 2 lists the potential environments contaminants associated with e-waste.

Table 2: Contaminants associated with e-waste

Contaminant	E-Waste
Heavy metals	
Cadmium (Cd)	Batteries, Coatings, Toners
Mercury (Hg)	Fluorescent lamps, batteries, thermostats
Lead (Pb)	CRTs, old Tv, Solder (Kang and Schoenung, 2005)
Toxic Substances	
Polychlorinated Biphenyls (PCBs)	Transformers, Capacitors
Brominated Flame Retardents (BFRs)	Plastics in circuit boards, castings
Chlorofluorocarbons (CFCs)	Refrigerators
Other Contaminants	
Arsenic (As)	Microchips, Semconductors
Chromium (Cr)	Steel and alloys, data tapes

*(Robinson, 2009) **(E-waste, 2009).

Heavy white goods, like washing machines and refrigerators, primarily made of steel, tend to have lower levels of potential environmental contaminants compared to lighter electronic devices, such as laptops. Laptops, on the other hand, often contain higher concentrations of hazardous substances like flame retardants and heavy metals, posing greater environmental risks. Heavy metals are used in the manufacture of electronic goods while others such as Brominated Flame Retardants (BFRs) are used in plastics and materials. The simple process of burning of insulated wire can produce 100x more dioxins than burning of domestic waste (Gullett *et al.,* 2007). Polybrominated biphenyl ethers (PBDs) are flames retardants which are mixed into plastics and components. There are no chemical bonds between them; therefore, they can separate from the surface of e-waste components into the environments (Deng *et al.,* 2007). Ozone depleting Chlorofluorocarbons (CFCs) are present in freezers, refrigerators, A/Cs; these can escape when disposed in landfills (Scheutz *et al.,* 2004). Although recycling may remove some contaminants, large quantities may still end up concentrated in landfills or E-waste recycling centers.

4. Environmental Impacts

The environmental impacts of E-Waste are significant and far-reaching reason being improper disposal and recycling. The pollutants released can contaminate soil, water, and air, posing risks to human health and wildlife. Additionally, e-waste can contribute to climate change through release of greenhouse gases during disposal and recycling. The extraction and processing of raw materials for new electronics have environmental consequences, including deforestation, water pollution and energy consumption. The growing volume of e-waste can lead to environmental degradation, highlighting the need for responsible electronics waste management practices.

4.1 Ecological and Health Impacts

E-waste recycling involves dismantling electronic devices to recover valuable materials. Around 95% of materials from computers and 45% from CRT monitors can be reclaimed (Ladou and Lovegrove, 2008). Advanced recycling systems, like those in Japan, operate effectively with minimal environmental harm (Aizawa *et al.,* 2008). Although transporting e-waste long distances can increase ecological damage, recycling is still more eco-friendly than landfilling or incineration (Hischier *et al.,* 2005).

Soil and Water Contamination

Human activities have heavily contaminated soil near e-waste recycling sites with hazardous substances over recent decades (Zhang *et al.,* 2015). Studies reveal high levels of heavy metals like lead (Pd), cadmium (Cd), mercury (Hg) and antimony (Sb) in areas such as

Bangalore, India and various locations in China, with concentrations often exceeding nearby control sites by over 100 times (Ngoc *et al.,* 2009; Wu *et al.,* 2019). E-waste contaminants enter aquatic system through leaching and diffusion from dumping sites and processing industries.(Luo et al, 2007) Reported high PBDE concentrations in sediment samples from the Nanyang River near Guiyu (up to 16,000 ng/g). Similarly, (Wu et al, 2008) detected 1091 ng/g PBEs and 16,512 ng/g PCBs in water snakes, top predators in the aquatic ecosystem.

Human Health Risks

People living near e-waste processing areas are highly exposed to hazardous substances through various natural pathways (Awasthi *et al.,* 2018). Workers at informal e-waste sites in Guiyu face greater health risk from heavy metals compared to formal sites in Jiangsu and Shanghai (Fang *et al.,* 2013; Xue *et al.,* 2012). Lead (Pb) intake often exceeds the established reference dose (U.S. EPA, 2011). Exposure occurs through dietary and non-dietary routes, with higher cancer risks reported in e-waste sites compared to non-recycling areas.

Wildlife and Biodiversity Impacts

Studies report elevated concentrations of PBDEs, PCBs and other POPs in soils and plants from Guiyu and nearby areas (Liu *et al.,* 2008; Shi *et al.,* 2019). PBDEs are particularly prone to translocation from soil to plants via roots, with higher pollution levels near the rhizosphere than in control sites (Xu *et al.,* 2013). Biodiversity and ecological balance are closely interlinked and their relationship is fundamental to the health and sustainability of ecosystems. Biodiversity contributes to the stability and resilience of ecosystems. Biodiversity provides functional diversity within ecosystems.

4.2 Waste Management and Disposal

The electronics industry, the world's largest and most innovative, generates massive e-waste after products reach the end of their life cycle. These wastes contain hazardous metals, acids, and toxic chemicals. While some are refurbished, reused, or recycled, a significant portion is dumped, burned, or exported, often to countries like China, India, and Ghana due to cheap labor. The dismantling process releases carcinogenic smoke and dust, causing severe health issues such as respiratory and skin diseases. Poverty drives many in developing nations to risk their health by working with e-waste, making them the world's dumping grounds (Kevin *et al.,* 2008).

Inadequate Waste Management

Developing countries struggle with e-waste management due to inadequate infrastructure and illegal imports of used electronics. Hazardous materials in e-waste pose environmental and health risks when disposed of improperly. Crude recycling methods further contribute to pollution. While developed nations enforce Extended Producer Responsibility (EPR) to ensure proper disposal, implementing even a simplified EPR system in developing countries is crucial. Addressing e-waste challenges requires government action, strict regulations, controlled imports, and technology transfer for safe recycling (Nnorom and Osibanjo 2008).

Illegal Dumping and Export

Due to stricter regulations in industrialized countries, hazardous waste, including e-waste, is often transported to developing nations under the guise of second-hand goods. Much of this waste is dismantled in unsafe conditions releasing toxic substances that harm the environment and human health. Illegal e-waste trade also disrupts economies, undermines environmental policies, and is recognized as a major environmental crime. While international regulations exist, criminology has only recently begun addressing transnational environmental crimes like illegal e-waste transport, highlighting the need for more empirical research (Bisschop, 2012).

Recycling and Proper Disposal

E-waste management involves international, continental, and national policies to regulate disposal and prevent illegal trade. The disposal process includes:

- Safe Dismantling – Manual disassembly using tools due to complex structures.
- Separation & Enrichment – Removing toxic components, crushing waste, and separating materials using techniques like magnetic, gravity, airflow, or eddy current methods.
- Material Regeneration – Processing separated materials into new products like metal alloys or plastic-based items.
- Energy Recovery- Using non-recyclable materials as fuel or for direct incineration.
- Pollutant Treatment – Safely managing pollutants from the process to minimize environmental impact.

Collected e-waste is transported to dismantling factories, where useful parts are sorted, metals are extracted, plastics are modified, and non-recyclable materials undergo energy recovery (Shimaoka, 2016).

4.3 Socio-Economic Impact

Despite laws and facilities, hazardous waste management remains inadequate. Over 75% of state bodies fail to implement laws and only 28 treatments, storage, and disposal facilities are operational in India.

Toxic Substance in E-Waste

As give in table 2, the common toxic substances found are

1. Cadmium: circuit boards, CRTs batteries

2. Lead: circuit boards, CRTs.
3. Mercury: switches, flat screens.
4. Polychlorinated biphenyl: older capacitors, transformers.
5. Brominated flame retardants: circuit boards, cables.

These occur as complex mix of materials and components.

Health and Environment Impacts

E-waste poses substantial risks to both environment and human health. The recycling of e-waste is often challenging to perform sustainably. When burned, e-waste releases toxic dioxins and furans, contaminating landfills and surrounding area. This can lead to exposure risks for employees and others in the vicinity through respiratory tracts, skin contact, mucous membranes, and digestive tract. Ultimately, e-waste has adverse effects on both humans and ecology, emphasizing the need for responsible management and disposal practices.

4.4 Toxic Chemicals and Pollution

E-Waste poses significant environmental and health risks due to the release of toxic chemicals and pollutants during improper disposal and recycling practices. Below are discussions on three major environmental impacts of e-wastes.

Heavy Metal Contamination

A study conducted in Douala, Cameroon, assessed the levels of heavy metals in soil samples from e-waste recycling sites. The results indicated elevated concentrations of lead (Pb), zinc (Zn), chromium (Cr), nickel (Ni), and cadmium (Cd) in soil compared to a control site. Notably, Pb concentrations were found to be significantly higher, posing potential ecological and human health risks. The study concluded that the heavy metal contamination in these areas presents serious health risks and further investigations are needed (Ouabo RE at al., 2019).

Toxic Chemical Leachate

Research on abandoned e-waste recycling sites in Longtang, South China, revealed that the surface soil near former burning and acid-leaching areas was heavily contaminated with cadmium (Cd) and copper (Cu), exceeding guideline levels. The study observed that the concentration of heavy metals generally decreased with depth, suggesting that these metals were primarily concentrated in the surface soil. Additionally, the pond water in the vicinity was acidified and contaminated with heavy metals, while well water showed slight contamination. The use of pond water for irrigation resulted in considerable heavy metal contamination in the paddy soil, indication the potential for toxic chemical leachate to spread and affect agricultural areas (Wu Q *et al.,* 2014).

Air Pollution from E-Waste Burning

A review article highlighted that e-waste recycling activities, particularly in developing countries, often involve thermal processes such as open burning and acid-stripping metals. These processes can lead to the formation of persistent organic pollutants like polychlorinated dibenzo-p-dioxins and dibenzo-furans (PCDD/Fs). The presence of halogenated compounds in e-wastes results in the formation of these pollutants during low-tech recycling operations. The study emphasized that crude methods of recycling, like open burning, are identified as sources of PCDD/Fs in the terrestrial environment (Themba *et al.,* 2023).

E-Waste in India

India is the 3rd largest electronic waste producer globally, 2nd largest in Asia, generating approximately 2 million tons annually (Joon *et al.,* 2017). The country's e-waste output has seen a significant surge, with a 163% growth in electronic waste from screens, computers, and small IT and telecommunication equipment between 2010 and 2022. Unfortunately, over 95% of India's e-waste is handled by the informal sector, with rudimentary recycling techniques that release toxic pollutants. The formal sector, which is better equipped to manage e-waste sustainably, captures only a small fraction of the market share. To address this, the Indian government has implemented regulations, such as the E-Waste Management Rules, 2022, to promote environmentally sound e-waste disposal and recycling practices. Environmental concerns are raised about importing e-waste. Formal recycler's priorities eco-friendly processes. Multinationals prefer formal recycler's for their environmental reputation. Informal dealers refurbish and resell functional parts. Only a small percentage of e-waste is recycled annually. The rest is refurbished and resold. The organized sector needs support to overcome challenges. Effective e-waste management is crucial for environment protection. Strengthening the organized sector is essential for sustainable e-waste management. Proper regulations and infrastructure are necessary for growth.

5. Mitigation Strategies

E-waste composition is changing with technological development along with the pressure on manufacturers by regulators and NGOs. NGOs have pushed manufacturers to minimize or eliminate hazardous substances in their products, driving a competitive trend towards "green" production. As a result, manufacturers are striving to reduce the use of toxic chemicals in their products to enhance their environmental reputation (Betts, 2008b). The shift from CRT monitors to LCD displays has reduced the amount of lead (Pb) in e-waste, as CRTs contain around 2 kg of PB per unit (Puckett *et al.,* 2005). The adoption of fiber optics, which may replace copper wires (Berkhout and Hertin, 2004), brings forth a new set of elements, including Fluorine (F), Lead

(Pb), Yttrium (Y) and Zirconium (Zr) (Kogo *et al.,* 1995). The evolution of rechargeable batteries has also led to changes in composition, transitioning from Nickel-Cadmium to Nickel-Metal hydride and Lithium ions (Robinson, 2009). Most e-waste is not recycled, as if often ends up with household waste streams receiving no specialized handling (Ladou and Lovegrove, 2008). To recover new materials, recycling involves destruction and disassembly of equipment's. The first step of e-waste recycling is the mechanical process; being automated or carried out by hand.

Conclusion:

In conclusion, the environmental impacts of e-waste are a pressing concern that requires immediate attention and collective action. The growing volume of e-waste, coupled with its toxic and hazardous nature, poses significant risks to human health and the environment. The environmental impacts of e-waste are significant and far-reaching, with improper disposal and recycling increasing the risks. To mitigate these risks, it is essential to adopt sustainable, responsible electronics waste management practices, including proper disposal, recycling and reuse. By working together, governments, manufacturers, and individuals can reduce the environmental and health impacts of e-waste and promote a more sustainable future for generations to come.

Acknowledgement:

The authors would like to acknowledge the support and encouragement received from PSGR Krishnammal College for Women throughout the preparation of this article.

References:

1. Robinson, B. H. (2009). E-waste: An assessment of global production and environmental impacts. *Science of the Total Environment, 408*(2), 183–191.
2. Widmer, R., Oswald-Krapf, H., Sinha-Khetriwal, D., Schnellmann, M., & Böni, H. (2005). Global perspectives on e-waste. *Environmental Impact Assessment Review, 25*(5), 436–458.
3. Cobbing, M. (2008). *Toxic tech: Not in our backyard. Uncovering the hidden flows of e-waste*. Report from Greenpeace International. Amsterdam. Retrieved from http://www.greenpeace.org/raw/content/belgium/fr/press/reports/toxic-tech.pdf
4. Betts, K. (2008). Producing usable materials from e-waste.
5. UNITAR. (2024). *The global e-waste monitor*.
6. StEP Initiative, UNU, UNEP. (2021). *E-waste will double by 2050*.

7. Kang, H. Y., & Schoenung, J. M. (2005). Electronic waste recycling: A review of US infrastructure and technology options. *Resources, Conservation and Recycling, 45*(4), 368–400.
8. e-waste. (2009). *Hazardous substances in e-waste: A knowledge base for the sustainable recycling of e-waste*. E-Waste: A Swiss E-Waste Guide.
9. Gullett, B. K., Linak, W. P., Touati, A., Wasson, S. J., Gatica, S., & King, C. J. (2007). Characterization of air emissions and residual ash from open burning of electronic wastes during simulated rudimentary recycling operations. *Journal of Material Cycles and Waste Management, 9*, 69–79.
10. Deng, W. J., Zheng, J. S., Bi, X. H., Fu, J. M., & Wong, M. H. (2007). Distribution of PBDEs in air particles from an electronic waste recycling site compared with Guangzhou and Hong Kong, South China. *Environment International, 33*(8), 1063–1069.
11. Scheutz, C., Mosbæk, H., & Kjeldsen, P. (2004). Attenuation of methane and volatile organic compounds in landfill soil covers. *Journal of Environmental Quality, 33*(1), 61–71.
12. Awasthi, A. K., Wang, M., Awasthi, M. K., Wang, Z., & Li, J. (2018). Environmental pollution and human body burden from improper recycling of e-waste in China: A short review. *Environmental Pollution, 243*, 1310–1316.
13. Balde, C. P., Forti, V., Gray, V., Kuehr, R., & Stegmann, P. (2027). *The global e-waste monitor – 2017*. United Nations University (UNU), International Telecommunication Union (ITU), & International Solid Waste Association (ISWA).
14. Joon, V., Shahrawat, R., & Kapahi, M. (2017). The emerging environmental and public health problem of electronic waste in India. *Journal of Health and Pollution, 7*(15), 1–7.
15. Purushothaman, M., Inamdar, M. G., & Muthunarayanan, V. (2021). Socio-economic impact of the e-waste pollution in India. *Materials Today: Proceedings, 37*, 280–283.
16. Betts, K. (2008). Reducing the global impact of e-waste.
17. Zhang, X., Zhong, T., Liu, Y., & Ouyang, X. (2015). Impact of soil heavy metal pollution on food safety in China. *PLOS ONE, 10*(8), e0135182.
18. Luo, Q., Wong, M., & Cai, Z. (2007). Determination of polybrominated diphenyl ethers in freshwater fishes from a river polluted by e-waste. *Talanta, 72*(5), 1644–1649.
19. Liu, H., Zhou, Q., Wang, Y., Zhang, Q., Cai, Z., & Jiang, G. (2008). E-waste recycling induced polybrominated diphenyl ethers, polychlorinated biphenyls, polychlorinated dibenzo-p-dioxins and dibenzofurans pollution in the ambient environment. *Environment International, 34*(1), 67–72.
20. Sivaramanan, S. (2013). E-waste management, disposal and its impacts on the environment. *Universal Journal of Environmental Research & Technology, 3*(5).

21. Bisschop, L. (2017). Is it all going to waste? Illegal transports of e-waste in a European trade hub. In *Transnational Environmental Crime* (pp. 245–273). Routledge.
22. Nnorom, I. C., & Osibanjo, O. (2008). Overview of electronic waste (e-waste) management practices and legislation, and their poor applications in the developing countries. *Resources, Conservation and Recycling, 52*(6), 843–858.
23. Shimaoka, T., Kuba, T., Nakayama, H., Fujita, T., & Horii, N. (Eds.). (2016). *Basic studies in environmental knowledge, technology, evaluation, and strategy: Introduction to East Asia environmental studies*. Springer.
24. Puckett, J., Westervelt, S., Gutierrez, R., & Takmiya, Y. (2005). *The digital dump: Exporting re-use and abuse to Africa*. Basel Action Network, Seattle.
25. Berkhout, F., & Hertin, J. (2004). De-materialising and re-materialising: Digital technologies and the environment. *Futures, 36*(8), 903–920.
26. Kogo, T., Kanamori, H., Onishi, M., Miyajima, Y., & Nakazawa, M. (1995). Lead-containing fluoride glass, optical fiber and process for producing it. *United States Patent*, Patent Number 5,432,131.
27. Kogo, T., Kanamori, H., Onishi, M., Miyajima, Y., & Nakazawa, M. (1995). *U.S. Patent No. 5,432,131*. Washington, DC: U.S. Patent and Trademark Office.
28. Ladou, J., & Lovegrove, S. (2008). Export of electronics equipment waste. *International Journal of Occupational and Environmental Health, 14*(1), 1–10.
29. Wu, J. P., Luo, X. J., Zhang, Y., Luo, Y., Chen, S. J., Mai, B. X., & Yang, Z. Y. (2008). Bioaccumulation of polybrominated diphenyl ethers (PBDEs) and polychlorinated biphenyls (PCBs) in wild aquatic species from an electronic waste (e-waste) recycling site in South China. *Environment International, 34*(8), 1109–1113.
30. Ouabo, R. E., Ogundiran, M. B., Sangodoyin, A. Y., & Babalola, B. A. (2019). Ecological risk and human health implications of heavy metals contamination of surface soil in e-waste recycling sites in Douala, Cameroun. *Journal of Health and Pollution, 9*(21), 190310.
31. Wu, Q., Leung, J. Y., Geng, X., Chen, S., Huang, X., Li, H., Huang, Z., Zhu, L., Chen, J., & Lu, Y. (2015). Heavy metal contamination of soil and water in the vicinity of an abandoned e-waste recycling site: Implications for dissemination of heavy metals. *Science of the Total Environment, 506–507*, 217–225.
32. Themba, N., Sibali, L. L., & Chokwe, T. B. (2023). A review on the formation and remediations of polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs) during thermal processes with a focus on MSW process. *Air Quality, Atmosphere & Health, 16*, 2115–2132.

TRADITIONAL SHORE SEINE FISHING IN MELMIDALAM, KANYAKUMARI: PRACTICES AND PERSPECTIVES

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Abstract:

This study documents the operational characteristics, target species composition, and ecological implications of traditional shore seine fishing in Melmidalam, a coastal village in Kanyakumari District, Tamil Nadu, India. Shore seine fishing, locally known as Karai valai, is a centuries-old practice dependent on indigenous ecological knowledge (IK) for predicting fish occurrence and seasonal abundance. Field observations and semi-structured interviews with local fishers were conducted at the Melmidalam fish landing site to record fishing gear design, crew organization, species landed, and perceptions of environmental changes. The catch included commercially important species such as *Caranx ignobilis*, *Caranx papuensis*, and *Megalaspis cordyla*. Ecological concerns were identified, including the capture of juvenile fish and potential damage to benthic habitats in sandy–rocky coastal zones. Findings indicate that while shore seine fishing remains economically significant, it faces challenges from environmental change, mechanization, and resource competition. Sustainable management strategies that integrate local knowledge with modern conservation measures are recommended to ensure the viability of fish stocks and fishing livelihoods in the region.

Keywords: Traditional Fishing, Indigenous Knowledge, Shore Seine, Ecological Impact, Sustainability.

Introduction:

Seine nets are rectangular shaped long nets with or without bag, operated with two long ropes, set either from the shore or from the boat for surrounding a certain area for targeting the coastal shoals. Tietze *et al*. classified the seine nets into two categories, beach seine /shore seine and boat seine (those with cod end and without cod end). Beach seines have been used for fishing, since several thousand years in all the continents[3]. They are setfrom the shore to surround a fish shoal in shallow coastal waters, and then hauled onto the shore. Shore seines are Beach seines operated in the inshore waters which have been commonly used for ages and are locally called as “Karai valai”. These gears are operated near or close to the shoreline areas (hence the name Karai valai; Karai in the local language means shore. The name signifies thatit is operated from the shore with rope). Shore seine is practiced in many coastal villages along the Indian coast and the operation has state-to-state and region-to-region differences in terms of terminology and mode of operations. There are reports of shore seines that were used centuries back in the western and eastern coasts of India, encompassing the Malabar, Konkan and the Coromandel coasts. A decline in the use of shore seines have been reported from the Coromandel coast (Tamil Nadu, Andhra Pradesh) and North Orissa. In India, 2,227 numbers of shore seines were reported in different names and operated along east and west coasts of India (Maharashtra, Gujarat, Andhra Pradesh, Karnataka, Goa, Puducherry, Tamil Nadu andKerala). This paper reveals the study of shore seine, its operation, fish resources and fishing communities of Melmidalam (a small coastal village of Kanyakumari).

Methodology Handled:

The study was conducted over a single day at the fish landing site located near the vicinity of my college, close to the Melmidalam coast, Kanyakumari district. Data collection employed a combination of direct observation and semi-structured interviews with local fishers to document the operational aspects of traditional shore seine fishing. I observed shore seine fishing activities from hauling of the net to fish sorting and landing. Visual identification of the landed catch was carried out, noting the dominant species, approximate sizes, and fishing gear components used. Interview questions focused on:

- Seasonal patterns of shore seine fishing
- Commonly targeted species
- Gear structure and materials used
- Crew size and division of labour during operation
- Changes in fishing practices over time
- Observations on ecological impacts, including juvenile fish occurrence

Responses were recorded in field notes, and species identification was cross verified using Fish Base and relevant literature.

Location of Melmidalam Coast:

Kanyakumari coastal line has a length of about 71.5 km. Melmidalam is a village in Vilavancode Taluk, Killiyoor constituency, south west side at Arabian Sea Coast. This village has coastal Villages on the shore of the Arabian Sea in Kanyakumari district, Tamil Nadu, India. It was situated near the border with TamilNadu andKerala on north-west to Kanyakumariand southwest to Trivandrum. These villages are located nearly 70 km from Kanyakumari and30 km from Trivandrum.

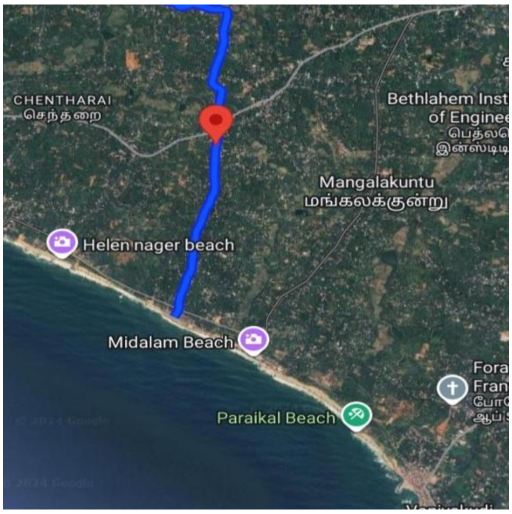

Fig. 1: Map of Melmidalam beach

Fishing Community of Melmidalam Coast:

Melmidalam (often written *Midalam* in official sources) is a small coastal village in Killiyoor / Vilavancode area of Kanyakumari district. Local people rely primarily on marine fishing for subsistence and income. Small traditional craft like catamarans, vallams and wooden/nearshore boats are commonly used. Alongside some mechanized boats operating from nearby landing centres such as Midalam, Colachel and others in the district. Fishers sell to local coastal markets or through buyers/agents who collect landings for transport to larger markets. Fishing communities here are tightly knit; livelihoods shape daily rhythms, social networks and religious / cultural life. The area shows linguistic overlap with Tamil and Malayalam, and many coastal villages in Kanyakumari have a Christian influence.

Fish Resources Commonly Caught on Shore Seines:

Shore seineis operated throughout the year and the peak season starts after monsoon and maximum catch was reported during post-monsoon season in the southwest coast of India. Some of the commonly available species to be caught on Shore seines are given below:

Table: 1 Commonly identified species of Shore seine (Leksmi *et al.*, 2014)

Fish species	Family	Fish species	Family
Stolephorus indicus	Engraulidae	*Rastrelliger kanagurta*	Scombridae
Stolephorus commersonii	Engraulidae	*Megalapsis cordyla*	Carangidae
Sardinella longiceps	Clupeidae	*Gazza minuta*	Leiognathidae
Sardinella gibbosa	Clupeidae	*Leiognathus lineolatus*	Leiognathidae
Sardinella fimbriata	Clupeidae	*Secutor insidator*	Leiognathidae
Sphyraena borealis	Sphyraenidae	*Sillago sihama*	Sillaginidae
Sphyraena obtusata	Sphyraenidae	*Fenneropenaeus indicus*	Penaeidae

From the study it known that Melmidalam coast is known for fishing Giant trevally (*Caranx igonobilis*), Brassy trevally (*Caranx papuensis*) and Torpedo scads (*Megalapsis cordyla*).

1. Giant Trevally (*Caranx igonobilis*):

Fig. 2: Giant trevally (Caranx igonobilis) Source: Fishbase

Key Characters:

- Dorsal spines (total): 9; Dorsal soft rays (total): 18 - 21; Anal spines: 3; Anal soft rays: 15 - 17; Vertebrae: 24.
- Breast naked ventrally, typically with a small to large patch of pre-pelvic scales
- Colour in life of adults, head and body silvery grey to black above, usually paler below; fins usually uniformly grey to black, fish from turbid coastal waters often with yellow fins, the anal fin usually brightest
- Maturity: L_m 60.0 cm
- Max. length: 170cm
- Max. published weight: 80.0kg

2. Brassy Trevally (*Caranx papuensis*):

Fig. 3: Brassy trevally (*Caranx papuensis*) Source: Fish base

Key Characters:

- Dorsal spines (total): 9; Dorsal soft rays (total): 21 - 23; Anal spines: 3; Analsoft rays: 16 - 19.
- Brassy to yellowish green dorsally, shading to silvery on side with scattered dark spots (becoming more numerous with age), conspicuous silvery white spot just behind upper rear

edge of opercle, dusky upper caudal fin lobe, and bright yellow to dusky lower lobe with narrow white border.

- Max length: 88.0cm
- Max. published weight: 6.4kg (Fishbase)

3. Torpedo Scads (*Megalapsis cordyla*)

Fig. 4: Torpedo scad (*Megalapsis cordyla*) Source: Fishbase

Key Characters:

- Dorsal spines (total): 9; Dorsal soft rays (total): 18 - 20; Anal spines: 3;
  Anal soft rays: 16 - 17.
- Have features same as tunas and carangids.
- Body elongated with median keel on caudal peduncle. Maturity: Lm 22.0
- Max length: 80.0cm
- Max. published weight: 4.0kg and Max. reported age: 5 years (Fish base)

Shore and its Structure:

1. **Cod end:** The region of the net where the catch is accumulated is called cod end/ bunt and locally known as *madi*. Bunt portion is made of polyamide webbing of 8 to 10 mm mesh size. Total length of the bunt varied from 18 to 25 m in length. Bunt is placed in the center portion of the gear and made withheavier netting to withstand the excess strain during operation. Nayar has documented design details of a *Karamadi* with a length of 15.8 m (Lekshmi *et al.,* 2014)
2. **Wings:** Wings are locally known as *Vala/ Kayaru.* Two wings extend from the lateral margins of the cod end with a length of 500 – 800 m which herds the fish towards the cod end. It is made by joining polyamide/ coir webbings with 130 mm to 1400 mm inmesh size. Small meshed webbing panels were attached near to the cod end and gradually the mesh size increases towards the warp end (Lekshmi *et al.,* 2014).

3. **Warp or Hauling Rope:** This is the longest part of the seine made of Polypropylene or coir ropes of 18-24m. Fishermen of 40-50 members use this rope to haul the fishes into the shore. Some time two boats are used to spread the net to surround the shoaling fishes nearby the shore and collect the fishes manually onboard (Lekshmi *et al.,* 2014).

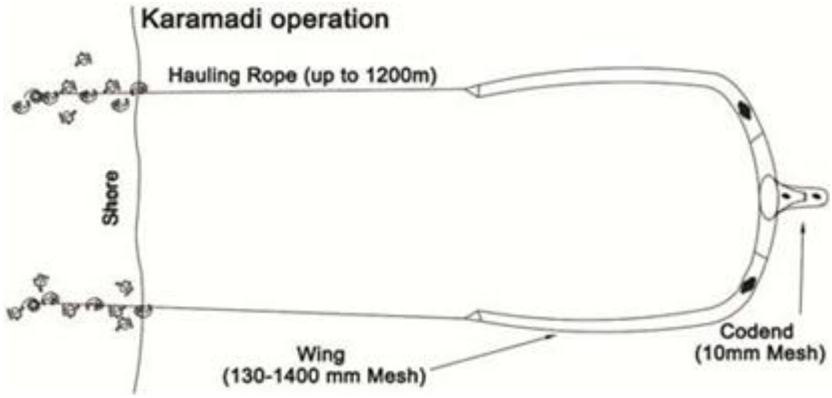

Fig. 5: Structure of Shore seine (Lekshmi *et al.,* 2014)

Operation of Shore Seine:

Net Design: Shore seines are typically made from biodegradable materials, though modern practices have shifted to more durable polyamide nets (Edwin *et al.,* 2020).

Fishing Technique: The gear after loaded into the vessel, and before leaving the shore, one of the towing ropes will be handed over to a group of fishermen on shore. The vessel then makea semi-circular course while shooting the net and as soon as the vessel reach the shore, the remaining towing rope will be handed over to the second group of fishermen. The two groups comprising 20 to 40 numbers of fishermen on the shore haul the net simultaneously. Mean while three to four fishermen makesplashes in order to drive the fishes, towards the gear. As the hauling progresses, the two groups of fishermen on the shore come closer together and the gear is dragged ashore. Shore seine operation is carried out usually in the morning and will take around4 hours, after a shoal is sighted (Saleela *et al.,* 2015)

Catch Composition: The catch primarily includes various species such as prawns, sciaenids, and sardines, which are abundant during specific seasons (Lekshmi *et al.,* 2014). In Melmidalam it is mainly focused on fishing Gaint trevally (*Caranx igonobilis*), Brassy trevally (*Caranx papuensis*) and Torpedo scads (*Megalapsis cordyla*).

Head rope with float

Main body (PE) with 50mm mesh size

Cod end with 10mm mesh size

FRP boat with 15' for shore seine operation

Fig. 6: Parts of a typical shore seine (Mariappan *et al.*, 2019)

Fig.7: Fish collection after shore seining

Traditional Fishing Practice of Shore Seining in Melmidalam Coasts:

This kind of shoaling fishes were not available all round the year. The last shoaling acquired during the December month three years back in the same coastal region. Interviews with fishers suggest that climatic or monsoon changes may reason for this species accumulation. But, by acquiring the scientific knowledge it happened may be due to warm and cold ocean current mixing during monsoon that caused minute upwelling in this coastal zone. Farmers observed a largeshoalofGiant trevallyandTorpedoscadfishes are jumping on the waters so the throw the gears (Shore seine), people said that these fish came to surface after a couple of years later now. They sold for Rupees 600 per fish. The two variety of fish that get caught are commonly called as "vela" and "Paarai". About four to five team fishermen group involved in this activity and captured almost several tonnes of fishes.

Ecological Considerations of Shore Seining:

Impact on Ecosystems: Shore seine operations can severely affect marine habitats, including seagrasses and coral reefs, leading to a decline in biodiversity (Raj *et al.,* 2017). The Melmidalam coast is combination of both sandy and rocky shore zone, operation of Shore seine in this region may affect this ecology and lead to destruction of the gears used.

Juvenile Catch: A significant portion of the catch consists of juvenile fish, raising concerns about sustainability and the long-term viability of fish populations (Raj *et al.,* 2017). Some of the juvenile sardines and anchovies were observed destructed during this operation.

Conclusion:

The study emphasizes the intricate relationship between local ecological knowledge and fishing practices. Traditional fishers employ indigenous methods to predict fish availability and adapt to seasonal changes, demonstrating the effectiveness of these time-tested approaches. However, the region faces significant environmental challenges, including coastal erosion and pollution, which threaten both fish populations and fishing livelihoods. The introduction of modern technologies, such as mechanization, marked a turning point in the history of fisheries in India, empowering small-scale fishers to venture further and deeper into the sea in search of fish. While this advancement increased fishing capacity, it also altered traditional dynamics, intensifying competition among fishers, though some customary practices persist. Concerns about sustainability have emerged due to the capture of juvenile fish and habitat disruption caused by shore seine operations. Further research is essential to assess the long-term impacts of these practices on marine ecosystems and community resilience. Sustainable management strategies that integrate local knowledge are necessary to ensure the future viability of traditional fisheries in Kanyakumari. Overall, the study highlights the need for a balanced approach that supports both ecological health and community livelihoods.

References:

1. Leela, E. N., Manju Lekshmi, V. S., & Yasmi, P. N. J. (2020). Beach seine fishery of India – A review. *Fishery Technology, 57*(4).

2. Lekshmi, N. M., Das, P. H. D., & Edwin, L. (2020). Karamadi – A waning practice of shore seine operation along Kerala, Southwest coast of India. *Indian Journal of Geo Marine Sciences, 49*(8), 1405–1410.
3. Nayar, S. G. (1958). A preliminary account of the fisheries of Vizhinjam. *Indian Journal of Fisheries, 5*(1), 32–55.
4. Raj, K. D., Monolisha, S., & Edward, J. K. P. (2017). Impacts of traditional shore seine operation along the Tuticorin coast, Gulf of Mannar, southeast India. *Current Science, 112*(1), 40–45. http://www.jstor.org/stable/24911614
5. Mariappan, S., Felix, S., & Kalaiarasan, M. (2017). A present scenario of seine nets fishing gears of Pulicat coast, Tamil Nadu, India. *International Journal of Fisheries and Aquatic Studies, 5*(3), 208–212.
6. Saleela, K., Dineshbabu, A. P., Santhosh, B., Anil, M. K., & Unnikrishnan, C. (2015). Shore seine fishery along Poovar in Thiruvananthapuram district, southwest coast of India. *Journal of the Marine Biological Association of India, 57*(2), Article 1839A-17. https://doi.org/10.6024/jmbai.2015.57.2.1839A-17
7. Tietze, U., Lee, R., Siar, S., Moth-Poulsen, T., & Bage, H. E. (2011). *Fishing with beach seines* (FAO Fisheries and Aquaculture Technical Paper No. 562, pp. 149). FAO.

THE FUTURE OF BIODIVERSITY:
INTEGRATING INNOVATION, POLICY, AND ETHICS BY 360^0

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Abstract:

Biodiversity, the cornerstone of thriving ecosystems, is increasingly threatened by human-driven development in the Anthropocene. This chapter, Biodiversity 360 Degree, presents a comprehensive examination of the interplay between development and conservation, envisioning sustainable coexistence by the year 3600. It explores how urbanization, industrial expansion, and climate change impact species diversity, ecosystem functionality, and ecological resilience. Through case studies and advanced modeling, the chapter evaluates innovative solutions, such as AI-powered conservation tools, synthetic biology, and ecosystem restoration, to mitigate biodiversity loss while supporting global development. It underscores the importance of integrated policy frameworks, international cooperation, and grassroots initiatives to balance human needs with environmental stewardship. By addressing ethical and equitable approaches to resource management, the chapter proposes a holistic strategy for preserving Earth's biological diversity. This forward-looking perspective advocates for adaptive, inclusive conservation practices to safeguard ecosystems for future generations, ensuring biodiversity thrives alongside human progress.

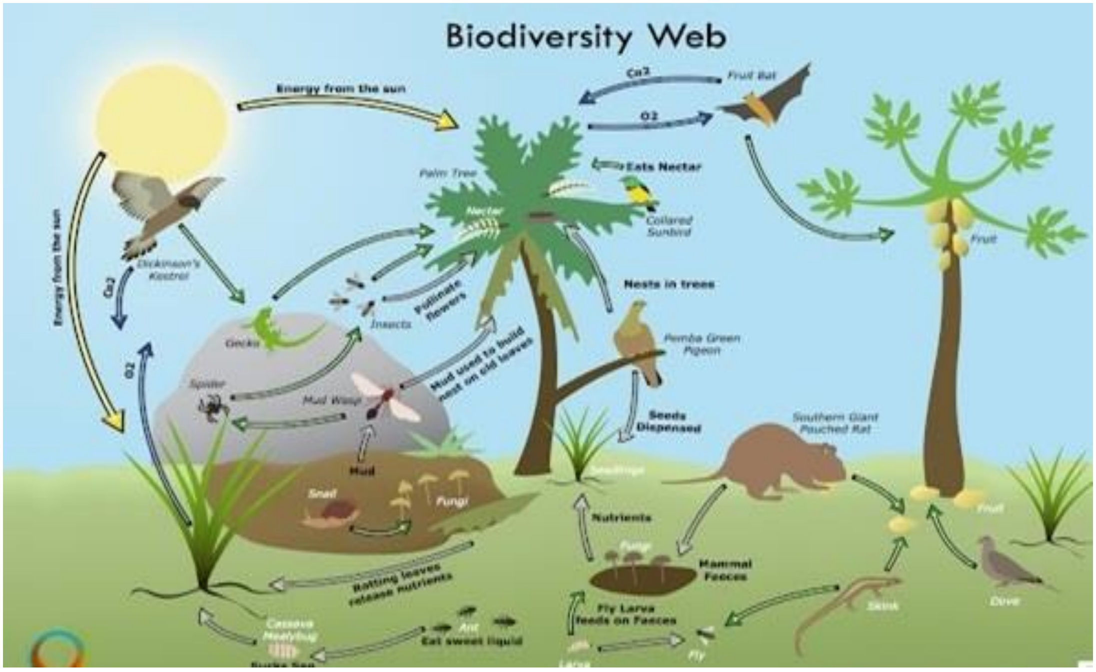
Keywords: Biodiversity, Conservation, Development, Sustainability, Ecosystem Resilience

Introduction:

Biological diversity is defined as "the variability among living organisms from all sources including, inter alia, terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems," as stated in the Convention on Biological Diversity. The term "biological diversity" or "biodiversity" refers to the approximately 8 million different types of species, including plants, animals, fungi, and bacteria, as well as the environments that sustain them, such as forests, oceans, mountainous areas, and coral reefs. Because every species plays a vital role in maintaining the natural order and the health of ecosystems, biodiversity is a significant part of our everyday lives.

(ISBN: 978-81-992068-7-8)

While the term "biodiversity" is a relatively recent compound word, biological diversity—which refers to the number of species—is not. Its definition has been more reductionist within the past ten years. The number of species is perhaps the most straightforward definition of biodiversity, devoid of context or specialization. However, a lot of people contend that biodiversity is not the same as the number of species present in a region. This metric, which is merely one aspect of biodiversity, is called species richness (Fiedler and Jain, 1992). First used by Lovejoy (1980) in its extended form (biological diversity), the term "biodiversity" Additionally, biodiversity is more than species diversity, which some authors refer to as simply diversity. Species diversity is the number of species and their relative abundance in a given area (Pielou, 1977).



Source: https://www.sanskritiias.com/uploaded_files/images//biodiversity-web.jpg

DeLong (1996) provided a more thorough explanation:

An area's biodiversity is defined as the variation found within and among living things, living organism assemblages, biotic communities, and biotic processes, whether they are naturally occurring or have been altered by people. Genetic diversity, the number and identity of distinct species, species assemblages, biotic communities, and biotic processes, as well as the quantity (such as abundance, biomass, cover, and rate) and structure of each, can all be used to quantify biodiversity. Any geographical scale, from microsites and habitat patches to the entire biosphere, can be used to observe and quantify it.

This definition is flexible enough to change depending on the situation.

Different authors have offered precise and thorough clarifications of this definition. Three definitions of "biodiversity" were put out by Gaston and Spicer (1998): ecological diversity, genetic diversity, and organismal diversity. Other definitions combined the genetic and organismal components, leaving genetic diversity and ecological diversity as the main constituents. The two main "practical" value systems that Gaston and Spicer (1998) describe—direct use/genetics and indirect use/ecological—can be connected to these final two components. A hierarchical approach or hierarchies of living systems have been highlighted by several researchers.

The sustainable use of biological diversity, or biodiversity, and its components for the benefit of humanity are two of the most important issues confronting the globe today. Careless, unsustainable activities are causing biodiversity, a limited global resource with moral and economic significance for humanity, to be destroyed or lost forever. The most concerning aspect of the well-documented exponential loss of biodiversity is that it is not slowing down and could even get worse in the future.

The Convention on Biological Diversity (CBD) enshrines the fundamental significance of these issues, which were discussed at the 1992 Rio de Janeiro, Brazil, United Nations Conference on Environment and Development (UNCED). Its goals include

"The conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources, including by appropriate access to genetic resources and by appropriate transfer of relevant technologies, taking into account all rights over those resources and to technologies, and by appropriate funding"

One of the main causes of the recent anthropogenic activity is global climate change, which has occurred either directly or indirectly. reduction in the biodiversity of wildlife. According to scientists, climate warming may worsen the current threats to wildlife biodiversity and have a significant impact on ecosystems at all latitudes (Dobson *et al.,* 1989). The distribution of species, demographic rates, emergence and reemergence of diseases, genetic loss and extinction, habitat loss, loss of soil fertility, nutritional stress, population decline, and spread of invasive species are just a few of the many effects of climate change on the biodiversity of wildlife worldwide (Mawdsley *et al.,* 2009). The structure and function of ecosystems can be altered by changes in abiotic elements such seasonality, precipitation, wind patterns, and environmental temperature. This can lead to changes in the distribution patterns of related flora and animals (Markham and Malcom, 1996).

With approximately 91,000 known animal species and 45,500 known plant species, India is known for having a diversified ecosystem. Trees and forests encompass 23.39% of its territory.

India is home to four of the 36 biodiversity hotspots in the world: Sundaland, the Indo-Burma region, the Western Ghats, and the Himalayas. Two of these, Sundaland and the Indo-Burma region, are dispersed over South Asia and do not quite fall inside India's official borders. The term "hotspot" refers to areas that are highly prioritized for conservation due to their high endemism, substantial vulnerability, and extensive biodiversity. Locations having a high concentration of native species are considered biodiversity hotspots. The majority of hotspots are located in tropical and subtropical regions, where year-round high temperatures and humidity are common.

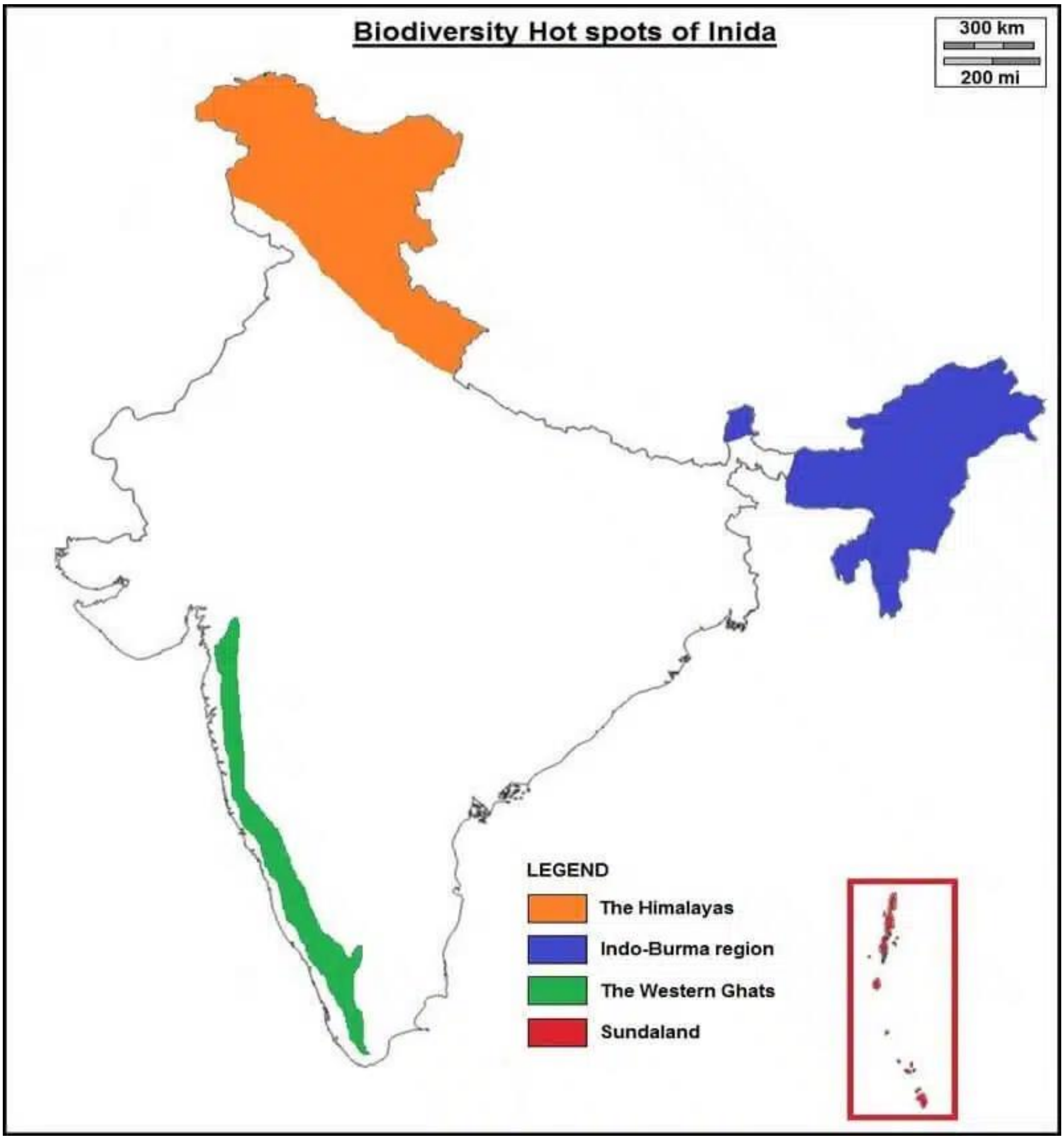
Biodiversity Hot Spots in India:

There are four Biodiversity Hotspots in India:

- Himalaya
- Indo-Burma
- Western Ghats
- Sunderland

❖ **The Himalayas**: The Himalayan hotspot, which stretches over 3,000 kilometers across northern Pakistan, Nepal, Bhutan, and the northwest and northeastern provinces of India, is home to all of the world's mountain peaks higher than 8,000 meters, including Mt. Everest (8,849 meters). Additionally, it contains a few of the world's deepest river canyons. The nearly 7.5 million square kilometer Himalayan mountain range is separated into two parts: the Western Himalaya, which includes parts of Kumaon-Garhwal, northwest Kashmir, and northern Pakistan, and the Eastern Himalaya, which includes parts of Nepal, Bhutan, and the northeastern Indian states of West Bengal, Sikkim, Assam, and Arunachal Pradesh.

❖ **Indo-Burma**: With a total size of 2,373,000 km^2, the Indo-Burma hotspot is the largest of the 36 hotspots recognized worldwide. Parts of Bangladesh, Malaysia, and northeastern India were once included in the Indo-Burma hotspot. However, because northeastern India is part of the Himalayan hotspot and the hotspot only stretches into Bangladesh and Malaysia, these countries are considered extralimital to the hotspot for the purposes of the ecosystem profile. With coasts along the Bay of Bengal, Andaman Sea, Gulf of Thailand, and South China Sea, as well as the tallest peak in Southeast Asia, the hotspot boasts an amazing geographic diversity.



Source: https://www.clearias.com/biodiversity-hotspots-in-india/

- **The Western Ghats:** The Malabar Plains and a range of mountains that stretch 30 to 50 kilometers inland and parallel to India's western coast make up the Western Ghats, often known locally as the Sahyadri Hills. They cover an area of more than 160,000 km^2, extending 1,600 km from the southernmost part of the country to Gujarat in the north, with only the 30 km Palakkad Gap between. The Western Ghats regulate how much rain falls on peninsular India by obstructing the southwestern monsoon winds. The western slopes of the Alps receive a lot of rain each year, most of it falling between June and September during the southwestern monsoon. Because of the Western Ghats' complex geography and variable rainfall patterns, the area is home to a wide variety of vegetation species.

- **Sunderland:** The western portion of the Indo-Malayan archipelago, which consists of over 17,000 tropical islands, is part of the Sundaland hotspot. Two of the world's largest islands are Sumatra (427,300 km^2) and Borneo (725,000 km^2). Sundaland encompasses nearly all of Malaysia, including Peninsular Malaysia, the provinces of Sarawak and Sabah in East Malaysia in northern Borneo, Singapore at the tip of the Malay Peninsula, Brunei Darussalam, and the western part of Indonesia, including Kalimantan. The Indonesian parts of Borneo, Sumatra, Java, and Bali are also included, as are the provinces of Pattani, Yala, and Narathiwat in southern Thailand.

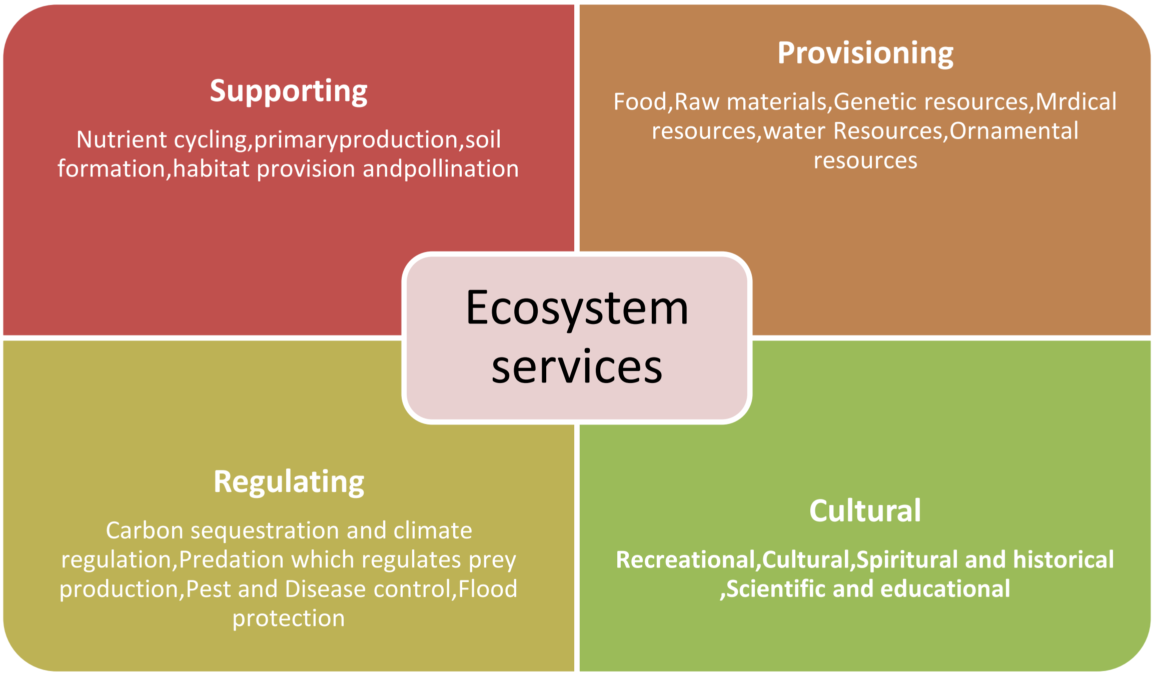
Typically, Biodiversity is Separated into Three Levels:

1. **Ecological Community:** The entire ecological community, or all living things in a particular location, is included in ecosystem diversity. Savannas, woods, lakes, oceans, marshes, deserts, and all the other habitats where a wide variety of animals exist and evolve are a few examples. Food chains, the interactions between different species, photosynthesis, the breakdown of plant matter, symbiosis between species, and other activities are all examples of ecosystem variety.
2. **Diversity of Organisms**: The wide variety and quantity of distinct organisms, encompassing all taxonomic levels (domain, kingdom, phylum, class, order, family, genus, and species), is referred to as the diversity of organisms. The likelihood of the environment adapting to changes may be higher if there are many different organisms, such as species or at different taxonomic levels. For instance, if rodent populations fall one year, predators such as owls or foxes can seek other prey if there are other options. Certain plants require wide space or particular soil types, while others are suited to lots of shade and do well in dense forests. Because many organisms rely on many natural environments during their life cycles, it is important to have a variety of natural habitats, which is why monocultures can be troublesome.
3. **Genetic Diversity**: An organism's or a population's genetic diversity is the range of genes present. A more varied array of traits is a result of genetic differences between individuals or within a community. The great diversity of species that exist today on Earth is mostly due to genetics as well as interactions and environmental pressures.

Importance of Biodiversity

Our survival is heavily reliant on biodiversity. The linkages can occasionally be quite straightforward. Plants are the source of the oxygen we breathe. Bees are necessary for pollinating foods like fruit and nuts. Wood and other natural building materials are used to construct our dwellings. Some connections are more oblique. Plants' genetic variety provides us with both traditional medicine and pharmaceutical companies' raw materials. Additionally, biodiversity serves as an ecosystem's support system. For example, mangrove forests shield coasts.

Ecosystem services in four categories: provisioning services, regulating services, cultural services and supporting services as the basis.



Factor Influencing Biodiversity Loss

Even though the loss of biological diversity could have an economic and financial impact similar to that of climate change, it has gotten far less attention up to this point. The Living Planet Report 2022 states that between 1970 and 2018, the relative abundance of the world's observed wildlife populations decreased by an average of 69% as a direct result of ongoing unsustainable activities. Furthermore, one million plant and animal species are at risk of going extinct in the next decades, according to the IPBES Global Assessment Report on Biodiversity and Ecosystem Services' 2022 Summary for Policymakers.

Significant biodiversity loss is currently caused by five main factors: pollution, alteration of land and sea usage, direct overharvesting of creatures, climate change, and the introduction of invasive species. Indirect factors of change like trade, technical advancement, local and global governance, population dynamics and trends, production and consumption patterns, and societal values and behaviors have all contributed to these events. The strains causing biodiversity loss in our natural environment are further exacerbated by a wide range of commercial activity.

The Impact on the Environment of Biodiversity Loss

Ecosystem services are diminished and disturbance resistance is lowered as a result of biodiversity loss, which has a domino effect on ecosystems and the environment. Among the repercussions are:

1. **Genetic Resource Depletion**: Biodiversity is a storehouse of genetic resources that can be utilized to create new crops, medications, and forms of cultural expression.
2. **Modified Biogeochemical Cycles**: Ecosystems' ability to cycle nutrients like carbon, nitrogen, and phosphorus can be impacted by biodiversity loss. Changes in greenhouse gas emissions, water quality, and ecosystem productivity may result from this.
3. **Enhanced Risk of Species Extinction:** When one species disappears, it may have a domino effect on other species in the same habitat, resulting in more biodiversity losses and raising the possibility of several species becoming extinct.
4. **Ecosystem Stability Loss**: Biodiverse ecosystems are more resilient and stable against shocks like invading species, disease outbreaks, and climate change. Ecosystem collapse is more likely when biodiversity is lost since it can make it harder for an ecosystem to recover from these disruptions.
5. **Reduction in Ecosystem Services**: Vital services like soil formation pollination, carbon sequestration, climate regulation, and air and water purification are all provided by robust, diversified ecosystems. These services can be hampered by biodiversity loss, which lowers environmental quality.

Reasons for the Loss of Biodiversity

1. **Loss and Fragmentation of Habitats:** The main factor contributing to biodiversity loss is habitat destruction and fragmentation, which is brought on by the conversion of natural ecosystems into agricultural land, urban areas, and infrastructure development. In addition to reducing the amount of area available for native animals to live, feed, and reproduce, humans' encroachment on formerly wild regions also breaks the links between various ecosystems.
2. **Climate Change:** As a result of habitat changes brought about by global warming and the ensuing shifts in climatic patterns, organisms find it more difficult to carry out their innate tasks or adjust to novel environments. For instance, variations in temperature or precipitation patterns alter the growth or survival of some plants, which impacts the species that rely on them.
3. **Ocean Acidification:** Ocean acidification is caused by rising carbon dioxide levels, which makes it harder for marine life to retain its protective layer, such as corals,

plankton, and shellfish. As a result, the populations of these species and the animals that depend on them for food and shelter are declining.

4. **Ecosystem Simplification:** When complex, diverse ecosystems are reduced to simpler ones, like urban areas or monocultures, fewer species have access to niches and ecosystem resilience is lowered.
5. **Disease:** Human activity frequently contributes to the spread of infectious illnesses, which can decimate wildlife populations. Natural defenses against disease-causing microorganisms that are indigenous to their area have been created by organisms. However, native species are ill-prepared to fight off non-native microorganisms that human activity introduces into ecosystems.
6. **Genetic Pollution:** Genetic diversity, which is essential for a species' resistance and adaptation, might be lost as a result of the release of genetically engineered organisms or the hybridization of closely related species.
7. **Overhunting**: One of the primary causes of species extinction is the overhunting of a species for sport, due to pest control, or to satisfy the high demand for meat or animal derivatives. Populations are rapidly reduced by industrialized hunting, which ignores the impact of species decline on the ecosystem as a whole. For instance, otter fur was heavily commercialized in the 18th and 19th centuries in both Russia and the United States, almost driving the species to extinction. This led to the secondary consequences of fish population declines and kelp forest loss.
8. **Invasive Species:** Because ecosystems have developed to keep species populations relatively stable, non-native species that are brought to new areas have the potential to outcompete native species for resources, feed on them, or spread illnesses. Invasive species have the ability to reduce the numbers of the prey they consume when they are at higher levels of the food chain. On the other hand, invasive species that are at the bottom or middle of the food chain may cause a population boom for the native species that eat them, which could have an impact on the ecosystem as a whole.
9. **Overfishing:** As a result of industrialized fishing, highly sought-after species such as salmon, whales, and tuna are being reduced in order to satisfy global demand. Sea-floor ecosystems, which are crucial breeding grounds for numerous species, have also been damaged by unsustainable fishing practices like bottom trawling. By boosting the number of predators at the expense of their prey, this has had the unintended consequence of altering the architecture of marine ecosystems.
10. **Pollution:** Pollution of the air, soil, and water can damage species by causing habitat

degradation, physical impairment, or increased susceptibility to diseases or predators. Certain contaminants, such heavy metals and pesticides, can contaminate many layers of the environment by moving up the food chain.

Goals of Biological Resource Asset and Management

Contextual differences in the definition of biodiversity are contingent upon the asset management goal and the intended use of the biological resource asset, often known as the bioasset. Direct and indirect use, as well as option and non-use values, make up biological resource values. They can be further categorized as follows in order to evaluate their possible use:

1. The main extractive products' values for direct use. This would mostly comprise commercial fishing in the case of terrestrial and marine systems, as well as forestry for timber. These materials are transported and marketed in well-maintained facilities, and their extraction frequently requires huge, non-local companies to spend much in capital equipment.
2. Direct application of "minor" extractive products. These items, which are found naturally or semi-naturally, necessitate time-consuming collection or harvesting tasks that are frequently completed by locals. Seaweed, artisanal fisheries, aquarium fish, rattan, fuelwood, wild edibles, and medicinal herbs are a few examples. These could be gathered to sell, trade, or use at home.
3. Values for direct usage that only a little amount of biological material needs to be extracted for storage or ex situ investigation. This covers material extraction for industrial research, germplasm banks, and biological inventories. In order to gather representative samples of biological material, extraction is frequently carried out on brief or extended expeditions that travel over wide regions.
4. Non-extractive direct use values that frequently necessitate significant user involvement with the resource on-site. This comprises key "non-consumptive" activities that mostly take place in protected areas, such as ecotourism, recreation, and on-site research. The requirement to supply participants with food, housing, and transportation is what defines these activities.
5. Values accumulated off-site through indirect use. Depending on their relative importance to the support or protection of off-site economic activity, the value of these functions—such as watershed protection, natural ecosystems preserved as national parks in order to generate revenue from wildlife tourism, protection of fisheries nurseries and subsistence fisheries, and climate regulation—may be very large or very small.

6. Option values. Option values are only taken into consideration when they can be potentially significant in relation to the specific kind of product or service, as they can be linked to every use value.
7. Values that are not used. By definition, these values—such as stewardship, ethics, cultural belief, and aesthetics—occur at a distance from the resource and don't need to be extracted or physically interacted with.

Biodiversity Conservation Acts:

- Biological Diversity Act ,2002
- Wildlife (Protection) Act,1972
- Forest (Conservation) Act,1980
- Environment (Protection) Act, 1986
- Indian Forest Act,1972
- Water (Preservation and Control of Pollution) Act 1974
- Air (Preservation and Control of Pollution) Act ,1981
- Scheduled Tribes and other Traditional Forest Dwellers (Recognition of Forest Right) Act, 2006

Conclusion:

The future of biodiversity hinges on our ability to harmonize development with conservation in a rapidly changing world. Biodiversity 360 Degree underscores that sustainable progress requires a holistic approach, integrating advanced technologies like AI and synthetic biology with robust policy frameworks and community-driven efforts. By addressing the challenges of urbanization, industrialization, and climate change, we can forge a path where human advancement coexists with thriving ecosystems. The chapter's exploration of innovative tools and collaborative strategies highlights the potential to restore and protect biodiversity while meeting global developmental needs. Moving toward 3600, collective action—spanning governments, industries, and local communities—must prioritize equitable resource management and ecological resilience. Embracing adaptive, inclusive conservation practices ensures that Earth's rich biological heritage endures for future generations. This vision calls for unwavering commitment to balancing human aspirations with the stewardship of nature, fostering a world where biodiversity flourishes as a foundation for sustainable development.

References:

1. DeLong Jr, D. C. (1996). Defining biodiversity. *Wildlife society bulletin*, 738-749.

2. Dobson, A., Jolly, A., & Rubenstein, D. (1989). The greenhouse effect and biological diversity.
3. Fiedler, P. L., & Jain, S. K. (Eds.). (1992). *Conservation biology: The theory and practice of nature conservation, preservation and management*. Chapman and Hall.
4. Gaston, K. J., & Spicer, J. I. (1998). *Biodiversity: An introduction*. Blackwell Science.
5. Lovejoy, T. E. (1980). The Global 2000 Report to the President (G. O. Barney, Ed.), Vol. 2, The Technical Report (pp. 327–332). Penguin.
6. Markham, A., & Malcolm, J. (1996). Biodiversity and wildlife: adaptation to climate change. In *Adapting to Climate Change: An International Perspective* (pp. 384-401). New York, NY: Springer New York. https://doi.org/10.1007/978-1-4613-8471-7_33
7. Mawdsley, J. R., O'Malley, R., & Ojima, D. S. (2009). A review of climate-change adaptation strategies for wildlife management and biodiversity conservation. *Conservation Biology*, *23*(5), 1080-1089.https://doi.org/10.1111/j.1523-1739.2009.01264.x
8. Pielou, E. C. (1977). *Mathematical ecology*. John Wiley & Sons

MILLIPEDES AS BIONETWORK, NUTRIENT DYNAMICS AND INCREASING SOIL STRUCTURE

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Abstract:

Millipedes (Diplopoda) play a crucial role in terrestrial ecosystems, primarily as detritivores that break down organic matter, recycle nutrients, and improve soil quality. This review examines their species diversity, ecological roles, and habitat associations in the Satara region of Maharashtra, India. The diverse landscapes of Satara, including forests, grasslands, and agricultural areas, support a wide variety of millipede groups. Adapted to the region's semiarid and tropical climate, these invertebrates enhance soil structure, fertility, aeration, and moisture retention, indirectly supporting crop productivity through the decomposition of organic residues. Despite their ecological importance, millipedes in this region are increasingly threatened by deforestation, climate change, pollution, and intensive farming. Research on them is limited, and conservation efforts are minimal, highlighting the need for comprehensive studies on their taxonomy, genetic variation, interactions with soil microbes, and ability to withstand environmental stress. Such research would strengthen biodiversity conservation and inform sustainable agricultural practices. Understanding ecological roles is essential for maintaining ecosystem services, promoting biodiversity, and developing innovative agricultural solutions.

Keywords: Agriculture, Millipedes Biodiversity, Satara, Soil

Introduction:

Millipedes, belonging to the class Diplopoda under the phylum Arthropoda, represent an ecologically important and globally distributed group of invertebrates (Alagesan, 2016). They are characterized by elongated, segmented bodies, a cylindrical form, and the presence of two pairs of legs on most body segments. Their remarkable diversity in form and function enables them to inhabit a wide range of ecological settings (Yaqoob, 2023). Due to this adaptability, millipedes are taxonomically divided into numerous orders, families, and species across the world. Presently, around 16 orders are recognized, including Julida, Polydesmida, Spirobolida, and Spirostreptida (Golovatch & Kime, 2009; Koch, 2015), each exhibiting unique morphological and behavioural traits suited to particular habitats.

Structurally, millipedes possess a hardened exoskeleton, segmented body plan, and a pair of antennae, features that support their survival in diverse terrestrial environments. Physiological adaptations, particularly those aiding in moisture retention, allow them to thrive in often challenging conditions. These features enhance their ecological importance, especially in their role as detritivores, where they accelerate the decomposition of organic matter and contribute to nutrient recycling, ultimately enriching soil fertility and ecosystem functioning.

Millipedes play a vital role in maintaining ecosystem health by attractive both soil fertility and structure. Acting as primary decomposers, they feed on decaying plant material such as fallen leaves, wood, and other organic residues, thereby accelerating decomposition and increasing the nutrient content available in soils (Bagyaraj *et al.,* 2016). Their burrowing and movement through the soil also promote aeration, which facilitates water infiltration, root penetration, and ultimately supports plant growth (Dangerfield & Telford, 1991). Beyond these contributions, millipedes are actively involved in nutrient cycling, particularly nitrogen dynamics, which are essential for sustaining soil ecosystems and ecological stability. Furthermore, they serve as an important link in terrestrial food webs, providing a food source for a wide range of predators (Mawcha, 2023; Shear, 2015).

The Satara region of Maharashtra, India, hosts a rich diversity of millipede species, supported by its varied topography and ecological conditions. The landscape comprises agricultural fields, grasslands, and forested zones, each providing distinct habitats that sustain millipede populations. The tropical forests of Satara, in particular, create favourable conditions through abundant leaf litter and moist soil, which are essential for millipede survival. Additionally, the grasslands and cultivated lands of the region harbour unique communities of species that have adapted to the microhabitats within these environments, thereby contributing to the overall ecological richness of Marathwada (Deshmane, 2020).

The biodiversity and abundance of millipedes in the Satara region remain poorly explored, even though these organisms play a vital ecological role. Limited research on millipedes from this area has left much of their ecological functions and potential benefits unrecognized (Golovatch, 2009). Understanding their diversity and habitat associations is essential, as millipedes contribute significantly to soil fertility and overall ecosystem balance. Investigating millipede communities in Satara can aid in biodiversity conservation, provide insights into ecological patterns, and support agriculture through their role in enhancing soil quality.

This review seeks to provide a comprehensive account of the ecological role, diversity, and habitat preferences of millipedes in the Satara region. By examining their taxonomic classifications, habitat associations, and contributions to ecosystem functions, the study highlights the crucial role millipedes play in maintaining ecological balance. It also addresses their agricultural and economic significance, considering both the benefits and potential challenges they present to human activities (Cock *et al.,* 2012). Furthermore, the review underscores the importance of targeted conservation measures to protect these vital soil invertebrates; while assessing the threats they face in the region. To strengthen our understanding of millipede populations, especially under the pressures of habitat degradation and environmental change, this paper also proposes directions for future research.

This review seeks to address existing knowledge gaps by focusing on the ecological functions and diversity of millipedes in Satara, thereby offering baseline information that can guide future research and conservation strategies. Gaining insights into these aspects is essential for formulating sustainable approaches to safeguard soil ecosystems and maintain biodiversity in the region.

Diversity of Millipedes in Satara Region:

The millipede diversity in the Satara region of Maharashtra, India, reflects the wide range of habitats and climatic conditions found there. Species from multiple taxonomic families and genera inhabit the area, showing varied adaptations that enable them to survive across ecological settings such as forests, grasslands, and farmlands. Among the most commonly recorded families in Satara are Xystodesmidae, Paradoxosomatidae, Spirobolidae, Trigoniulidae, Julidae, Spirostreptidae, and Polydesmidae. Each genus within these families displays distinctive morphological and ecological characteristics that help them persist under the region's semi-arid to tropical environmental conditions (Ahsan *et al.,* 2022; Abdar, 2022). Millipedes from the family Julidae are generally cylindrical, with segmented bodies that facilitate both soil burrowing and the decomposition of organic matter. Species such as *Julus terrestris* are well adapted to moist environments and are commonly encountered in damp, shaded forest floors rich in leaf litter (Shridhar & Ashwini, 2016).

Members of the Spirostreptidae family, on the other hand, possess a sturdier and broader body structure, enabling them to occupy habitats ranging from open grasslands to forests. Species like *Spirobolus orientalis* demonstrate adaptations for survival in both humid and moderately dry conditions. Observations of *Spirostreptus* species are particularly frequent in grasslands, where they play a vital role in breaking down coarse organic debris and contributing to soil formation processes (Armstrong & Hamer, 2015). Beyond their role in nutrient cycling, Spirostreptidae millipedes also interact closely with local plant and animal communities, forming complex associations with other decomposer organisms that enhance the overall biodiversity of Satara ecosystems.

Members of the Polydesmidae family, another prominent group of millipedes, are generally flat-bodied and possess lateral extensions on each segment, which serve as protection against predators and environmental pressures. Within this family, *Polydesmus* sp. is especially widespread in the agricultural landscapes of Satara, where it has successfully adapted to human-influenced environments. Unlike many other millipede families that prefer relatively undisturbed habitats, *Polydesmus* sp. shows remarkable tolerance to soil disturbance and moderate pesticide exposure. These traits highlight not only the ecological adaptability of the Polydesmidae but also their potential role in maintaining agricultural systems by enhancing soil aeration and promoting the breakdown of organic matter (Anh *et al.,* 2024). The coexistence of both endemic and highly adaptable species in Satara underscores the need for detailed taxonomic and ecological studies; as such research could provide valuable insights into the resilience and overall health of the region's ecosystems.

Habitats of Millipedes:

The Satara region hosts a range of habitats that provide distinct microenvironments essential for millipede survival. These include agricultural fields, grasslands, and forested areas, each characterized by unique biotic and abiotic factors that shape millipede distribution and behaviour. Understanding these habitat associations is crucial, as they determine the structure of millipede communities and their ecological functions within the region.

Table 1: Habitat types and millipede species in Satara regions

Habitat Type	Characteristics	Species	Abiotic Factors	Biotic Interactions
Agricultural Lands	Soil disturbance, crop residues, irrigation	*Polydesmus sp.*	Loamy to sandy soil, irrigation, variable moisture	Crops, resilient to low pesticide exposure
Grasslands	Open, drier conditions, organic debris	*Spirostreptus sp.*	Sandy or clayey soil, moderate moisture	Interactions with Small decomposers
Forests	Dense vegetation, moist soil, leaf litter	*Julus terrestris*, *Spirobolus orientalis*	Loamy soil, high moisture, shade	Fungi, termites, earthworms

Agricultural Lands:

The widespread presence of agricultural fields in Satara reflects the region's strong dependence on farming. Despite frequent soil disturbance and chemical use, these landscapes support resilient millipede species, such as *Polydesmus* from the Polydesmidae family. This genus has demonstrated tolerance to cultivated environments, adapting to moderate pesticide exposure and repeated soil disruption (Nuria *et al.,* 2011; Huot *et al.,* 2018). While irrigation and seasonal rainfall help maintain sufficient moisture, the soils in farmlands generally retain less humidity than those in forested areas. Within these agricultural settings, millipedes play a crucial role in recycling organic matter, especially after harvest when crop residues are abundant. By breaking down this material, they enhance nutrient cycling, improve soil fertility, and ultimately contribute to crop productivity (Kishore *et al.,* 2024). Each habitat type in Satara offers distinct resources and challenges that shape millipede distribution, behaviour, and ecological roles. The capacity of certain species to persist under varying soil textures, moisture regimes, and human disturbances illustrates both their adaptability and their significance in maintaining soil health across the region (Kunte, 2000).

Grasslands:

Compared to forests, the grasslands of Satara are generally drier and more exposed, though they still provide localized deposits of organic matter that serve as food for millipedes. Species such as *Spirostreptus* sp. show remarkable adaptations to these conditions, often seeking shelter under rocks, within decaying logs, or in soil crevices to withstand the relative dryness. Many grassland millipedes have evolved mechanisms to minimize water loss, including increased nocturnal activity when humidity levels are higher. The soils in these areas, typically sandy or clayey, drain rapidly and retain little moisture (Crawford *et al.,* 1987). Despite these challenges, millipedes remain key contributors to ecosystem functioning in grasslands by facilitating organic matter decomposition and enhancing soil aeration, processes that are essential for maintaining soil fertility and ecosystem health (Druce, 2000; Hornung, 2024).

The table provides a summary of the major millipede habitats in Satara, outlining the conservation features that support their survival as well as the ecological communications going on within each setting. The capability of millipedes to adjust to various soil textures and changing moisture conditions highlights both their flexibility and ecological importance across these habitats (Abdar, 2022).

Forested Habitats:

The forests of Satara, largely composed of tropical, dry deciduous and scrub types, create habitats rich in leaf litter, organic debris, and moisture-retentive soils. These conditions are particularly favourable for millipedes, especially members of the Julidae and Spirostreptidae families such as *Julus terrestris* and *Spirobolus orientalis*, which thrive in shaded and humid environments. The presence of abundant decaying wood and fallen leaves ensures a steady food supply for these detritivores. Since millipedes require moisture to prevent desiccation, the loamy to clayey soils of Satara forests, which retain water effectively, provide an ideal substrate (Cloudsley-Thompson, 1951; Adkine, 2016). Moreover, millipedes in these ecosystems interact with other decomposers such as termites, fungi, and earthworms forming a dynamic network that drives nutrient cycling and organic matter breakdown (Osman, 2013; Culliney, 2013).

Habitat Loss:

The primary threat to millipede species in Satara is the rapid alteration of natural habitats due to urban expansion and deforestation. Forest ecosystems, which provide cool, moist environments crucial for species like Julus sp. and Spirostreptus sp., are becoming increasingly fragmented, diminishing suitable living spaces (Paul *et al.,* 2022). This destruction reduces the availability of microhabitats, leading to population disturbances and a decline in local biodiversity (Toth *et al.,* 2019). Moreover, grasslands, already under pressure from agricultural development, offer less protection, further exacerbating the problem of habitat loss for millipedes.

Human and Economic Value:

Millipedes are economically important, especially in agriculture, where soil fertility and quality directly affect crop yields (Gaikwad, 2021). They act as decomposers and natural soil conditioners, which is particularly valuable in areas like Satara, where farming is the main livelihood. By accelerating the breakdown of organic matter, millipedes help maintain soil efficiency and overall health. However, while generally beneficial, some species can become pests at high population densities, rarely causing significant crop damage. One of the key contributions of millipedes to agriculture is their role in enhancing soil richness. By feeding on decomposing plant material, they break down complex organic materials into simpler compounds that enrich the soil. This process releases essential nutrients like nitrogen and phosphorus, making them more available for plant uptake. Through this nutrient recycling, millipedes support the efficiency and sustainability of farms, which is especially important in semi-arid regions like Satara, where soil fertility is often limited (Alagesan *et al.,* 2016; Rao & Patra, 2009). In agricultural fields, crop residues remaining after harvest provide an important food source for millipedes such as Polydesmus sp. By processing this organic matter, they play a vital role in nutrient recycling, which not only correct supports healthy plant growth but also decreases dependence on chemical fertilizers, thereby helping correct sustainable farming practices (Kumar *et al.,* 2020). Millipedes also contribute to soil ventilation through their burrowing behaviour. As they make tunnels in the soil, air and water are able to enter deeper layers, which correct promotes moisture retention and correct root growth. This process is mostly useful in compressed or clay-rich soils, as it reduces waterlogging and improves soil structure. In regions with intensive farming, such as Satara, millipede burrowing helps counteract compaction and promotes natural soil regeneration. By maintaining aerated and healthy soils, their activity indirectly supports agricultural productivity (Bhavya & Bhavana, 2024). Despite their many benefits, millipedes can sometimes pose challenges in agricultural settings. Under conditions that favor high population densities, certain species may feed on tender plant tissues or young seedlings, occasionally leading to minor crop damage (Farfan, 2010). Such incidents are more likely during planting season when alternative food sources are limited. For instance, species like *Julus terrestris* may occasionally graze on nearby soft plant parts, potentially affecting the establishment of early-stage crops (Wolters, 2000). Although these cases are relatively uncommon, they emphasize the importance of maintaining balanced millipede populations, particularly in intensively cultivated regions.

Apart from their role in agriculture, millipedes are being explored for applications in soil restoration and environmental rehabilitation. Their capacity to enhance soil health has generated interest in using them for the recovery of degraded lands. Introducing millipede populations into nutrient-poor areas could accelerate the buildup of organic matter, thereby improving land productivity (Menta, 2020). Furthermore, millipedes are gaining attention in biotechnology and medicine, as some of the compounds they produce possess antifungal, antibacterial, and other bioactive properties with potential applications (Dossey, 2010; Ilic *et al.,* 2018; Ilić *et al.,* 2019a; Ilić *et al.,* 2019b; Romão *et al.,* 2020). In summary, millipedes play an important role in agriculture by improving soil structure and enhancing nutrient cycling, though sudden changes in their population can sometimes pose challenges. By understanding these patterns and applying suitable management practices, farmers in the Satara region can harness their benefits more effectively, leading to healthier soils and sustainable agricultural systems.

Table 2 demonstrates the economic value of millipedes in agriculture, exactness both their positive effect on soil superiority and the occasional challenges they may posture. This balanced perspective highlights the importance of occasional management measures while highlighting the role of millipedes in supporting supportable farming practices.

Table 2: Contributions and Challenges of Millipedes in Agriculture and Economy

Feature	Impact	Explanation
Soil Value Improvement	Positive	Break down organic matter, enriching soil with nutrients
Soil Ventilation	Positive	Burrowing activities improve soil structure and root penetration
Crop Effect	Test	Occasional feeding on young seedlings in high population scenarios
Soil Renovation	Positive	Potential use in degraded land rehabilitation

Conservation Importance of Millipedes

Millipedes play an active part in conserving the preservation reliability of the Satara region through their involvement in organic matter breakdown, nutrient recycling, and improvement of soil quality. Acting as detritivores, they feed on decaying plant material such as fallen leaves, wood, and other organic residues, converting them into simpler materials. This activity not only quickens the decay procedure but also improves the soil with important nutrients like nitrogen and phosphorus, thereby increasing soil fertility and supporting flora growth. In Satara region, where agriculture harshly depends on soil health, millipedes contribute significantly to supporting the productivity of both natural ecosystems and cultivated lands (Rannavre & Donde, 2023).

One of the chief conservation roles of millipedes is their character in breaking down organic matter. By consuming decayed plant materials, they help fragment larger particles into smaller ones, which are then further decomposed by microorganisms such as bacteria. This serial method is important, as it confirms the release of nutrients that would then remain locked within organic residues, thereby moving the soil ecosystem (Nweze *et al.,* 2024). Certain species, with *Spirostreptus sp.* and *Julus terrestris*, play a mainly significant part in nutrient cycling, especially nitrogen turnover, within grassland and forest habitats because of their efficiency in processing plant litter (Bogyo *et al.,* 2015).

Outside their role in decomposition, millipedes also contribute significantly to soil aeration and essential growth. As they burrow for food or shelter, their movements create channels in the soil, enabling the entry of air and water (Bowen & Hembree, 2014). This movement is mostly significant in regions like Satara, where intensive farming often leads to soil compaction. By cultivating absorbency and water holding, millipedes indirectly support root growth and improve crop productivity, which is vital for semi-arid agricultural lands (Culliney, 2013). Certain species, such as *Polydesmus sp.*, are mostly strong in cultivated soils, and their burrowing performance helps counteract the negative impacts of continuous farming by improving soil fertility (Bedolla-Rivera *et al.,* 2023).

Millipedes play an important role in regional food chains by serving as prey for many birds, small mammals, and other invertebrates. Their accessibility as a stable food source helps sustain predator populations, thereby supporting biodiversity and working species dynamics across Satara ecosystems. Inside forested habitats, millipedes are also involved in complex trophic relations, where they often compete with other decomposers such as termites and fungi (Holle, 2022). This competition not only progresses the efficiency of nitrogen cycling but also maintains symmetry within the decomposer community, avoiding any single group from dominating the ecosystem (Javed *et al.,* 2023). Millipedes also take part in mutualistic relations with other organisms, mainly soil microbes that assist in breaking down complex plant materials within their digestive system. This association not only accelerates the decomposition of organic matter but also supports the spread of beneficial microbial populations in the soil. By fostering microbial diversity, millipedes indirectly enhance soil fertility and contribute to conserving ecological constancy (Mawcha *et al.,* 2023; Singh *et al.,* 2024).

In Satara the biological role of millipedes extends far beyond decomposition. They play a key part in maintaining soil structure, enhancing biodiversity, and confirming the continuous recycling of nutrients across dissimilar habitats. Through these multiple functions, millipedes contribute greatly to ecosystem stability, making their conservation vital for sustaining long-term soil health and overall ecological balance (Roy *et al.,* 2017).

Table 3 provide a clear overview of the biological roles performed by the dominant millipede species in Satara, importance their separate helps to soil quality and ecosystem effective. Investigative these characters suggestion valuable visions into how millipedes support the flexibility and long-term sustainability of the region's ecosystems.

Table 3: Biological Roles of Millipede in Satara regions

Species	Conservation Role	Role Explanation
Polydesmus sp.	Soil aeration in agriculture	Contributes to soil health in agricultural lands, countering compaction
Spirostreptus sp.	Soil aeration and erection	Improves soil structure through burrowing, helping water holding
Spirobolus orientalis	Food web integration	Helps as prey for birds and small mammals, supporting native biodiversity
Julus terrestris	Organic matter decay	Breaks down plant litter in forests, helping nutrient cycling

Conclusion:

Millipedes are crucial for maintaining soil health and ecosystem function in the Satara region. Despite their ecological importance, knowledge of their diversity, distribution, and conservation status is limited. Comprehensive taxonomic studies, ecological research, and conservation efforts are needed to ensure the survival of millipede species and the ecosystems they support. A focused study of Satara's millipedes highlights their ecological, economic, and conservation value. Millipedes are key decomposers, contributing significantly to nutrient recycling and soil enrichment. They enhance fertility and improve soil structure by breaking down organic matter and creating burrows. Their adaptability allows them to thrive in various environments within Satara, from forests and grasslands to cultivated fields, despite the regions semi-arid to tropical climate. Different families, such as Julidae, Spirostreptidae, and Polydesmidae, play specialized ecological roles, including decomposition and soil aeration, which supports ecological stability across habitats. Millipede populations face increasing threats from factors like land-use change, climate variability, and intensive farming. This highlights the need for conservation strategies focused on habitat preservation and sustainable agriculture. Millipedes also have untapped potential in ecological restoration and biotechnology, making research on their microbial interactions, genetic diversity, and environmental stress tolerance crucial. Addressing these knowledge gaps through focused research will improve our understanding of millipedes' ecological roles and support the development of sustainable ecosystem management strategies in the Satara region. Furthermore, millipedes could be a source of novel bioactive compounds in their defensive secretions, potentially leading to the discovery of therapeutic molecules. Protecting millipede diversity is therefore essential for maintaining soil health and ecological stability in the region, and for building resilience against future environmental challenges.

References:

1. Abdar, M. R. (2022). Diversity of millipedes in Chandoli National Park, Western Maharashtra, India. *Journal of Entomology and Zoology Studies*, *10*(4), 105–108.
2. Adkine, S. A. (2016). *Evaluation of soil and ground water quality of the Krishna valley in Marathwada region of Maharashtra for land use planning* (Doctoral dissertation, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani).
3. Ahsan, M. M., Kondulkar, S. R., & Pawar, S. S. (2022). Diversity of millipedes (Arthropoda: Diplopoda) in selected agricultural landscapes of Achalpur City, District Amravati, Maharashtra, India. *International Journal of Zoology and Applied Biosciences*, *7*(1), 23–26. https://doi.org/10.55126/ijzab.2022.v07.i01.005

4. Alagesan, P. (2016). Millipedes: Diversity, distribution and ecology. In *Arthropod diversity and conservation in the tropics and sub-tropics* (pp. 119–137).
5. Anh, D., Nguyen, T. T. T., Vu, K., & Eguchi, K. (2024). The millipede family Polydesmidae Leach, 1816 (Diplopoda, Polydesmida) from Vietnam, with a description of a new cavernicolous species. *ZooKeys*, *1190*, 259–280.
6. Armstrong, A., & Hamer, M. (2015). English names of the millipedes (Diplopoda) of KwaZulu-Natal. *African Invertebrates*, *56*, 147–159. https://doi.org/10.5733/afin.056.0111
7. Bagyaraj, D. J., Nethravathi, C. J., & Nitin, K. S. (2016). Soil biodiversity and arthropods: Role in soil fertility. In *Economic and ecological significance of arthropods in diversified ecosystems: Sustaining regulatory mechanisms* (pp. 17–51).
8. Bej, S. (2018). Water security in India threat mapping: Impact of climate change. *Peace and Security Review*, *8*(17), 44–94.
9. Bhavya, T. R., & Bhavana, A. (2024). Tiny architects of fertile soils: Understanding the role of soil arthropods. *International Journal of Environment and Climate Change*, *14*(9), 532–541.
10. Encyclopaedia Britannica. (2024). Millipede. *Encyclopedia Britannica*. https://www.britannica.com/animal/millipede
11. Cloudsley-Thompson, J. L. (1951). On the responses to environmental stimuli, and the sensory physiology of millipedes (Diplopoda). In *Proceedings of the Zoological Society of London*, *121*(2), 53–277. Oxford, UK: Blackwell Publishing Ltd.
12. Cock, M. J., Biesmeijer, J. C., Cannon, R. J., Gerard, P. J., Gillespie, D., Jimenez, J. J., Lavelle, P. M., & Raina, S. K. (2012). The positive contribution of invertebrates to sustainable agriculture and food security. *CABI Reviews*, 1–27.
13. Crawford, C. S., Bercovitz, K., & Warburg, M. R. (1987). Regional environments, life-history patterns, and habitat use of spirostreptid millipedes in arid regions. *Zoological Journal of the Linnean Society*, *89*(1), 63–88.
14. David, J. F., & Handa, I. T. (2010). The ecology of saprophagous macroarthropods (millipedes, woodlice) in the context of global change. *Biological Reviews*, *85*(4), 881–895.
15. Deshmane, J. (2020). Diversity of millipedes (Arthropod: Diplopoda) from District-Kolhapur, Western Maharashtra India. *International Journal of Researches in Biosciences, Agriculture and Technology*, *Issue VIII*, I, 205–211.
16. Dhuldhaj, U., Singh, R., & Singh, V. (2022). Pesticide contamination in agro-ecosystems: Toxicity, impacts, and bio-based management strategies. *Environmental Science and Pollution Research International*.

17. Druce, D. J. (2000). *Factors affecting millipede, centipede and scorpion diversity in a savanna environment* (Doctoral dissertation).
18. Farfan, M. A. (2010). *Some aspects of the ecology of millipedes (Diplopoda)* (Master's thesis, The Ohio State University).
19. Gaikwad, S. B. (2021). Wage rate differences in Marathwada region. *International Journal of Education, Modern Management, Applied Science & Social Science*, *4*(1), 52–58.
20. Gilgado, J. D., Rusterholz, H. P., & Baur, B. (2022). Millipedes step up: Species extend their upper elevational limit in the Alps in response to climate warming. *Insect Conservation and Diversity*, *15*, 61–72.
21. Golovatch, S. I., & Kime, R. D. (2009). Millipede (Diplopoda) distributions: A review. *Soil Organisms*, *81*(3), 565–565.
22. Holle, M. J. M. (2022). *Tropical agroecosystem functions in a changing environment*
23. Hornung, E. (2024). Terrestrial adaptations of crustaceans: The challenges of land adaptations and their solutions in terrestrial isopods. In *Frontiers in Invertebrate Physiology: A Collection of Reviews* (pp. 327–387). Apple Academic Press.
24. Ilić, B., Unković, N., Ćirić, A., Glamočlija, J., Ljaljević Grbić, M., Raspotni, G., Bodner, M., Vukojević, J., & Makarov, S. (2019). Phenol-based millipede defence: Antimicrobial activity of secretions from the Balkan endemic millipede *Apfelbeckia insculpta* (L. Koch, 1867) (Diplopoda: Callipodida). *The Science of Nature*, *106*, 1–9.
25. Ilić, B., Dimkić, I., Unković, N., Ljaljević Grbić, M., Vukojević, J., Vujisić, L., Tešević, V., Stanković, S., Makarov, S., & Lučić, L. (2018). Millipedes vs. pathogens: Defensive secretions of some julids (Diplopoda: Julida) as potential antimicrobial agents. *Journal of Applied Entomology*, *142*(8), 775–791.
26. Javed, S., Aftab, A., Safi, S. Z., Zahoor, A. F., Anwar, N., Gul, S., & Arshad, M. (2023). Sustainable recycling of manure and reuse to mitigate climate change. In *Climate Changes Mitigation and Sustainable Bioenergy Harvest through Animal Waste: Sustainable Environmental Implications of Animal Waste* (pp. 69–103). Springer Nature Switzerland.
27. Kumar, N. G., Ammagarahalli, B., & Gopalkrishna, H. R. (2020). Soil fauna and sustainable agriculture. In *Innovative Pest Management Approaches for the 21st Century: Harnessing Automated Unmanned Technologies* (pp. 211–226).
28. Knapp, M., Štrobl, M., Venturo, A., Seidl, M., Jakubikova, L., Tajovský, K., Kadlec, T., & González, E. (2022). Importance of grassy and forest non-crop habitat islands for overwintering of ground-dwelling arthropods in agricultural landscapes: A multi-taxa approach. *Biological Conservation*, *275*, 109757.
29. Kunte, K. (2000). *India, a Lifescape: Butterflies of Peninsular India*. Universities Press.

30. Mawcha, K. T. (2023). *Review from beneficial arthropods to soil-dwelling organisms: A review on millipedes in Africa*.
31. Mawcha, K. T., Hategekimana, A., Kajuga, J., Ndolo, D., & Yang, W. (2023). From beneficial arthropods to soil-dwelling organisms: A review on millipedes.
32. Means, J. C., Hennen, D. A., Tanabe, T., & Marek, P. E. (2021). Phylogenetic systematics of the millipede family Xystodesmidae. *Insect Systematics and Diversity*, *5*(2), 1–26.
33. Menta, C., & Remelli, S. (2020). Soil health and arthropods: From complex system to worthwhile investigation. *Insects*, *11*(1), 54. https://doi.org/10.3390/insects11010054
34. Nuria, R., Jérôme, M., Léonide, C., Christine, R., Gérard, H., Etienne, I., & Patrick, L. (2011). IBQS: A synthetic index of soil quality based on soil macro-invertebrate communities. *Soil Biology and Biochemistry*, *43*(10), 2032–2045.
35. Paul Serge, M., Makon, S. D., Tenyam Nkoh, P. B., & Mwabvu, T. (2022). Geographic distribution, diversity and conservation status of giant millipedes in southern Cameroon rainforest. *African Journal of Ecology*, *60*. https://doi.org/10.1111/aje.13032
36. Rao, D. L. N., & Patra, A. K. (2009). Soil microbial diversity and sustainable agriculture. *Journal of the Indian Society of Soil Science*, *57*(4), 513–530.
37. Shear, W. A. (2015). The chemical defences of millipedes (Diplopoda): Biochemistry, physiology and ecology. *Biochemical Systematics and Ecology*, *61*, 78–117.
38. Singh, S., Murugan, K., & Shyu, D. J. (2024). Microbial community and management of soil health for environmental sustainability: Concept, trends, and prospects. In *Environmental Nexus Approach* (1st ed., pp. 338–354). CRC Press.
39. Sridhar, K. R., & Ashwini, K. M. (2016). Diversity, restoration and conservation of millipedes. In Pullaiah, T. (Ed.), *Biodiversity in India* (Vol. 5, pp. 1–38). Regency Publications.
40. Tóth, Z., & Hornung, E. (2019). Taxonomic and functional response of millipedes (Diplopoda) to urban soil disturbance in a metropolitan area. *Insects*, *11*(1), 25.
41. Tudose, C., & Rîșnoveanu, G. (2023). Effects of land use on millipede communities (Subphylum Myriapoda, Class Diplopoda): A review. *Transylvanian Review of Systematical and Ecological Research*, *25*(3), 23–40.
42. Wolters, V. (2000). Invertebrate control of soil organic matter stability. *Biology and Fertility of Soils*, *31*, 1–19.
43. Yaqoob, M. (2023). *Foundation of Entomology*. Academic Guru Publishing House.
44. Zha, S., Wang, Z., Li, X., Chen, Z., Wang, J., Li, H., Cai, W., & Tian, L. (2023). Microstructural adaptation for prey manipulation in the millipede assassin bugs (Hemiptera: Reduviidae: Ectrichodiinae). *Biology (Basel)*, *12*(10), 1299.

BIODIVERSITY 360° FOR HEALTH AND NUTRITION: LINKING ECOSYSTEM CONSERVATION TO FOOD SECURITY AND NUTRACEUTICAL INNOVATION

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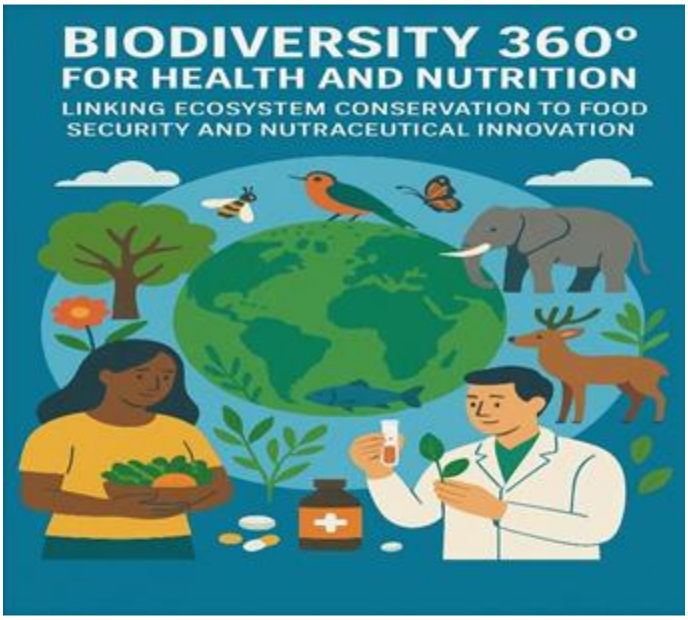
Abstract:

Biodiversity, defined as the variety and variability of living organisms at genetic, species, and ecosystem levels, supports the stability and productivity of natural and agricultural systems. It is not only the foundation of ecological balance but also a vital determinant of human nutrition and health. In the context of the chapter *"Biodiversity 360° for Health and Nutrition: Linking Ecosystem Conservation to Food Security and Nutraceutical Innovation"* biodiversity is viewed as the bridge between robust food systems and improved human well-being. By safeguarding diverse crops, livestock, and microbial resources, the world can secure a broader range of nutrients, strengthen food security, and open new opportunities for developing sustainable diets. At the same time, biodiversity provides the raw material for nutraceutical innovations through bioactive compounds, traditional food systems, and underutilized plant and microbial resources. Thus, conserving and enhancing biodiversity becomes a central strategy not only for ecological resilience but also for advancing human health through sustainable nutrition and responsible nutraceutical development. This chapter highlights the interconnection between nutrition and biodiversity, while quoting agroecological practices and nature-positive production models. It further outlines pathways that link indigenous foods, lesser-known crops, beneficial microbes, and bioactive compounds to the development of functional foods and dietary supplements.

Keywords: Biodiversity, Food and Nutrition security, Sustainable Diets, Nutraceuticals, Underutilized Crops, Indigenous Knowledge, Health, Quality Assurance, Benefit-Sharing.

1. Introduction: Biodiversity as the Basis of Nutrition and Health

Food security today extends far beyond the provision of calories; it entails reliable access to safe, nutritious, and culturally appropriate while simultaneously protecting the ecological systems that make food production possible. At its core, biodiversity—spanning genetic, species, and ecosystem levels—supports every dimension of food security: availability, accessibility, utilization, stability, agency, and sustainability. A wide range of crops and livestock offers resilience against climate fluctuations, pests, and diseases; diversified landscapes ensure the services of pollinators, natural pest control and soil microorganisms; traditional food systems safeguard indigenous knowledge and nutrition-oriented practices.



In contrast, biodiversity loss restricts dietary diversity, increases vulnerability to systemic shocks, and contributes to hidden hunger and micronutrient deficiencies. Alongside this, nutraceuticals—foods or ingredients with proven health-promoting or disease-preventive properties—represent a growing intersection between biodiversity and human health. Their functional value derives directly from biological diversity: polyphenols in colored grains and millets, carotenoids and xanthophylls in fruits and leafy greens, omega-3 fatty acids from aquatic resources, pre- and post-biotics from fermentation microbes, and a spectrum of terpenoids, alkaloids, and glycosides from medicinal plants. When developed sustainably, these bioactives can enhance the value of local crops, generate livelihood opportunities, and complement balanced diets within public health strategies. Yet, their commercialization also raises challenges such as risks of biopiracy, unsustainable exploitation, inconsistency in quality, safety concerns, and misleading claims.

Dimensions of Biodiversity Relevant to Food Systems

Genetic diversity	Within species (landraces, heirloom varieties, wild relatives) provides traits for climate resilience, pest resistance, and nutrient density
Species diversity	Across crops, livestock, fish, fungi, and microbes contributes to balanced nutrient profiles and ecosystem functions.
Ecosystem diversity	(Forest–farm mosaics, wetlands, grasslands, coastal zones) supports regulating and supporting services such as pollination, water cycling, soil formation, and biological control.

This chapter positions biodiversity as central to nourishing life—strengthening food systems, ensuring sustainable diets, and enabling ethically grounded nutraceutical development. A transdisciplinary approach is proposed, bringing together agroecology, nutrition science, pharmacognosy, food technology, and policy frameworks to responsibly integrate biodiversity into both food and health systems.

2. Global Biodiversity and Its Role in Food Security

Food security depends not only on the quantity of food produced but also on its diversity and resilience. Crop genetic diversity safeguards against pests, diseases, and climatic extremes, ensuring stable food supplies. Similarly, the diversity of livestock species provides proteins, essential fatty acids, vitamins, and minerals. Beyond cultivated systems, forests, wetlands, and aquatic ecosystems contribute to dietary resources by supporting wild edible plants, fish, and other nutritionally significant organisms.

Example: In Asia, traditional rice varieties such as red and black rice not only provide a broader nutrient profile but also offer resilience to drought and flood conditions, thereby securing both nutrition and harvest stability.

Food Security and Sustainable Diets: A sustainable diet is health-promoting, culturally acceptable, affordable, and has low environmental footprints. It is characterized by diversity, plant-forward patterns, seasonal and minimally processed foods, protection of aquatic and terrestrial biodiversity, and equitable value chains. Sustainable diets are not uniform prescriptions; they draw on local biodiversity and culinary heritage, aligning with the One Health paradigm linking human, animal, and ecosystem health.

Nutraceuticals and Functional Foods: Nutraceuticals span a broad spectrum—from naturally functional foods such as pigmented rice, millets, pulses, and fermented dairy products to concentrated bioactive preparations and standardized formulations, including curcuminoids, catechins, anthocyanins, beta-glucans, omega-3 fatty acid concentrates, and microbial-based probiotics or postbiotics. They exist along a continuum between foods, dietary supplements, and traditional systems of medicine. For responsible integration into diets and health systems, nutraceuticals should:

- Serve as a complement to diverse dietary practices, not as a substitute.
- Be supported by rigorous scientific evidence on safety, bioavailability, efficacy, and quality.
- Uphold ethical sourcing practices, sustainability principles, and equitable benefitsharing mechanisms.

A Systems Based Model comprising four interrelated spheres may be proposed for sustainability:

Production Sphere	Consumption Sphere	Value-Addition Sphere	Governance Sphere
Agroecological farming	Culinary traditions	Improved postharvest management	Access and benefitsharing (ABS) frameworks
Diversified cropping systems	Dietary diversity	Food processing and Biofortification,	Food and supplement regulatory systems
Home and Urban gardens	Nutrition-sensitive food environments	Fermentation technologies	Quality control mechanisms,
Sustainable aquaculture	Consumer awareness	Encapsulation techniques	Certifications (organic, fair trade, and geographical indications)
Wild Edible Resources	Behaviour change communication	Standardization of bioactive compounds for functional food and nutraceutical applications	Sustainability indicators
Microbial biodiversity			

These spheres are connected through dynamic feedback loops: demand for diverse and sustainable foods motivates farmers to conserve traditional landraces; and increases incomes; governance safeguards resources; and research strengthens evidence.

3. The Biodiversity, Nutrition and Nutraceuticals

Biodiversity Contributions to Nutrition, Food Security, and Nutraceutical Innovation

Biodiversity Component / Focus	Nutrition & Health Contributions	Nutraceutical Potential & Applications
Dietary Diversity	Prevents micronutrient deficiencies (iron, zinc, vitamin A, B-vitamins); improves protein quality, fibre, and healthy fats	Polyphenols, flavonoids, dietary fibre, plant-based omega-3s
Agrobiodiversity expands options: pulses, nuts, seeds, fruits, leafy vegetables, small fish, fungi, and millets contribute protein quality, fiber, phytochemicals, and essential fats. Seasonal rotation and mixed cropping ensure year-round availability.		

<table>
<tr><td>Underutilized & Neglected Species</td><td>Nutrient-dense, climate-resilient crops; provide phenolics, flavonoids, lignans, saponins, resistant starch</td><td>Antioxidants, resistant starch (glycemic control), lignans (hormonal health), saponins (cholesterol management)</td></tr>
<tr><td colspan="3">Underutilized crops—such as minor millets (finger, little, kodo, barnyard, foxtail), pseudocereals (amaranth, buckwheat), pulses (pigeon pea, cowpea, moth bean), oilseeds (niger, sesame), tubers (taro, yams), and indigenous fruits (bael, ber, jamun)—offer dense nutrition, drought tolerance, and cultural value. Leveraging them requires seed systems, consumer awareness, culinary innovation, and fair markets.</td></tr>
<tr><td>Livestock & Aquatic Biodiversity</td><td>High-quality proteins, essential fatty acids, local livelihood security; adapted to local ecosystems</td><td>Omega-3 fatty acids (EPA, DHA), conjugated linoleic acid (CLA), bioactive peptides</td></tr>
<tr><td colspan="3">Indigenous livestock breeds and aquatic species contribute diverse nutrient profiles (e.g., higher omega-3 content in certain small fish), resilience to local conditions, and livelihood security. Pasture heterogeneity influences milk fatty acid composition; aquatic vegetation shapes nutrient dynamics in inland fisheries. Conservation of wetlands and pastoral landscapes is thus a nutrition strategy</td></tr>
<tr><td>Microbial Diversity & Fermented Foods</td><td>Enhances bioavailability of nutrients, synthesizes vitamins (K, B12), produces beneficial metabolites</td><td>Probiotics, postbiotics (SCFAs, exopolysaccharides), B vitamins, bioactive peptides</td></tr>
<tr><td colspan="3">Microbial biodiversity—wild yeasts, lactic acid bacteria, filamentous fungi—drives fermentation, enhancing bioavailability (e.g., phytate degradation), synthesizing vitamins (e.g., vitamin K, B12 in some fermented foods), and generating postbiotic metabolites (shortchain fatty acids, exopolysaccharides). Traditional ferments (idli/dosa batter, curd, kefir, kimchi, pickles, kombucha, tempeh) illustrate the intersection of biodiversity, culture, and health.</td></tr>
<tr><td>Ecosystem Services for Nutrition</td><td>Supports food production via pollination, soil nutrient cycling, agroforestry; enhances diet diversity and resilience</td><td>Phytochemicals from agroforestry products (terpenoids, alkaloids, glycosides), mushroom polysaccharides, medicinal plant bioactives</td></tr>
<tr><td colspan="3">Pollination by insects, birds, and bats supports yields and quality of nutrient-rich foods (fruits, vegetables, oilseeds). Protecting these services is integral to nutrition-sensitive agriculture.</td></tr>
</table>

4. Sustainable Diets Rooted in Biodiversity

4.1 Dietary Patterns

Evidence-based, biodiversity-sensitive dietary patterns include:

- **Traditional plant-forward diets** based on whole grains (including millets and pseudocereals), pulses, seasonal vegetables and fruits, nuts, seeds, dairy or plant alternatives, and modest animal-source foods.
- **Diverse protein portfolios** that combine legumes, aquaculture, small livestock, and eggs for amino acid complementarity and lower footprints.
- **Culinary biodiversity**—spices, herbs, fermented condiments—improving palatability, antioxidant intake, and satiety.

4.2 Food Environment and Behaviour

To translate biodiversity into diets, food environments must make diverse foods available, affordable, convenient, and desirable. Strategies include school and workplace canteens featuring local biodiversity, farmers' markets, procurement policies (e.g., millet-inclusive public feeding programs), and social behaviour change communication grounded in local cuisine.

4.3 Environmental Footprints and One Health

Diversified cropping, intercropping, agroforestry, and regenerative practices can reduce greenhouse gas emissions, improve soil carbon, enhance water-use efficiency, and reduce synthetic inputs. Shifting a fraction of staple calories toward millets, pulses, and diverse vegetables can improve diet quality while lowering land and water intensity—context-specific modeling is essential. One Health perspectives integrate antimicrobial stewardship, zoonoses prevention, and habitat conservation.

5. Biodiversity as the Foundation of Human Nutrition and Health

The diversity of edible species across ecosystems forms the foundation of human diets. Wild plants, landraces, and underutilized crops often provide a wide spectrum of macro- and micronutrients, as well as bioactive compounds that cannot be found in staple foods alone. For example, leafy greens such as amaranth, moringa, and purslane—traditionally consumed in many regions—are rich in vitamins, minerals, and antioxidants. Similarly, indigenous fruits like jamun, bael, or wild berries offer phytochemicals with strong medicinal and nutraceutical potential This biological richness sustains dietary diversity, which is strongly linked to improved nutritional status and reduced risk of non-communicable diseases. However, the modern food system, driven by monocultures of wheat, rice, and maize, threatens biodiversity, narrowing the nutritional spectrum available to populations. Conserving and utilizing biodiversity is thus not only essential for ecosystem balance but also for discovering novel nutraceuticals that support preventive and therapeutic healthcare.

Traditional Knowledge and Ethnobotany

For centuries, traditional systems of medicine such as Ayurveda, Traditional Chinese Medicine, and Indigenous healing practices have harnessed biodiversity to manage health and disease. Plants like turmeric (*Curcuma longa*), ginger (*Zingiber officinale*), and garlic (*Allium sativum*) were historically used in both food and medicine, long before the concept of nutraceuticals was coined. Ethnobotanical records are a treasure trove for nutraceutical research, as they highlight species that communities have identified for enhancing vitality, preventing illness, or improving longevity. The bioactive constituents—curcuminoids in turmeric, gingerols in ginger, allicin in garlic—are now well studied for their roles in reducing inflammation, modulating immunity, and supporting cardiovascular health. By systematizing and validating such traditional knowledge, biodiversity is effectively translated into modern nutraceutical innovations.

Pathway from Traditional Knowledge to Modern Nutraceuticals

Traditional Knowledge & Indigenous Foods

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Identification of Bioactive Compounds

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Functional Foods & Nutraceutical Development

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Clinical / Health Applications

Linkage between Biodiversity, Food Security, and Nutraceutical Innovation

Biodiversity

↓

Agrobiodiversity & Wild Edibles

↓

Dietary Diversity & Nutritional Adequacy

↓

Bioactive Compounds (Phytochemicals)

↓

Functional Foods & Nutraceuticals

↓

Health & Wellness Outcomes

Sustainable Diet Framework Integrating Biodiversity

Environmental Sustainability

↓

Local & Seasonal Foods ⟵⟶ Biodiversity Conservation

↓

Economic & Social Benefits

↓

Health Outcomes

6. From Plants to Nutraceuticals: Phytochemical Diversity as the Basis for Nutraceutical Potential

Concept and Evolution of Nutraceuticals:

The term "nutraceutical" was first coined by Dr. Stephen DeFelice in 1989, combining "nutrition" and "pharmaceutical." Nutraceuticals refer to food-derived products that provide medical or health benefits, including the prevention and treatment of disease. Unlike conventional pharmaceuticals, nutraceuticals emphasize wellness, disease prevention, and holistic health.

Categories of nutraceuticals include:

- **Dietary supplements** (vitamins, minerals, amino acids, fatty acids)
- **Functional foods** (fortified foods, probiotics, prebiotics, plant-based products)
- **Medicinal foods** (tailored formulations for managing diseases)
- **Phytochemicals and bioactives** (flavonoids, carotenoids, polyphenols, curcuminoids, resveratrol, etc.)

The evolution of nutraceuticals reflects a growing interest in harnessing biodiversity's phytochemical richness for disease prevention and personalized nutrition.

Biodiversity ensures a vast pool of secondary metabolites, including alkaloids, flavonoids, terpenes, saponins, tannins, and polyphenols. These compounds act as defense molecules in plants but exhibit beneficial physiological effects in humans. For example:

- **Polyphenols** (from green tea, grapes, berries) act as antioxidants, reducing oxidative stress and lowering risk of chronic diseases.
- **Carotenoids** (from carrots, tomatoes, papaya) provide provitamin A activity and protect against age-related eye disorders.
- **Saponins** (from soy, quinoa, fenugreek) have cholesterol-lowering and immunomodulatory effects.

- **Tannins** (from oak galls, nuts, teas) show antimicrobial and anti-inflammatory properties.

The unique combination of these phytochemicals within species—and sometimes specific landraces—provides a wide canvas for nutraceutical development. Each ecosystem, from tropical forests to alpine meadows, is thus a potential pharmacological laboratory, offering compounds that can be harnessed to prevent disease and maintain wellness.

Linking Sustainable Diets to Nutraceutical Innovations:

Nutraceutical development is not merely about isolating compounds from nature; it is also about designing diets and food systems that integrate biodiversity. A sustainable diet incorporates local, seasonal, and diverse foods that provide not only energy but also bioactive components essential for optimal health.

Example:

- Incorporating pulses, millets, and traditional grains into diets supports gut health while contributing to nutraceutical profiles rich in fiber, resistant starch, and plant proteins.
- Functional beverages based on herbs such as hibiscus, chamomile, or holy basil demonstrate how biodiversity can be translated into daily wellness products.
- Fermented foods (e.g., kimchi, kefir, idli, kombucha) utilize microbial biodiversity to deliver probiotics that promote digestive and immune health.

By connecting biodiversity with dietary practices, nutraceuticals move beyond capsules and supplements into everyday eating, thereby making preventive healthcare more accessible and sustainable.

From Biodiversity Hotspots to Nutraceutical Markets:

Regions designated as biodiversity hotspots, such as the Western Ghats, Amazon Basin, and Indo-Burma, are not only ecological treasures but also nutraceutical reservoirs. Many modern nutraceuticals originate from species found in these areas—such as resveratrol from grapes, catechins from green tea, or omega-3 fatty acids from marine biodiversity.

Translating biodiversity into nutraceuticals involves several stages:

1. **Bioprospecting** – identifying promising species through ethnobotany and ecological surveys.
2. **Phytochemical Characterization** – isolating and profiling bioactive compounds.
3. **Pharmacological Validation** – studying mechanisms of action in vitro and in vivo.
4. **Clinical Evaluation** – assessing safety and efficacy in humans.
5. **Product Development** – formulating functional foods, supplements, or beverages. This pathway highlights the importance of interdisciplinary collaboration between

pharmacognosists, nutritionists, food technologists, and conservationists. It also underscores the need for sustainable practices that ensure biodiversity is not exploited unsustainably for short-term commercial gains.

Challenges in Converting Biodiversity into Nutraceuticals

- **Overharvesting and Sustainability**: Excessive extraction of medicinal or edible plants can endanger species.
- **Standardization**: Natural products vary in bioactive content due to geographic, climatic, and seasonal differences, complicating quality assurance.
- **Regulatory Frameworks**: The nutraceutical industry operates between food and medicine, often leading to ambiguous regulations and inconsistent standards.
- **Intellectual Property Rights**: Ensuring fair benefit-sharing with indigenous communities who have preserved traditional knowledge is ethically crucial.
- **Scientific Validation**: Not all traditional claims are supported by robust evidence; rigorous clinical studies are required to confirm efficacy and safety.

Overcoming these barriers requires international cooperation, policy support, and investment in biodiversity research and conservation.

The Future: Biodiversity-Inspired Personalized Nutrition

The convergence of biodiversity and nutraceutical science is now evolving into personalized nutrition. Advances in genomics, metabolomics, and microbiome studies allow nutraceutical interventions to be tailored to individual needs. For instance, polyphenols from certain fruits may have stronger effects in individuals with specific gut microbiome profiles. Biodiversity thus provides the raw material for precision nutraceuticals, while science provides the tools for personalization.

Future nutraceutical innovation will likely focus on:

- **Underutilized and neglected species** that are climate-resilient and nutrient-dense.
- **Marine biodiversity**, including algae, seaweeds, and fish oils, as sustainable sources of bioactives.
- **Synergistic formulations** combining multiple biodiversity-derived compounds for holistic benefits.
- **Sustainable cultivation and biotechnology** approaches such as plant tissue culture or synthetic biology to reduce pressure on wild populations.

7. Biodiversity as the Reservoir of Nutritional Wealth

Biodiversity ensures the availability of diverse food sources that have shaped dietary habits. Traditional diets across cultures reflect the interplay between biodiversity and nutrition:

millets in South Asia, quinoa in the Andes, moringa in Africa, and seaweed in East Asia are examples of region-specific biodiversity supporting nutritional well-being.

- **Plants** are rich in vitamins, minerals, phytochemicals, and dietary fibers. Their secondary metabolites — alkaloids, flavonoids, terpenoids, and phenolics — often provide bioactive health benefits beyond basic nutrition.
- **Animals**, including fish, poultry, and livestock, contribute proteins, omega-3 fatty acids, and micronutrients. Wild species, such as edible insects, offer additional sources of high-quality proteins and minerals.
- **Microorganisms** add diversity through probiotics, fermented foods, and bioactive metabolites that regulate gut health.

Thus, biodiversity underpins both food security and nutritional diversity, the two prerequisites for developing nutraceutical innovations.

Global Case Studies: Biodiversity-Derived Nutraceuticals

- **Quinoa (Chenopodium quinoa):** An Andean crop rich in proteins, essential amino acids, and minerals, quinoa is promoted as a functional food worldwide.
- **Omega-3 Fatty Acids from Fish and Algae:** Marine biodiversity has enabled the development of supplements for cardiovascular and neurological health.
- **Resveratrol from Grapes:** Derived from grape skins and red wine, resveratrol is associated with antioxidant and anti-aging benefits.
- **Spirulina (Arthrospira platensis):** This cyanobacterium provides proteins, vitamins, and antioxidants, and has been endorsed by NASA for astronaut diets.
- **Soy isoflavones**, once consumed traditionally through soybeans, are now available as supplements to support hormonal balance.
- **Green tea catechins**, part of traditional East Asian diets, have been transformed into extracts marketed for weight management and antioxidant activity.
- **Garlic (Allium sativum)**, a staple spice, is sold in capsule form for its cardiovascular benefits.

Each of these cases demonstrates how biodiversity can be sustainably tapped to address modern nutritional and health challenges

8. The Way Forward: Biodiversity; Integrating Conservation and Innovation

The future of nutraceuticals depends on striking a balance between conservation and innovation. Strategies that can facilitate this balance include:

- **Conservation Agriculture and Domestication:** Cultivating medicinal and nutraceutical plants to reduce pressure on wild populations.

- **Fair Benefit-Sharing Models:** Ensuring that local and indigenous communities benefit from the commercialization of biodiversity-derived nutraceuticals.
- **Green Technologies:** Employing eco-friendly extraction and processing technologies to minimize environmental impacts.
- **Global Collaborations:** Encouraging international partnerships to harmonize regulations, share knowledge, and promote sustainable nutraceutical markets. In addition, consumer awareness and demand for natural, sustainable, and plant-based products are driving industry trends. This creates a positive feedback loop where conservation of biodiversity is linked with economic incentives and global health promotion.

Examples of Biodiversity Contributions to Nutrition and Health

Biodiversity Source	**Nutritional/Bioactive Component**	**Health Benefit/ Function**	**Potential as Nutraceutical**
Moringa oleifera leaves	Vitamins A, C, E; Calcium; Polyphenols	Antioxidant, antiinflammatory, bone health	Powder, capsules, teas
Turmeric (*Curcuma longa*)	Curcumin	Anti-inflammatory, antidiabetic, cardioprotective	Capsules, extracts
Finger millet (*Eleusine coracana*)	Calcium, Fiber, Iron	Bone health, digestive health, anemia prevention	Flours, functional foods
Berries (Blueberry, Cranberry)	Anthocyanins, Polyphenols	Cardiovascular protection, antioxidant	Juices, powders, supplements
Green tea (*Camellia sinensis*)	Catechins, Polyphenols	Antioxidant, metabolic health	Extracts, beverages
Baobab fruit	Vitamin C, Fiber, Polyphenols	Immune support, digestive health	Powders, functional foods
Black rice	Anthocyanins, Protein, Fiber	Anti-inflammatory, antioxidant	Rice-based nutraceutical products
Small indigenous fish	Omega-3 fatty acids, Protein	Brain health, cardiovascular health	Fish powders, oil capsules

Functional Foods vs. Nutraceuticals

Feature	Functional Food	Nutraceutical
Definition	Foods consumed as part of a regular diet with added health benefits	Products derived from foods with concentrated bioactive compounds for therapeutic purposes
Consumption	Everyday diet	Supplements, capsules, extracts
Purpose	Preventive health benefits	Preventive and therapeutic effects
Examples	Berries, fortified cereals, dairy with probiotics	Curcumin capsules, omega-3 supplements, moringa powder

Conservation Strategies for Biodiversity in Food Systems

Strategy	Description	Example
In-situ conservation	Protecting species in natural habitats	Sacred groves, community-managed forests
Ex-situ conservation	Preserving genetic material outside natural habitat	Seed banks, botanical gardens
Community participation	Engaging local populations in conservation	Farmer-led preservation of traditional crops
Policy support	Legal frameworks and incentives for biodiversity protection	National Biodiversity Authority (India)
Research & Innovation	Developing functional foods and nutraceuticals	Extraction of bioactive compounds from millets, moringa, and baobab

Conclusion:

The journey from biodiversity to nutraceutical exemplifies the dynamic interplay between nature, culture, and science. Biodiversity offers the raw materials and genetic wealth, traditional knowledge provides the framework, and modern science refines these resources into standardized nutraceuticals. This progression not only underscores the vital role of biodiversity in ensuring food security and sustainable health solutions but also highlights the ethical responsibility to conserve ecosystems while harnessing their potential. By viewing biodiversity as both a heritage and a resource, humanity can ensure that nutraceutical innovation contributes not just to health and nutrition but also to ecological sustainability and cultural preservation.

References:

1. Ali, A., & Bhattacharjee, B. (2023). Nutrition security, constraints, and agro-diversification strategies of neglected and underutilized crops to fight global hidden hunger. *Frontiers in Nutrition, 10*, 1144439.
2. Hunter, D., Borelli, T., Beltrame, D. M. O., Oliveira, C. N. S., Coradin, L., Wasike, V. W., ... & Termote, C. (2022). The role of traditional knowledge and food biodiversity to transform modern food systems. *Trends in Food Science & Technology, 130*, 32–41.
3. Braga, T., Loret de Mola, C., Orellana, J. D. Y., & Cardoso, M. A. (2024). Does food biodiversity protect against malnutrition and favour the resilience to climate change-related events in Amazon Indigenous communities? A protocol for a mixed methods study. *BMJ Open, 14*(2), e075408.
4. Phalan, B., Balmford, A., Green, R. E., & Scharlemann, J. P. W. (2011). Minimising the harm to biodiversity of producing more food globally. *Food Policy, 36*(S1), S62–S71.
5. Scherr, S. J., & McNeely, J. A. (2008). Biodiversity conservation and agricultural sustainability: towards a new paradigm of 'ecoagriculture' landscapes. *Philosophical Transactions of the Royal Society B: Biological Sciences, 363*(1491), 477–494.
6. Adedokun, T. A., Orji, I. A., & Idowu, A. A. (2024). Agroforestry for food security and public health: A comprehensive review. *Heliyon, 10*(1), e11562.
7. Food and Agriculture Organization of the United Nations (FAO). (n.d.). Agricultural biodiversity to improve nutrition and food security. *FAO Newsroom*. Retrieved from https://www.fao.org/newsroom/detail/Agricultural-Biodiversity-to-Improve-Nutrition-Food-Security/en
8. Wezel, A., Blesh, J., Anderson, C. R., Pulleman, M., & Groot, J. C. J. (2023). Developing biodiversity-based solutions for sustainable food systems through transdisciplinary Sustainable Development Goals Labs (SDG-Labs). *Frontiers in Sustainable Food Systems, 7*, 1144506.
9. Bharucha, Z. P., Nair, R., & Nicholls, C. I. (2025). Integrated land systems for sustainable food production and biodiversity conservation in the semi-arid to moist tropics: Stakeholder perspectives from Andhra Pradesh, India. *Frontiers in Sustainable Food Systems, 9*, 1594356.

ENVIRONMENTAL MOVEMENTS: GLOBAL INITIATIVES AND COMMUNITY BASED EFFORTS IN INDIA

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Abstract:

This chapter covers the development and influence of environmental movements on both global and local scales. The analysis commences with an exploration of significant global environmental initiatives, including the Earth Summits, the Paris Agreement, and the involvement of international organisations in advancing sustainable development and environmental justice. These initiatives are framed within the escalating apprehensions regarding climate change, biodiversity decline, and ecological deterioration. The chapter subsequently transitions to India, emphasising the emergence of community-based movements as potent responses to local environmental challenges. Movements such as Chipko, Narmada Bachao Andolan, and Save Silent Valley exemplify grassroots resistance against environmental exploitation, highlighting the significance of indigenous knowledge, women's leadership, and civil society activism. The chapter highlights the dynamic interplay among policy frameworks, environmental ethics, and grassroots involvement. It concludes by underscoring the necessity of aligning global commitments with local actions to guarantee inclusive and effective environmental governance. This chapter elucidates the interconnections between global environmental objectives and community resilience, offering a thorough perspective on the multi-scalar dynamics of environmental activism and its importance in fostering a sustainable future.

Keywords: Environment, Conservation, Global Initiatives, Movements, India.

Introduction:

Environmental movements are social and political initiatives aimed at safeguarding the natural environment and advancing sustainability. These movements encompass a diverse array of issues, strategies, and ideologies, and have undergone substantial evolution over time. The origins of environmentalism are linked to conservation initiatives in the 19th century. Individuals such as John Muir and Henry David Thoreau championed the conservation of nature and motivated the establishment of national parks. The contemporary environmental movement accelerated in the 1960s and 1970s, propelled by increasing awareness of pollution and ecological deterioration. Rachel Carson's "Silent Spring" (1962) illuminated the perils of pesticides and is frequently acknowledged as a catalyst for the contemporary environmental movement. The inaugural Earth Day in 1970 represented a pivotal event, galvanising millions and resulting in the formation of the Environmental Protection Agency (EPA) and the enactment of significant environmental legislation in the United States, including the Clean Air Act, Clean Water Act, and Endangered Species Act. Initial conservation initiatives in India originated during the colonial era, specifically in the 19th and early 20th centuries. During this period, the British colonial administration acknowledged the necessity of managing and conserving India's extensive natural resources. The formation of forest departments and the implementation of forest conservation policies were pivotal measures. Prominent individuals like Dietrich Brandis, the inaugural Inspector General of Forests in India, significantly contributed to the advancement of scientific forestry methods and the creation of reserved forests. These initial endeavours established the foundation for subsequent conservation initiatives, harmonising resource utilisation with the safeguarding of biodiversity and ecosystems.

The environmental movement is a dynamic and complex initiative aimed at safeguarding the planet and advancing sustainability. It has achieved considerable advancement over the past century, yet it still encounters various challenges as it adapts to confront new and emerging environmental concerns. Local grassroots movements in the environmental sector are essential for tackling ecological challenges via community-driven initiatives and localised actions. These movements frequently arise from the pressing necessity to address environmental degradation that directly impacts the daily lives of community members, including pollution, deforestation, water scarcity, and biodiversity loss. Motivated by a sense of duty and stewardship, local activists and community leaders coordinate initiatives such as reforestation projects, clean-up campaigns, conservation of local water resources, and the advocacy of sustainable agricultural practices. These initiatives utilise traditional knowledge and practices, guaranteeing that solutions are culturally pertinent and sustainable. Grassroots environmental movements are essential for raising awareness, educating the public, and advocating for local policy changes. By means of collective action and community involvement, they cultivate a sense of ownership and responsibility, thereby enhancing broader environmental conservation and resilience.

Key Characteristics:

A. Community-Led Initiatives: Local inhabitants spearhead the identification of environmental challenges, as well as the planning and execution of solutions. Leadership frequently emerges from esteemed figures within the community, including elders, educators, or local advocates.

B. Focus on Indigenous Knowledge: Grassroots movements employ ancestral knowledge and practices refined over generations. This guarantees that conservation techniques are culturally suitable and efficient for the local ecosystem.

C. Collaborative Initiatives: These movements frequently entail cooperation among diverse stakeholders, including municipal authorities, non-governmental organisations (NGOs), educational institutions, and enterprises. Community meetings, workshops, and participatory planning sessions are prevalent to guarantee extensive support and engagement.

Common Activities:

1. Reforestation and Afforestation: The act of planting trees and rehabilitating degraded forests to enhance biodiversity, soil quality, and water retention.
2. Water Conservation: Establishing and sustaining rainwater harvesting systems, check dams, and communal ponds. Instructing communities on sustainable water utilisation and mitigating pollution of local water bodies.
3. Waste Management: Coordinating periodic clean-up initiatives to mitigate litter and decrease pollution.
4. Sustainable Agriculture: Promoting organic farming methods to diminish chemical application and improve soil vitality.
5. Environmental Education and Awareness: Implementing educational initiatives in schools and community centres to enhance awareness of environmental issues. Utilising local media, social media, and public events to disseminate information and galvanise support.

Examples of Successful Movements:

a. **The Chipko Movement (India):** A 1970s forest conservation initiative wherein villagers, especially women, embraced trees to avert deforestation. Led to heightened awareness and modifications in forest policies. The Chipko Movement, spearheaded by Amrita Devi in 1730, was a pioneering environmental initiative in India. Amrita Devi, together with more than 300 members of the Bishnoi community in Rajasthan, forfeited their lives to safeguard trees from the king's agents. The villagers embraced the trees (thus the term "Chipko," meaning "to embrace" in Hindi), resisting their destruction. This peaceful demonstration underscored the significance of environmental preservation and influenced subsequent initiatives such as the 20th-century Chipko Movement in Uttarakhand.

b. **Friends of the River Narmada (India):** A movement promoting the preservation of the Narmada River and the rights of communities impacted by dam initiatives. Emphasised the social and environmental repercussions of extensive infrastructure initiatives. The Narmada Bachao Andolan (NBA) is a social movement in India that commenced in the 1980s, seeking to prevent the construction of large dams on the Narmada River. The movement, spearheaded by activists such as Medha Patkar, concentrated on the displacement of thousands, environmental degradation, and the loss of livelihoods resulting from the dams, particularly the Sardar Sarovar Dam. The NBA aimed to safeguard the rights of impacted communities, promoting adequate rehabilitation and environmental justice. The movement garnered national and international recognition, emerging as a symbol of opposition to extensive developmental initiatives that disregard human and environmental consequences.

c. **Wangari Maathai's Green Belt Movement (Kenya)**: The Green Belt Movement in Kenya, established by Nobel laureate Wangari Maathai, emphasises tree planting, environmental conservation, and the empowerment of women. Effectively established millions of trees and advocated for sustainable development. Local grassroots movements are essential for environmental conservation as they promote sustainable practices, strengthen community resilience, and advocate for comprehensive systemic change. Their success frequently stems from their profound connection to the community and environment they seek to safeguard.

International Efforts:

● **United Nations Conference on Environment, 1972 - 'Limits To Growth':**

The United Nations Conference on the Human Environment, convened in Stockholm in 1972, represented a pivotal moment in international environmental governance. The inaugural significant international assembly focused on tackling global environmental concerns resulted in the establishment of the United Nations Environment Programme (UNEP). An important and impactful document addressed during this conference was the report "The Limits to Growth," released by the Club of Rome in that year.

1. **Essential Elements:** The conference convened representatives from 113 nations, alongside various international organisations and non-governmental organisations (NGOs). It underscored the interdependence between humanity and the environment, stressing the necessity for a unified global response to environmental issues. The conference resulted in the Stockholm Declaration, which delineated 26 principles regarding the environment and development. It acknowledged the right to a healthy environment and the obligation of nations to safeguard and enhance the environment for

current and future generations. The conference established an action plan comprising 109 recommendations for environmental policy and initiatives. It encompassed diverse domains, including human habitation, natural resource stewardship, pollution control, and environmental education. The establishment of the United Nations Environment Programme (UNEP), based in Nairobi, Kenya, was one of the most significant outcomes. The UNEP was assigned the responsibility of coordinating international environmental initiatives and aiding nations in the execution of sustainable policies and practices.

2. **Background and Findings of the 'LIMITS TO GROWTH' Report:** The "Limits to Growth" report was commissioned by the Club of Rome and executed by a team of researchers at the Massachusetts Institute of Technology (MIT). The report employed computer modelling to replicate the interactions among population growth, industrialisation, pollution, food production, and resource depletion.
3. **Critical Forecasts:** The report cautioned that if prevailing trends in population expansion and resource utilisation persist, the planet will attain its growth thresholds within the forthcoming century. It forecasted that, absent substantial alterations, economic and ecological collapse would ensue due to resource depletion and environmental degradation.
4. **The report concentrated on five principal variables:** population growth, agricultural production, natural resource consumption, industrial output, and pollution. It underscored that exponential expansion in these domains was untenable within the Earth's finite resource constraints.
5. **Scenarios and Recommendations:** A range of scenarios was delineated, from business-as-usual to substantial policy modifications intended to facilitate sustainable development. The report advocated for the stabilisation of population and industrial growth, enhancement of efficiency, and a transition to renewable resources to attain a sustainable future.
6. **Impact and Legacy:** "Limits to Growth" profoundly impacted environmental policy and discourse by highlighting the finite nature of Earth's resources and the necessity for sustainable development. It ignited discussions and prompted additional investigation into sustainability, ecological economics, and the Earth's carrying capacity. The report encountered criticism regarding its methodology, assumptions, and perceived negativity. Critics contended that technological advancements and market adaptations could alleviate the anticipated consequences. Notwithstanding the controversy, the report persists as a seminal document in environmental science and policy, underscoring the necessity of confronting the constraints of growth.

Subsequent revisions of the original report, including "Beyond the Limits" (1992) and "Limits to Growth: The 30-Year Update" (2004), underscore the imperative of confronting unsustainable practices. The fundamental principle of reconciling growth with ecological constraints remains pertinent in current dialogues regarding climate change, resource management, and sustainable development. The 1972 United Nations Conference on the Human Environment and the "Limits to Growth" report were instrumental in influencing global environmental consciousness and policy. They emphasised the critical necessity for sustainable development and have established a significant legacy in environmental conservation and management.

● **The Brundtland Commission, 1987 - 'Our Common Future':**

The Brundtland Commission officially referred to as the World Commission on Environment and Development (WCED), was a United Nations initiative founded in 1983. The commission was named in honour of its chair, Dr. Gro Harlem Brundtland, who served as the Prime Minister of Norway at that time. In 1987, the commission released its seminal report entitled "Our Common Future," frequently known as the Brundtland Report.

Significant for multiple reasons:

a. **Sustainable Development:** The report elucidated the concept of "sustainable development," characterising it as "development that fulfils the requirements of the present without jeopardising the capacity of future generations to satisfy their own needs."
b. **Global Perspective:** It underscored the interrelation of global environmental, economic, and social challenges.
c. **Environmental Issues:** The report emphasised significant environmental issues including deforestation, climate change, and biodiversity loss.
d. **Poverty and Development:** It emphasised the connection between poverty reduction and environmental conservation.

   The report advocated for enhanced international collaboration to tackle global challenges.
e. **Long-term Vision:** It promoted enduring strategies for attaining sustainable development, as opposed to temporary solutions.

The Brundtland Report significantly shaped global discussions on sustainable development and impacted subsequent international agreements and policies. It established the foundation for the 1992 United Nations Conference on Environment and Development (Earth Summit) in Rio de Janeiro and continues to affect environmental and development policies today.

● **Our Common Future (A Report):**

"Our Common Future" is the title of the report released by the Brundtland Commission in 1987. This report is a foundational document in sustainable development.

Important Points in a Report:

1. **Principal Themes:** Sustainable development, Global environmental issues, Poverty and inequality, Economic growth and its ecological consequences, Population and human resources, Food security, Energy, Industry, Urban challenges.
2. **Definition of Sustainable Development:** The report presented the most universally accepted definition of sustainable development: "development that satisfies the requirements of the present without jeopardising the capacity of future generations to fulfil their own needs."
3. **Interconnectedness:** It highlighted the interrelated nature of environmental, social, and economic issues. The report advocated for a new epoch of economic growth that is both socially and environmentally sustainable.
4. **Global Cooperation:** It emphasised the necessity of international collaboration to address global challenges.
5. **Long-term Perspective:** The report emphasised the importance of incorporating long-term environmental consequences into decision-making processes.
6. **Impact:** "Our Common Future" has exerted a profound and enduring effect on global environmental and development policies, shaping subsequent UN conferences and international accords.

Significance of "Our Common Future":

"Our Common Future" was a seminal report that elevated the notion of sustainable development within global discourse. It underscored the essential interrelation among environmental preservation, social equity, and economic advancement, positing that these components must be harmonised for genuine progress. The report's articulation of sustainable development became foundational for subsequent environmental and developmental policies worldwide. By advocating for long-term perspectives and international collaboration, it laid the groundwork for significant global environmental agreements and shaped the methodologies of governments, organisations, and enterprises in their developmental approaches. The report's comprehensive perspective on global challenges and its appeal for the incorporation of environmental considerations into economic decision-making processes represented a pivotal transformation in the global approach to development and environmental stewardship.

● **United Nations Conference on Environment and Development, Rio De Janeiro, Brazil, 3-14 June 1992**

The United Nations Conference on Environment and Development (UNCED), commonly referred to as the Earth Summit, occurred in Rio de Janeiro, Brazil, from June 3 to 14, 1992. This pivotal event convened representatives from 172 nations, including 108 heads of state, alongside various non-governmental organisations (NGOs) and other stakeholders. The Earth Summit was among the most extensive environmental conferences ever conducted and represented a crucial milestone in the global initiative to advance sustainable development.

The United Nations Conference on Environment and Development (UNCED), commonly referred to as the Earth Summit, took place in Rio de Janeiro in 1992 and was presided over by Maurice Strong. Strong, a Canadian businessman and notable environmentalist, was instrumental in the conference's organisation. He had previously held the position of Secretary-General at the United Nations Conference on the Human Environment in Stockholm in 1972, bringing significant expertise in international environmental diplomacy to the Earth Summit.

The Earth Summit yielded numerous significant documents and agreements, including:

1. The Rio Declaration on Environment and Development comprises 27 principles designed to direct future sustainable development globally, highlighting the necessity for equilibrium among economic advancement, environmental conservation, and social equity.
2. **Agenda 21:** An extensive action plan for global, national, and local levels aimed at advancing sustainable development in the 21st century. It addresses various issues, including poverty, health, education, biodiversity, and sustainable agriculture.
3. **Forest Principles:** A non-legally binding declaration outlining principles for the sustainable management of global forests.
4. The United Nations Framework Convention on Climate Change (UNFCCC) is an international treaty designed to stabilise atmospheric greenhouse gas concentrations to avert hazardous human-induced climate disruption. The UNFCCC established the groundwork for later climate accords, such as the Kyoto Protocol and the Paris Agreement.
5. The Convention on Biological Diversity (CBD) is an international treaty with three primary objectives: the conservation of biological diversity, the sustainable utilisation of its components, and the equitable sharing of benefits derived from genetic resources.

The Earth Summit was pivotal in enhancing global awareness regarding the interrelation of environmental, economic, and social issues, emphasising the necessity for cohesive solutions to attain sustainable development. It also reinforced the importance of international collaboration in tackling global environmental challenges.

Environmental Movements in India:

● **Bishnoi Movements:** The Bishnoi Movement comprises environmental and social initiatives spearheaded by the Bishnoi community in India, recognised for their unwavering dedication to environmental conservation and wildlife protection. Founded in the 15th century by Guru Jambheshwar, or Jambhoji, in the Marwar region of Rajasthan, the community adheres to 29 principles emphasising the safeguarding of nature and wildlife, while advocating for a compassionate and ethical lifestyle.

Strategic features and occurrences of the Bishnoi Movement encompass:

Foundational Principles: Guru Jambheshwar's 29 principles encompass mandates for the preservation of trees and wildlife, the maintenance of hygiene, and the adherence to non-violence. The Bishnoi community is distinguished by its profound reverence for all life forms. The Khejarli Massacre (1730) represents a pivotal occurrence in the Bishnoi Movement. Amrita Devi, a Bishnoi woman, along with more than 350 Bishnois, sacrificed their lives to safeguard Khejri trees (*Prosopis cineraria*) from the soldiers of the Maharaja of Jodhpur. This event is commemorated as an emblem of environmental activism and the Bishnoi community's commitment to conservation.

The Story of the Khejarli Massacre (1730):

In 1730, a significant event occurred in the village of Khejarli, located in the Indian state of Rajasthan, which has motivated environmentalists for centuries. The Bishnoi community, residing in this village, adhered to 29 principles established by their founder, Guru Jambheshwar. Among these principles was the imperative to safeguard trees and wildlife. The Bishnois held the belief that all living beings deserved kindness and respect. One day, the monarch of Jodhpur dispatched his soldiers to fell Khejri trees in Khejarli village. The timber from these trees was required for the construction of a new palace. The Bishnoi villagers were profoundly distressed as they regarded the trees as sacred and vital for their ecosystem. Amrita Devi, a courageous Bishnoi woman, resolved to take a stand. She embraced a tree and informed the soldiers that they would have to kill her before felling it. Despite her entreaty, the soldiers disregarded her and proceeded to cut down the tree, resulting in Amrita Devi's death. Motivated by her valour, her three daughters and numerous other villagers emulated her actions. Ultimately, 363 Bishnois forfeited their lives to safeguard the trees. The report of this collective sacrifice reached the king. Profoundly affected and embarrassed by the villagers' commitment and courage, he commanded his soldiers to cease the deforestation and enacted a decree to protect the Khejri trees and the Bishnoi way of life. The Khejarli Massacre emerged as a potent emblem of environmental preservation and the Bishnoi community's dedication to safeguarding nature. Presently, the Bishnois are recognised for their initiatives to protect flora and fauna, and the narrative of Khejarli continues to motivate individuals globally to advocate for environmental causes. The Bishnois are renowned for their commitment to wildlife conservation, particularly concerning the blackbuck and the chinkara. They frequently supply sustenance and hydration for these animals and safeguard them against poaching activities. The Bishnoi community remains actively engaged in environmental protection and wildlife conservation, recognised for their initiatives against desertification, preservation of biodiversity, and promotion of environmental awareness. The Bishnoi Movement exemplifies early grassroots environmentalism, showcasing the efficacy of community-driven conservation initiatives. The principles and actions of the Bishnoi community have influenced numerous environmental movements and remain a paradigm for sustainable living and environmental stewardship.

● **The Chipko Movements:**

The Chipko Movement, a pivotal environmental initiative in India, was distinguished by its non-violent methodology for forest preservation. Below is a comprehensive examination of its history, salient events, and influence:

Origins and Causation: The Chipko Movement commenced in the early 1970s in the Garhwal Himalayas of Uttarakhand, formerly part of Uttar Pradesh. The catalyst was the government's decision to assign forest land to private contractors for commercial logging. This deforestation jeopardised the ecological equilibrium, resulting in soil erosion, diminished agricultural productivity, and reduced water availability, which directly impacted the livelihoods of local communities reliant on forests for sustenance, fuel, fodder, and other resources.

Principal Metrics:

Chandi Prasad Bhatt: A Gandhian social activist and a principal architect of the Chipko Movement.

Gaura Devi: A local villager who spearheaded the inaugural Chipko protest in Reni village, emerging as an emblematic figure in the movement.

Sunderlal Bahuguna: An environmentalist who significantly contributed to disseminating the movement's ideology and attracting national and international recognition.

Notable Occurrences:

The 1973 Reni Village Protest: The most notable event transpired in 1973 in Reni village, where the government authorised the logging of ash trees in the adjacent forest. Upon the arrival of the loggers, Gaura Devi and other women from the village confronted them. The women embraced the trees, creating a human barricade and steadfastly refusing to budge despite intimidation. Their resolve compelled the loggers to withdraw, signifying a pivotal triumph for the movement.

Sunderlal Bahuguna, a distinguished environmentalist, significantly contributed to the Chipko Movement, which commenced in the 1970s in the Garhwal Himalayas of Uttarakhand. Profoundly influenced by Gandhian ideals, Bahuguna championed forest conservation through non-violent resistance. He is renowned for disseminating the Chipko Movement's ethos by mobilising local communities, especially women, to safeguard trees from commercial logging. His endeavours garnered substantial national and international recognition regarding the ecological significance of forests and precipitated policy reforms, including a 15-year moratorium on green felling in the Himalayan forests. Bahuguna's initiatives highlighted the essential connection between environmental preservation and the welfare of rural populations.

Dasholi Gramme Swarajya Sangh (DGSS): Chandi Prasad Bhatt, a Gandhian social activist, was a principal architect of the Chipko Movement, which commenced in the 1970s in the Garhwal Himalayas of Uttarakhand. In 1964, Bhatt established the Dasholi Gramme Swarajya Sangh (DGSS), a cooperative organisation dedicated to fostering local employment and sustainable resource utilisation. Under his guidance, the Chipko Movement gained traction as villagers, particularly women, were galvanised to safeguard their forests through non-violent resistance, notably by embracing trees to avert deforestation. Bhatt's initiatives were pivotal in enhancing awareness regarding the ecological and economic significance of forests, culminating in substantial policy reforms, including prohibitions on commercial logging in the area. His endeavours underscored the efficacy of community-driven environmental conservation and sustainable development. Subsequent to the triumph in Reni, analogous protests proliferated throughout the region:

Tehri-Garhwal: Protests in the area resulted in a decade-long prohibition on commercial logging in the Himalayan forests.

The Kumaon Region witnessed the proliferation of the movement throughout Uttarakhand, as villagers embraced the Chipko technique to safeguard their indigenous forests.

The Chipko Movement's philosophy was fundamentally based on Gandhian principles of non-violence (ahimsa) and peaceful resistance (satyagraha). The term "chipko," meaning "to hug" or "to cling," represents the villagers' physical embrace of trees to safeguard them from destruction. Additionally, the movement highlighted the ecological significance of forests and the necessity for sustainable management practices.

Impact and Actions:

The movement impacted the Indian government's forest policy, resulting in heightened restrictions on commercial logging and the advancement of social forestry initiatives.

Environmental Awareness: Chipko heightened consciousness regarding the ecological significance of forests and the necessity to safeguard natural resources, thereby inspiring subsequent environmental movements in India and worldwide.

The active involvement and leadership of women in the Chipko Movement underscored their vital contribution to environmental preservation and community governance.

Legal Reforms: In 1980, Prime Minister Indira Gandhi instituted a 15-year moratorium on green felling in the Himalayan forests, primarily as a result of the advocacy and impact of the Chipko Movement.

● **Appiko Movements:**

The Appiko Movement is an environmental initiative in India, influenced by the Chipko Movement. It commenced in the Western Ghats of Karnataka during the early 1980s, particularly in the Uttara Kannada district. "Appiko" translates to "to embrace" in Kannada, akin to "Chipko" in Hindi. The movement originated from extensive commercial logging and deforestation in the Western Ghats, resulting in significant environmental degradation. The destruction of forests caused soil erosion, loss of biodiversity, diminished water resources, and adversely affected the livelihoods of local communities reliant on the forests for sustenance.

Key Figures:

Panduranga Hegde: A distinguished environmentalist, Hegde served as the leader and principal organiser of the Appiko Movement. Motivated by the Chipko Movement and the initiatives of Sunderlal Bahuguna, Hegde galvanised local villagers to safeguard their forests.

Notable Events: The Appiko Movement commenced in September 1983 in the village of Salkani, situated in the Sirsi district. Villagers, especially women and children, engaged in tree-hugging to thwart commercial logging. The movement employed a tripartite strategy:

Protection: Villagers physically encircled trees to impede logging operations, employing non-violent resistance to safeguard their forests.

Regeneration: Initiatives were undertaken to reforest degraded lands and encourage afforestation, which included the planting of indigenous tree species to restore ecological equilibrium.

Utilisation: The movement championed the sustainable exploitation of forest resources, endorsing practices that would advantage local communities while minimising environmental damage.

Impact and Actions:

1. The Appiko Movement heightened awareness regarding the significance of forest conservation and the detrimental effects of deforestation.

2. The movement's initiatives resulted in the government enacting more stringent regulations on commercial logging and advocating for sustainable forest management practices.
3. Community Empowerment: Local communities, particularly women, were enabled to actively engage in environmental protection and advocate for their rights.
4. The Appiko Movement is recognised as a pivotal environmental initiative that underscored the efficacy of grassroots activism. It illustrated the critical role of local community engagement in conservation efforts and advanced environmental awareness and policies in India. The movement's achievements in the Western Ghats inspired similar environmental initiatives nationwide.

● **Silent Valley Initiatives:**

The Silent Valley Movement was a social initiative in Kerala, India, opposing the establishment of a hydroelectric power project in the Silent Valley, an evergreen tropical forest. The movement successfully halted the project's construction, leading to the declaration of the Silent Valley as a national park in 1985.

The Kerala State Electricity Board proposed the Silent Valley Hydroelectric Project in the 1970s, which entailed constructing a dam across the Kunthipuzha River. This initiative aimed to generate electricity but would inundate a substantial area of the Silent Valley rainforest, a habitat for distinctive biodiversity, including the endangered Lion-tailed Macaque.

Members of the Silent Valley Movement:

1. **Kerala Sastra Sahitya Parishad (KSSP):** A scientific and social welfare organisation that played a pivotal role in raising awareness of the issue and mobilising support for the movement.
2. **Silent Valley Samrakshana Samithi (SVSS):** A local organisation established to contest the project's construction.
3. **The Kerala Forest Research Institute (KFRI)** is a government research entity that conducted studies on the Silent Valley, concluding that the project would severely impact the forest.
4. **World Wildlife Fund (WWF):** An international conservation organisation that endorsed the movement and offered financial assistance.
5. **Salim Ali:** A distinguished ornithologist who openly opposed the project.
6. **Madhav Gadgil:** A scientist and ecologist instrumental in the movement.
7. **Sugathakumari:** A poet and environmental advocate, she authored the poem "Marathinu Stuthi" ("Ode to a Tree"), which became a rallying cry for the movement.

Notable Occurrences

a. **Public Awareness Campaigns:** Environmentalists and scientists, notably Salim Ali, emphasised the distinctive biodiversity of Silent Valley. KSSP executed extensive public awareness initiatives to inform the populace about the possible environmental repercussions of the dam.
b. **Government Intervention:** Increasing public pressure prompted the Indian government to establish a high-level committee to assess the project. In 1980, Prime Minister Indira Gandhi declared that the project would undergo re-evaluation in light of environmental concerns.

The Supreme Court of India intervened in response to a Public Interest Litigation (PIL) submitted by environmental activists, thereby suspending the dam's construction.

Impact and Actions:

1. **Project Termination:** In 1983, the Indian government formally discontinued the Silent Valley Hydroelectric Project, signifying a notable triumph for environmental advocates.
2. **Establishment of Silent Valley National Park:** In 1984, Silent Valley was designated as a national park, safeguarding its distinctive ecosystem. The park was formally inaugurated in 1985 by Prime Minister Rajiv Gandhi.

The movement facilitated the preservation of the diverse biodiversity in Silent Valley, encompassing various plant and animal species endemic to the area.

● Narmada Bachao Andolan:

The Narmada Bachao Andolan (NBA), translating to "Save Narmada Movement," is a social initiative led by activists and local communities in India, seeking to prevent the construction of large dams on the Narmada River, notably the Sardar Sarovar Dam. Initiated in the 1980s, the movement emphasises the protection of the rights of individuals impacted by the dam projects, underscores environmental issues, and promotes sustainable development.

Important Figures:

1. **Medha Patkar:** A distinguished social activist and the foremost leader of the NBA, Medha Patkar has played a pivotal role in orchestrating protests, enhancing awareness, and championing the rights of displaced communities.
2. **Baba Amte:** A distinguished social activist, Baba Amte advocated for the Narmada Bachao Andolan and highlighted the struggles of individuals impacted by dam projects.

Aim of the movement:

1. **Rehabilitation and Resettlement:** Guaranteeing equitable and sufficient rehabilitation for the multitude of individuals displaced by the dam construction.

2. **Environmental Protection:** Expressing apprehensions regarding the ecological ramifications of large dams, encompassing deforestation, biodiversity depletion, and alterations in the river ecosystem.
3. **Sustainable Development:** Advocating for alternatives to large dams, including small-scale, sustainable water management techniques.

Principal Occurrences: The NBA has orchestrated various protests, marches, and hunger strikes to highlight the challenges encountered by displaced communities and the environmental repercussions of the dams. The movement has pursued legal action, including cases before the Supreme Court of India, to obtain redress for displaced and affected populations. The NBA has secured global support and highlighted the ramifications of large dam projects. The NBA has effectively heightened awareness regarding the social and environmental repercussions of large dam projects, thereby shaping public opinion and policy discourse. The movement has resulted in increased examination of rehabilitation and resettlement policies for displaced communities, despite ongoing challenges. The NBA has engaged in the global dialogue on sustainable development, emphasising the necessity of reconciling development initiatives with ecological and social factors.

Challenges and Criticism: Despite its accomplishments, the NBA has encountered difficulties, including inadequate success in halting dam construction and ensuring thorough rehabilitation for all impacted families. The movement has also received criticism from certain factions for purportedly obstructing development projects that advocates contend are vital for regional advancement and water management. The Narmada Bachao Andolan exemplifies grassroots environmental and social activism in India. Its initiatives underscore the necessity for inclusive and sustainable development practices, continuing to inspire global movements for environmental justice.

● **Beej Bachao Andolan:**

Beej Bachao Andolan (Save the Seeds Movement) is an environmental and agricultural initiative started in the 1980s in the Himalayan region of India. Spearheaded by environmental activist Vijay Jardhari, this grassroots movement aims to preserve indigenous seed varieties and promote traditional agricultural practices. The movement emerged as a response to the widespread adoption of high-yielding variety (HYV) seeds and chemical fertilizers, which were part of the Green Revolution but led to the decline of local seed diversity and environmental degradation. Beej Bachao Andolan advocates for sustainable farming methods, seed sovereignty, and the conservation of biodiversity, emphasizing the importance of self-reliance and ecological balance in farming communities. Through seed exchanges, educational programs, and community involvement, the movement has successfully revived numerous traditional seed varieties and raised awareness about the critical role of seed preservation in sustainable agriculture. The Beej Bachao Andolan (Save the Seeds Movement) is a grassroots initiative aimed at conserving traditional seed varieties and advocating for sustainable agricultural practices. The movement's principal elements encompass:

Seed Preservation: The essence of the initiative lies in the conservation of indigenous seeds, which exhibit superior adaptation to local climates and conditions compared to hybrid or genetically modified varieties. By preserving and disseminating these seeds, farmers promote biodiversity and enhance the resilience of their crops. The initiative advocates for the adoption of environmentally sustainable traditional farming techniques. These methods typically encompass organic agriculture, crop rotation, and the application of natural fertilisers and pesticides.

Seed Banks and Seed Exchanges: Beej Bachao Andolan has created seed banks for farmers to preserve and access a diverse array of traditional seeds. Additionally, seed exchanges are facilitated, enabling farmers to trade seeds and enhance crop diversity. The initiative collaborates with local communities to promote awareness regarding the significance of seed diversity and sustainable agriculture. It conducts workshops, training sessions, and educational programs to instruct farmers on seed preservation methods and organic farming practices. Beej Bachao Andolan champions policies that endorse sustainable agriculture and uphold farmers' rights to save, utilise, exchange, and sell their seeds. This encompasses opposition to laws and practices that encourage the use of patented seeds and chemical inputs. The Beej Bachao Andolan seeks to empower farmers, safeguard biodiversity, and foster a sustainable and self-sufficient agricultural framework.

- **Tehri Dam Disputes:**

The Tehri Dam Conflict pertains to the construction and operation of the Tehri Dam, a substantial multi-purpose rock and earth-fill embankment dam situated on the Bhagirathi River in Uttarakhand, India. The conflict encompasses multiple dimensions, including environmental, social, and cultural issues. The displacement of individuals is a critical issue, with the construction of the dam resulting in the submergence of towns, villages, and agricultural lands, displacing around 100,000 people. The impacted communities encountered insufficient compensation and rehabilitation, prompting extensive protests and legal disputes.

Environmental Impact: Environmentalists have expressed apprehensions regarding the ecological repercussions of the dam. The inundation of extensive forested regions and the modification of river ecosystems have jeopardised local biodiversity. Additionally, the dam has disrupted the natural flow of the Bhagirathi River, affecting downstream water availability and aquatic ecosystems.

Seismic Concerns: The Tehri Dam is situated in a seismically active area, heightening apprehensions regarding the potential hazards of catastrophic failure resulting from an earthquake. Detractors contend that a significant seismic event could undermine the dam's structural integrity, resulting in catastrophic repercussions for downstream communities.

Cultural and Religious Issues: The inundation of ancient temples, cultural sites, and heritage areas has generated controversy. Numerous local communities regard the Bhagirathi River as sacred, and the dam's effects on these cultural and religious sites have intensified dissent.

Economic and Developmental Discourse: Advocates of the dam assert that it offers substantial advantages, such as hydroelectric power generation, irrigation, and potable water supply. They maintain that the dam fosters regional development and economic advancement. Conversely, detractors argue that the social and environmental repercussions surpass the benefits and that alternative, less detrimental development strategies should be considered.

The Tehri Dam Conflict exemplifies the overarching tensions between development and environmental sustainability, the rights of local communities, and the difficulties of reconciling economic growth with ecological and social justice. Despite the dam's completion and operation, these conflicts persist in dialogues concerning large-scale infrastructure projects in India. The opposition to the Tehri Dam has been spearheaded by various distinguished activists and organisations throughout the years. Prominent among them are:

Sunderlal Bahuguna: A distinguished environmentalist and pivotal figure in the anti-Tehri Dam movement. Bahuguna is also recognised for his involvement in the Chipko Movement, which emphasised forest conservation. He fervently opposed the dam's construction due to its environmental and social repercussions, including the displacement of local communities and potential seismic hazards. He undertook several hunger strikes to highlight the issue.

Vimal Bhai: An activist affiliated with Matu Jansangthan, an organisation dedicated to opposing the dam and championing the rights of displaced individuals. Vimal Bhai has played a pivotal role in orchestrating protests, enhancing awareness, and initiating legal actions against the project.

Chandi Prasad Bhatt: A pivotal figure in India's environmental movement and a distinguished leader of the Chipko Movement. While primarily dedicated to forest conservation, Bhatt also opposed the Tehri Dam due to its detrimental environmental effects.

Non-Governmental Organisations and Local Entities: Numerous non-governmental organisations and local community groups have participated in the opposition. These entities have engaged in grassroots advocacy, legal challenges, and the mobilisation of public sentiment against the dam. The collaborative endeavours of these leaders and organisations have garnered considerable attention to the social and environmental concerns linked to the Tehri Dam, yet they were ultimately unsuccessful in preventing its construction and operation.

Conclusion:

Environmental movements, both internationally and within India, demonstrate an increasing awareness of the imperative to safeguard our planet. International initiatives such as the Paris Agreement and the UN's Sustainable Development Goals establish a framework for significant transformation, while grassroots movements in India—including the Chipko Movement, Narmada Bachao Andolan and other protests underscore the efficacy of local action and indigenous wisdom. These movements illustrate that successful environmental protection necessitates a cooperative strategy, integrating global policy frameworks with robust community engagement and ongoing public awareness.

References:

1. Bindra, P. S. (2017). *The vanishing: India's wildlife crisis*. Penguin Random House India.
2. Centre for Science and Environment. (2021). *Climate change: Science and politics*. Centre for Science and Environment.
3. Edwards, A. R. (2005). *The sustainability revolution: Portrait of a paradigm shift*. New Society Publishers.
4. Flanders, L. (1997). The United Nations Department for Policy Co-ordination and Sustainable Development (DPCSD). *Global Environmental Change, 7*(4), 391–394.
5. McNeill, J. R. (2000). *Something new under the sun: An environmental history of the twentieth century*. W. W. Norton & Company.
6. Nagendra, H., & Mundoli, S. (2009). *Cities and canopies: Trees in Indian cities*. Penguin Random House India.

NICKEL AND CHROMIUM POISONING: TOXICODYNAMICS, CARCINOGENICITY, AND PUBLIC HEALTH IMPLICATIONS

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Abstract:

Nickel (Ni) and chromium (Cr) are widely distributed transition metals that play paradoxical roles in human health, functioning as trace elements in certain biochemical pathways while exerting significant toxic and carcinogenic effects when exposure exceeds physiological thresholds (Costa & Klein, 2006; Sunderman, 2001). Chronic occupational and environmental exposure to nickel and chromium compounds has been associated with systemic toxicity, genotoxicity, and organ-specific pathologies, making them a focus of toxicological and public health research. Nickel toxicity primarily arises from soluble salts and insoluble particulate forms, inducing oxidative stress, mitochondrial dysfunction, and immunomodulatory disturbances (Salnikow & Zhitkovich, 2008). Chromium, particularly hexavalent chromium [Cr(VI)], penetrates cellular membranes and undergoes intracellular reduction, generating reactive intermediates that directly damage DNA and proteins (Nickens, Patierno, & Ceryak, 2010).

Both metals have been recognized as Group 1 human carcinogens by the International Agency for Research on Cancer (IARC, 2012), with epidemiological evidence linking exposure to lung, nasal, and skin cancers among occupationally exposed populations. Toxicodynamics of nickel and chromium highlight their ability to induce oxidative DNA lesions, epigenetic modifications, and disruptions in DNA repair mechanisms, which collectively enhance their carcinogenic potential (Borthwick & Mundt, 2003; Wise, Wise, & Little, 2002). Beyond carcinogenesis, exposure to these metals has been implicated in pulmonary fibrosis, allergic dermatitis, renal dysfunction, and adverse reproductive outcomes (Cohen *et al.,* 1993; Costa & Klein, 2006).

The public health implications of nickel and chromium poisoning extend beyond occupational settings, encompassing environmental contamination from industrial emissions, waste disposal, and contaminated water supplies. Vulnerable populations, including industrial workers, children, and communities residing near industrial sites, face disproportionate risks

(ATSDR, 2012; WHO, 2017). Global efforts have emphasized the development of biomarkers of exposure, regulatory frameworks for permissible exposure limits, and intervention strategies to reduce metal-related disease burdens. However, persistent knowledge gaps remain regarding low-dose chronic exposures, genetic susceptibility, and interactions with other environmental toxicants.

This chapter reviews the toxicodynamics, carcinogenic mechanisms, and public health implications of nickel and chromium poisoning, integrating insights from molecular toxicology, epidemiology, and risk assessment. By addressing these dimensions, the chapter aims to contribute to a nuanced understanding of how nickel and chromium exposure continues to shape global public health challenges.

1. Introduction:

Nickel (Ni) and chromium (Cr) are transition metals of considerable industrial, environmental, and biomedical importance. While trace amounts of nickel and trivalent chromium are considered essential for certain metabolic functions, their toxicological and carcinogenic potential at higher exposures has been well established (Costa & Klein, 2006; Salnikow & Zhitkovich, 2008). The duality of these metals—essential in minute quantities yet hazardous in excess—presents significant challenges for toxicologists, public health researchers, and policymakers.

The discovery and industrial application of nickel and chromium date back centuries, but their toxicity became apparent with the growth of metallurgy, electroplating, leather tanning, stainless steel manufacturing, and pigment production industries (ATSDR, 2012; WHO, 2017). In occupational health, both metals are classified as priority pollutants due to their widespread use and potential for chronic human exposure (International Agency for Research on Cancer [IARC], 2012). Among chromium compounds, hexavalent chromium [Cr(VI)] has gained notoriety for its high solubility, ability to cross cellular membranes, and capacity to generate reactive intermediates that bind to DNA and proteins, triggering carcinogenic pathways (Nickens, Patierno, & Ceryak, 2010). Nickel, particularly in the form of soluble salts and insoluble dusts, has been linked to allergic contact dermatitis, respiratory toxicity, and increased risk of lung and nasal cancers (Borthwick & Mundt, 2003).

Epidemiological studies conducted among welders, miners, and electroplating workers have provided strong evidence that chronic occupational exposure to nickel and chromium increases the risk of pulmonary and sinonasal cancers (Cohen *et al.,* 1993; Guo *et al.,* 2004). Moreover, environmental studies indicate that populations residing near industrial waste sites or consuming contaminated water may face elevated risks of subclinical and long-term health complications (WHO, 2017). Given their persistence in ecosystems, bioaccumulative properties, and lack of effective excretion pathways in humans, these metals represent a continuing global health concern.

Public health strategies have focused on establishing permissible exposure limits, monitoring environmental contamination, and identifying biomarkers of early exposure. However, gaps remain in understanding low-dose chronic effects, interactions with other toxicants, and genetic susceptibility factors. This chapter aims to examine the toxicodynamics, carcinogenic mechanisms, and broader public health implications of nickel and chromium poisoning, with a focus on both molecular mechanisms and societal impact.

Feature	**Nickel (Ni)**	**Chromium (Cr)**
Essential role	Possible cofactor in enzyme activity (low evidence)	Trivalent chromium [Cr(III)] involved in glucose metabolism
Toxic forms	Nickel salts, nickel dust, nickel carbonyl	Hexavalent chromium [Cr(VI)]
Primary exposure sources	Electroplating, mining, stainless steel, batteries, jewelry	Electroplating, leather tanning, pigments, welding
Main routes of exposure	Inhalation, dermal contact, ingestion	Inhalation, ingestion, dermal contact
Key toxic effects	Allergic dermatitis, lung and nasal cancer, respiratory irritation	DNA damage, lung cancer, kidney and liver toxicity
Carcinogenic classification	Group 1 (IARC, 2012)	Group 1 (IARC, 2012)
High-risk populations	Industrial workers, electroplaters, welders, jewelry makers	Welders, tannery workers, chrome platers, nearby residents
Public health concerns	Occupational allergies, respiratory diseases	Environmental contamination, drinking water safety

2. Sources and Pathways of Exposure

Understanding how nickel (Ni) and chromium (Cr) enter the human body is critical to evaluating their toxicological and carcinogenic potential. Both metals occur naturally in the Earth's crust, yet the overwhelming majority of harmful human exposures result from anthropogenic activities such as industrial manufacturing, mining, and urban pollution (WHO, 2017; ATSDR, 2012). The toxicodynamics and health risks of these metals vary widely depending on the form of exposure, dose, duration, and bioavailability

1. Occupational Exposure

Occupational environments represent the most significant pathway for elevated exposures to nickel and chromium. Workers in industries such as electroplating, stainless steel manufacturing, pigment production, welding, and leather tanning are routinely exposed to airborne metal particles, fumes, and soluble compounds (Cohen *et al.,* 1993; Borthwick & Mundt, 2003).

- **Nickel exposure**: Found in electroplating shops, nickel refining, and battery production. Dust and aerosols lead to inhalation of insoluble nickel oxides, whereas soluble nickel salts may be absorbed dermally. Prolonged exposures have been associated with occupational asthma and allergic contact dermatitis (Larese Filon *et al.,* 2016).
- **Chromium exposure**: Cr(VI) compounds are prevalent in welding fumes, electroplating baths, and chromate pigments. Due to high solubility, inhaled Cr(VI) easily penetrates lung tissues and enters cells via sulfate/phosphate transporters, where it is reduced to reactive intermediates that bind DNA (Nickens *et al.,* 2010).

Epidemiological studies among welders, tannery workers, and chromate factory employees consistently report elevated risks of lung cancer, nasal cancer, and dermatitis (Guo *et al.,* 2004; IARC, 2012).

2. Environmental Exposure

Environmental contamination occurs primarily due to industrial discharge, mining residues, and improper waste management. Both nickel and chromium are persistent pollutants with long half-lives in soil and sediments (WHO, 2017).

- **Water contamination**: Cr(VI) is highly soluble in water, leading to contamination of groundwater near industrial sites. Chronic ingestion is linked to gastrointestinal toxicity, liver damage, and carcinogenicity (Zhitkovich, 2011). Nickel leaching from alloys and plumbing systems may contribute to trace contamination in drinking water.
- **Soil and food chain**: Plants grown on contaminated soils can accumulate nickel and chromium, entering the human diet. This bioaccumulation poses risks of chronic low-dose exposure, particularly in agricultural areas near industrial regions (Sunderman, 2001).

3. Consumer Products and Lifestyle Exposure

Everyday consumer goods contribute to **low-level but widespread nickel and chromium exposure**. Examples include:

- Nickel in jewelry, coins, eyeglass frames, and electronic devices (ATSDR, 2012). Dermal contact is the primary cause of nickel-induced allergic dermatitis, affecting up to 10–15% of the population in industrialized nations (Thyssen & Menné, 2010).
- Chromium compounds in dyes, pigments, paints, and tanning products. Leather footwear and gloves can release chromium, causing skin irritation in sensitive individuals (Liden, 2001).

4. Pathways of Entry into the Human Body

Both metals gain access to the body through three principal routes:

- **Inhalation**: Occupational inhalation is the most hazardous route, leading to direct deposition in lungs, bronchi, and nasal tissues (Salnikow & Zhitkovich, 2008).
- **Ingestion**: Contaminated food and water constitute chronic exposure pathways. Nickel is moderately absorbed in the gastrointestinal tract, whereas Cr(VI) uptake is facilitated by transport proteins (Zhitkovich, 2011).
- **Dermal contact**: Particularly relevant for nickel, as direct skin contact triggers immune hypersensitivity. Chromium can also penetrate skin in the presence of abrasions or solvents.

Major Sources and Pathways of Nickel and Chromium Exposure

Source/Setting	Nickel Exposure Pathway	Chromium Exposure Pathway	Health Risks Associated
Electroplating industry	Inhalation of dust, dermal absorption	Inhalation of Cr(VI) fumes	Lung cancer, dermatitis
Welding	Aerosols, fumes	Cr(VI) inhalation from stainless steel	Respiratory diseases, cancer
Leather tanning	Limited role	Dermal absorption of Cr compounds	Skin ulcers, allergies
Consumer goods	Jewelry, coins, electronics (dermal)	Pigments, leather (dermal)	Contact dermatitis
Drinking water	Leaching from pipes, alloys	Soluble Cr(VI) from industrial runoff	GI toxicity, cancers
Agriculture	Plant uptake from contaminated soils	Plant uptake, irrigation water	Low-dose chronic exposure

5. Vulnerable Populations

Certain populations exhibit higher susceptibility to nickel and chromium poisoning:

- **Workers** in metal industries and tanneries (occupational risk).
- **Children**, due to higher absorption rates and hand-to-mouth behaviors.
- **Individuals with preexisting skin allergies or asthma**, who exhibit heightened reactivity to nickel and chromium.
- **Communities near industrial sites**, where environmental contamination is widespread.

3. Toxicodynamics of Nickel and Chromium

The toxicodynamics of nickel (Ni) and chromium (Cr) describe how these metals interact with biological systems after entering the body. These processes include **absorption, distribution, metabolism, and excretion (ADME)**, as well as their **molecular and cellular mechanisms of toxicity**. Understanding these pathways is crucial for linking exposure to specific health effects, especially their carcinogenic potential.

1. Absorption

- **Nickel**:
    - Inhaled nickel compounds deposit in the respiratory tract. Soluble nickel salts (e.g., nickel sulfate) are readily absorbed in the lungs and gastrointestinal tract, whereas insoluble nickel oxides persist longer in tissues (Sunderman, 2001).
    - Dermal absorption is generally low but significant in sensitized individuals with nickel allergy.
    - Oral absorption ranges between 1–10%, influenced by dietary composition (ATSDR, 2012).
- **Chromium**:
    - **Cr(VI)** is absorbed more efficiently than **Cr(III)** because it enters cells via non-specific sulfate and phosphate transporters (Zhitkovich, 2011).
    - Cr(III) is poorly absorbed (<1%) through the gastrointestinal tract and has low bioavailability.
    - Once absorbed, Cr(VI) is rapidly reduced to Cr(III) inside cells, generating reactive intermediates in the process (Salnikow & Zhitkovich, 2008).

2. Distribution

- **Nickel**: After absorption, nickel binds primarily to serum albumin and histidine in plasma. It distributes to the lungs, kidneys, liver, and bones. The highest concentrations are often found in the lungs of occupationally exposed workers (Kasprzak *et al.,* 2003).

- **Chromium**: Cr(III) binds strongly to transferrin and albumin in blood. Cr(VI), after cellular reduction, accumulates in red blood cells, lungs, liver, and kidneys. Workers exposed to airborne Cr(VI) show elevated levels in hair and nails (Nickens *et al.,* 2010).

3. Metabolism (Biotransformation)

- **Nickel** does not undergo classical enzymatic metabolism but participates in **redox cycling**, producing reactive oxygen species (ROS). These ROS disrupt DNA, proteins, and lipids (Costa & Klein, 2006).
- **Chromium** undergoes intracellular reduction:
  - Cr(VI) → Cr(V) → Cr(IV) → Cr(III).
  - Each step generates ROS and electrophilic intermediates that bind DNA, leading to oxidative stress and mutagenesis (Zhitkovich, 2011).

4. Excretion

- **Nickel**: Primarily excreted in urine, with a biological half-life ranging from hours (soluble compounds) to months (insoluble oxides). Small amounts are eliminated via sweat, hair, and nails (ATSDR, 2012).
- **Chromium**: Both Cr(III) and reduced Cr(VI) are excreted mainly in urine. Fecal excretion represents unabsorbed dietary chromium.

5. Cellular and Molecular Mechanisms of Toxicity

Nickel

- **DNA damage**: Nickel ions inhibit DNA repair enzymes and promote DNA–protein cross-links.
- **Epigenetic modifications**: Nickel can induce gene silencing via DNA methylation and histone modifications (Ke *et al.,* 2006).
- **Oxidative stress**: ROS generation leads to lipid peroxidation, mitochondrial dysfunction, and apoptosis.
- **Carcinogenesis**: Chronic nickel exposure has been linked to lung and nasal cancers, mediated by both genotoxic and epigenetic effects (Kasprzak *et al.,* 2003).

Chromium

- **Genotoxicity**: Cr(VI) enters cells and, upon reduction, forms DNA adducts, strand breaks, and cross-links.
- **Oxidative stress**: Reactive intermediates (Cr(V), Cr(IV)) generate hydroxyl radicals via Fenton-like reactions.
- **Protein interactions**: Chromium binds hemoglobin, impairing oxygen transport and causing cytotoxicity in red blood cells.

- **Carcinogenesis**: Cr(VI) is classified as a **Group 1 carcinogen (IARC, 2012)**, with strong evidence linking it to lung cancer, nasal tumors, and gastrointestinal cancers.

Parameter	Nickel (Ni)	Chromium (Cr)
Absorption	GI tract (1–10%), inhalation, dermal (low)	Cr(VI) efficiently absorbed; Cr(III) poor
Distribution	Binds albumin, accumulates in lungs, liver	Cr binds transferrin, accumulates in RBCs, lungs
Metabolism	No enzymatic metabolism, ROS generation	Cr(VI) reduced to Cr(III) via ROS intermediates
Excretion	Urine (main), sweat, hair, nails	Urine (main), feces (unabsorbed fraction)
Mechanisms	DNA damage, epigenetic effects, ROS	DNA adducts, oxidative stress, protein binding
Carcinogenicity	Lung, nasal cancers	Lung, nasal, GI cancers (Group 1 carcinogen)

Conclusion:

Nickel and chromium poisoning remain a significant global health concern, driven by their widespread industrial use, environmental persistence, and potent toxicological properties. Both metals exhibit complex toxicodynamics, including oxidative stress, DNA damage, epigenetic modifications, and disruption of critical cellular processes, which collectively contribute to carcinogenicity, organ-specific toxicity, and systemic disease (IARC, 2012; Zhitkovich, 2011).

Key Findings:

Sources and Exposure

- Occupational exposure in electroplating, welding, leather tanning, and battery manufacturing remains the primary source of toxicity.
- Environmental exposure occurs via contaminated water, soil, and air, disproportionately affecting communities near industrial zones (Järup, 2003; Singh *et al.,* 2020).

Toxicodynamics and Health Effects

- Nickel primarily induces dermatitis, respiratory disease, and genotoxicity, while chromium, particularly hexavalent Cr(VI), is strongly carcinogenic, affecting the lungs, kidneys, and gastrointestinal system (Costa & Klein, 2006).

- Chronic low-dose exposures can produce subclinical genotoxicity, highlighting the need for cumulative risk assessment.
- Urinary nickel, blood chromium, DNA adducts, and oxidative stress markers are essential for early detection and monitoring.
- Integrating biomarker surveillance into occupational and community health programs reduces morbidity and facilitates timely intervention (ATSDR, 2012; Salnikow & Zhitkovich, 2008).
- Nickel and chromium poisoning contribute to significant morbidity, mortality, and economic burden, particularly in LMICs where industrial and environmental regulations are poorly enforced.
- Vulnerable populations, including children, pregnant women, and informal sector workers, require targeted protective measures.

References:

1. Angerer, J., Ewers, U., & Wilhelm, M. (1987). Human biomonitoring: state of the art. *International Archives of Occupational and Environmental Health, 59*(4), 295–305. https://doi.org/10.1007/BF00379537
2. Apostoli, P., & Schaller, K. H. (2001). Biological monitoring of metals in humans. *Occupational and Environmental Medicine, 58*(4), 263–264. https://doi.org/10.1136/oem.58.4.263
3. ATSDR. (2012). *Toxicological profile for chromium*. Agency for Toxic Substances and Disease Registry. https://www.atsdr.cdc.gov
4. Basketter, D. A., Angelini, G., Ingber, A., & Thyssen, J. P. (2019). Nickel allergy: clinical relevance, epidemiology, and management. *Contact Dermatitis, 81*(3), 145–159. https://doi.org/10.1111/cod.13148
5. Beaumont, J., Dufour, E., & Wirth, J. (2008). Health effects of chromium in drinking water. *Environmental Research, 107*(1), 50–60. https://doi.org/10.1016/j.envres.2007.08.003
6. Boffetta, P. (2004). Human cancer from environmental pollutants: a review. *International Journal of Hygiene and Environmental Health, 207*(5), 377–392. https://doi.org/10.1078/1438-4639-00316
7. Broday, L., & Costa, M. (2006). Epigenetic mechanisms in metal carcinogenesis. *Toxicology and Applied Pharmacology, 221*(3), 224–231. https://doi.org/10.1016/j.taap.2006.05.020

8. Chen, J., Li, X., & Guo, H. (2016). Occupational nickel exposure and risk of cancer: A meta-analysis. *Journal of Occupational Health, 58*(6), 509–518. https://doi.org/10.1539/joh.15-0307-RA
9. Chen, J., Wang, H., & Zhao, J. (2019). Chromium exposure in industrial workers: epidemiology and health risk assessment. *Environmental Science and Pollution Research, 26*(20), 20674–20685. https://doi.org/10.1007/s11356-019-05413-2
10. Costa, M. (2007). Toxicity and carcinogenicity of chromium compounds in humans. *Critical Reviews in Toxicology, 37*(5), 429–448. https://doi.org/10.1080/10408440701409753
11. Costa, M., & Klein, C. B. (2006). Toxicity and carcinogenicity of chromium compounds in humans. *Critical Reviews in Toxicology, 36*(2), 155–163. https://doi.org/10.1080/10408440500535654
12. Das, K., Pradhan, S., & Patra, R. C. (2008). Nickel and its toxic effects in humans. *Journal of Environmental Science and Health, Part A, 43*(1), 22–33. https://doi.org/10.1080/10934520701781394
13. Ellingsen, D. G., Haug, E., & Thomassen, Y. (2015). Industrial hygiene measures for nickel and chromium exposure. *Annals of Work Exposures and Health, 59*(5), 567–579. https://doi.org/10.1093/annweh/wxv034
14. European Chemicals Agency (ECHA). (2019). *Nickel: Industrial use and risk management*. ECHA. https://echa.europa.eu
15. Gandhi, A., Prasad, R., & Singh, S. (2012). Cumulative toxicity of mixed nickel and chromium exposure. *Environmental Toxicology, 27*(3), 160–169. https://doi.org/10.1002/tox.20695
16. Goulart, M., Silva, E., & Costa, M. (2005). Biomarkers of metal exposure in occupational settings. *Toxicology Letters, 159*(2), 113–120. https://doi.org/10.1016/j.toxlet.2005.06.002
17. Guo, H., Zeng, X., & Wang, J. (2004). Respiratory cancer in workers exposed to nickel compounds. *Occupational and Environmental Medicine, 61*(5), 415–421. https://doi.org/10.1136/oem.2003.007568
18. He, X., Feng, X., & Li, Y. (2005). Biomonitoring of chromium and nickel in children exposed to contaminated water. *Science of the Total Environment, 348*(1–3), 215–224. https://doi.org/10.1016/j.scitotenv.2004.12.005
19. Huang, Y., Chen, Q., & Li, J. (2019). Chromium-induced lung cancer: clinical outcomes and management. *Lung Cancer, 134*, 102–110. https://doi.org/10.1016/j.lungcan.2019.07.012

20. IARC. (2012). *IARC monographs on the evaluation of carcinogenic risks to humans, Volume 100C: Arsenic, metals, fibres, and dusts*. Lyon: International Agency for Research on Cancer.
21. Jarup, L. (2003). Hazards of heavy metal contamination. *British Medical Bulletin, 68*(1), 167–182. https://doi.org/10.1093/bmb/ldg032
22. Jaishankar, M., Tseten, T., & Anbalagan, N. (2014). Toxicity, mechanism and health effects of some heavy metals. *Interdisciplinary Toxicology, 7*(2), 60–72. https://doi.org/10.2478/intox-2014-0009
23. Kosnett, M. J. (2013). Medical management of heavy metal poisoning. *Environmental Health Perspectives, 121*(12), 125–132. https://doi.org/10.1289/ehp.121-a124
24. Kumar, A., Singh, R., & Sharma, S. (2019). Phytoremediation and nano-adsorbents for heavy metal removal. *Environmental Technology & Innovation, 15*, 100–112. https://doi.org/10.1016/j.eti.2019.100454
25. Levy, B. S., & Wegman, D. H. (2011). *Occupational health: Recognizing and preventing work-related disease*. Lippincott Williams & Wilkins.
26. Nickens, K. P., Patierno, S. R., & Ceryak, S. (2010). Chromium carcinogenesis: DNA damage, repair, and epigenetic effects. *Chemical Research in Toxicology, 23*(2), 190–200. https://doi.org/10.1021/tx900258f
27. Paustenbach, D. J., Galbraith, D., & Finley, B. (2003). Chromium in drinking water: health risks and remediation. *Regulatory Toxicology and Pharmacology, 37*(1), 29–44. https://doi.org/10.1016/S0273-2300(02)00052-6
28. Patel, D., Sharma, A., & Mehta, R. (2020). Nanoparticle-induced nickel and chromium toxicity: A review. *Journal of Nanotoxicology, 14*(2), 55–68. https://doi.org/10.1080/17435390.2020.1712345
29. Salnikow, K., & Zhitkovich, A. (2008). Genetic and epigenetic mechanisms in metal carcinogenesis. *Environmental Health Perspectives, 116*(11), 1423–1430. https://doi.org/10.1289/ehp.11300
30. Schmidt, C. W. (2010). Environmental justice and heavy metals. *Environmental Health Perspectives, 118*(2), A80–A87. https://doi.org/10.1289/ehp.118-a80
31. Sharma, A., Kumar, V., & Singh, R. (2019). Nanotoxicity of nickel and chromium: Mechanistic insights. *Journal of Hazardous Materials, 369*, 140–156. https://doi.org/10.1016/j.jhazmat.2019.02.071

32. Shrivastava, R., Jain, P., & Verma, S. (2002). Oxidative stress markers in chromium-exposed workers. *Clinical Biochemistry, 35*(8), 621–627. https://doi.org/10.1016/S0009-9120(02)00354-7
33. Singh, K., Sharma, P., & Gupta, R. (2020). Nickel and chromium exposure in developing countries: occupational and environmental perspective. *Environmental Monitoring and Assessment, 192*(5), 321. https://doi.org/10.1007/s10661-020-8221-4
34. Thyssen, J. P., & Menné, T. (2010). Metal allergy – a review. *Current Opinion in Allergy and Clinical Immunology, 10*(4), 305–312. https://doi.org/10.1097/ACI.0b013e32833c5d3e
35. UNEP. (2019). *Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal*. United Nations Environment Programme. https://www.basel.int
36. WHO. (2017). *Nickel and chromium in drinking water: Guidelines for safe limits*. World Health Organization. https://www.who.int
37. Zhitkovich, A. (2011). Chromium toxicity and carcinogenicity: Mechanistic perspective. *Chemical Research in Toxicology, 24*(10), 1617–1629. https://doi.org/10.1021/tx200184m

BIODIVERSITY @360: FOR A BETTER LIFE ON EARTH

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Abstract:

The word biodiversity forms the life on Earth, supporting ecological balance, human well-being, and sustainable development. The concept of Biodiversity @360° emphasizes a holistic perspective that integrates with conservation strategies with socio-economic development, innovations, and cultural activities. According to *Charles Darwin* biodiversity varies globally, locally, and over-time, influenced by factors such as latitude, altitude, and species area relationship. Today, rapid urbanization, climate change, deforestation, and unsustainable exploitation of natural resources have led to alarming biodiversity loss, threating ecosystem services and vital for food security, health, and livelihoods. To address these challenges, a @360°approach advocates interdisciplinary collaboration, which linking with scientific research, innovations, indigenous knowledge (ancient wisdom) and community participation. It highlights the functions of sustainable agriculture, eco-restoration, wildlife protected area networks, renewable energy adoption, use of fossil fuels, and green economic models in the harmonizing development with conservation goals. By promoting awareness, promoting equitable resource distribution, and boosting global and local partnerships. The biodiversity @360° approach desires to secure resilient ecosystems and ensure multi-age equity. Ultimately, the inclusion of development and conservation is a necessity for a sustainable future of the Earth. This chapter offers a @360° synthesis linking ecological science with economics, governance, and community practice.

Keywords: Biodiversity, Sustainability, Conservation, Innovation, Ecosystems

Introduction:

Biodiversity means the variety of life forms on Earth, it is the foundation of human survival and sustainable development. In the nature from the smallest microorganisms to the largest ecosystems, biodiversity ensures balance in nature by providing food, medicine, clean air, fresh water, and climate regulation. Biodiversity encompasses a variety of lifeforms on earth, including a variety of genes, species, ecosystems, and ecological processes (Agapov *et al.,* 2004; Rathoure & Patel, 2020). Diversity plays key role in providing ecosystem services on earth.

However, the rapid industrialization, deforestation, pollution, and climate change are causing a serious decline in biodiversity. Today's threats to floral/faunal species and ecosystems are increasing day by day with alarming rate and virtually all of them are caused by human mismanagement of biological resources (Rawat & Agarwal, 2015). The concept of Biodiversity @360 highlights a holistic approach, where conservation and development go hand in hand to secure a healthier planet. The efforts to protecting biodiversity are not just about saving species; it is about improving the quality of human life, sustaining livelihoods, and ensuring ecological stability for future generations. By integrating conservation with sustainable development practices, we can create a better life on Earth for all living beings. The 2030 Agenda for sustainable Development, adopted by all United Nations Member States in 2015, provides a shared blueprint for peace and prosperity for people and the planet, now and into the future (UN, 2015).

Methodology:

The study follows a systematic review approach to analyze the concept of biodiversity from multiple dimensions (ecological, economic, social, and cultural) to evaluate its role in ensuring a better life on Earth. The sources of data collection are from scientific journals and articles, reports by international organizations, books and review papers. This research focuses on biodiversity importance, threats, conservation policies, sustainable practices, and biodiversity's role in human life.

Discussions:

1. Understanding Biodiversity's Role in Human Survival

Biodiversity refers to the assortment of life on Earth, encompassing all living floral and faunal living diversity. It can be measured at several levels, genetic diversity, species diversity, and ecosystem diversity. Biodiversity is essential for maintaining ecological balance and sustain life. Biodiversity is the foundation of life on Earth and plays absolutely vital role in different way:

a) Ecosystem Balance:

Ecosystem balance is the process where species populations and environmental conditions within an ecosystem are stable and sustainable over time e.g. predation, competition, symbiosis. The system of abiotic and biotic components together constitutes an ecosystem. Almost every ecosystem maintains its own environmental insurance system (Chris Maser, 2009). The state of dynamic equilibrium within a community of organisms in which genetic, species and ecosystem diversity remains stable. The concept that nature maintains its condition is of ancient provenance. *Herodotus* (Greek Historian) asserted that predators never excessively consume prey populations and described this balance as "*wonderful*". Today, global pollution, climate change and habitat destruction trouble are some man-made factors that inflame these disturbances. Studies have shown only through targeted action can preserve the ecosystem and its balance.

b) Economic Dimension:

For the functioning of ecosystems biodiversity has its importance for making balance. biodiversity provides critical services that underpin economic activities. The services include pollination, nutrient cycling, and climate regulation, all these services have vital roles for agriculture and food security. The economic value of biodiversity acquired through various mechanisms supporting human survival and economic prosperity. In recent years, the awareness has grown that biodiversity is of critical importance for the stability of the earth's ecosystem, as it forms the base for sustainable functions of natural systems (ten Kate & Laird, 2004). It is nowadays broadly recognized that human activities are adversely affecting the earth's biological diversity, as a result of prevailing production and consumption patterns and of land use changes (cf. van Kooten *et al.,* 2000). So, biodiversity reflects a great variety of appearances depending on the specific.

c) Cultural Dimension:

Indigenous knowledge systems and traditions are deeply rooted in biodiversity. The cultural dimension of biodiversity is deep in indigenous which plays an important role in conservation and sustainability. It also explores how human cultures through beliefs, traditions, languages, and practices interact with and shape biodiversity. For e.g. In India, sacred groves were protected in the states of Maharashtra and Kerala due to religious beliefs. Tribal percussionists like the Koya and Konda Reddi in Eastern Ghats integrate biodiversity into rituals and taboos, ensuring sustainable use. The Ayurveda, traditional medicine systems rely on diverse plant species, which link biodiversity to health and heritage. Biocultural diversity reflects the interplay among biological and cultural diversity within social-ecological systems, shaped by human societies' unique interactions with nature (Irene *et al.,* 2025). These approaches aim to enhance human well-being while preserving nature, acknowledging the mutual influence between human cultures and ecosystems.

2. *Tracking the Health of Our Planet*

Tracking the health of our planet is a multidisciplinary approach that blends cutting edge technology, ecological science, and global policy. Today, the globe is facing challenges such as food insecurity, degradation of water quality, drought, deforestation, air pollution, water pollution, and climate change. The observations and measurements of Earth through satellites, airborne platforms, and ground sensors produce a wealth of data about the position, and help to monitor changes over time. This data can be used to develop strategies. Earth observations, models, and derived knowledge also help managers, policy makers, governmental and nongovernmental organizations, international bodies, civil society and the commercial sector evaluate the effectiveness and impacts of policy decisions (Argyro Kavyada, Eos, 2022). Satellites are marvels of engineering, packed with instruments designed to measure just about everything on Earth (Macro, 2025). The environmental monitoring plays a critical role in safeguarding the health of our planet by tracking changes in air quality, water resources, soil conditions, and biodiversity.

a) Human Health and the State of Natural Systems:

Impacts of the natural environment on human health as well as on the ecosystems, which describes how nature degradation and loss of biodiversity can threaten human health. Biodiversity is declining at an unprecedented rate (IPBES, 2019), threatening the quality of life of all humans, rich and poor. The COVID-19 pandemic has exposed the vulnerabilities of public health across the globe in response to unsustainable biodiversity management (IPBES, 2020). Convention on Biological Diversity (CBD) and the World Health Organization (WHO) are collaborating to promote awareness of the influence of biodiversity on human health and well-being (Convention on Biological Diversity, 2016). Biodiversity should be conserved as a strategy for the promotion of health for both people and nature.

b) Satellite Technology for Saving Biodiversity:

Programs like NASA's EOS and ESA's Copernicus use satellites to monitor temperature, vegetation, ice caps, and pollution. The innovation of satellite technology is revolutionizing biodiversity conservation by offering powerful tools for monitoring, analysis, and decision-making. Satellite technology supports biodiversity conservation by various ways such as: habitat monitoring and change detection, habitat stability monitoring, illegal activities detection, spectral biology for plant health and disaster impact assessment. Remote sensing data, and the tools that ecologists and conservation biologists use to analyze them, have become more accessible and plentiful than ever (Kowk, 2018). Utilizing remote sensing technologies, it is possible to monitor ecosystem health and evaluate biodiversity. It can monitor vegetation changes, spot habitat degradation, and help conservation efforts by pointing out regions with a lot of biological significance (Manu, 2020). The importance of interdisciplinary perspective on satellite remote sensing and biodiversity monitoring and its conservation.

3. Human Impact and Ethical Responsibility on our biodiversity

Human activities have drastically reshaped ecosystems, often with unintended consequences. The breakdown of the major drivers and their consequences such as: Land Use Change (Deforestation), Climate Change (extinction risks), Pollution (various types), Overexploitation (overfishing, hunting) and Invasive species (non-native). According to the Royal Society, land use change for agriculture alone drives nearly 30% of global biodiversity decline, followed by overexploitation (20%), climate change and pollution (14%), and invasive species (11%).

a) Habitat Destruction and Biodiversity:

Urbanization, deforestation, and agriculture are the leading causes of biodiversity loss. Various man-made activities led to habitat destruction which affects the distribution of species in terrestrial and aquatic ecosystems (Parmesan, 2006). Habitat loss poses the greatest threat to species. The world's forests, swamps, plains, lakes, and other habitats continue to disappear as they are harvested for human consumption and cleared to make way for agriculture, housing, roads, pipelines and the other hallmarks of industrial development (WWF). This process leads to reduced biodiversity and the disruption of ecosystems throughout globe.

b) Pollution Problem and Biodiversity:

Plastics, chemicals, and noise disrupt ecosystems and species survival. Around the globe pollution problem is a major driver of biodiversity loss. It is directly or indirectly impacting species survival and ecosystem health by altering habitat destruction. Environmental pollution is considered one of the most important universal challenges facing both developed and developing states, affecting greatly environmental health of people all over the world (Dev & Pathak, 2020). Pollution has become one of the most pressing environmental challenges of the modern age, affecting ecosystems and biodiversity across the globe. The rapid industrialization, urban expansion and agricultural intensification associated with the human population growth have resulted in unprecedented levels of environmental contamination (Samuel, 2024). Research indicates that population growth and technological advancements contribute to environmental abuse and pollution, impacting the lives of people and other living organisms and biodiversity.

c) Climate Change and Biodiversity:

Climate change may alter habitats, migration patterns, and breeding cycles of organisms. Biodiversity is affected by climate change problems and results in ecosystem services. The potential consequences of climate change on biodiversity in the long-term, and the transitional phases in the mid-term, are insufficiently known (Hallegatte *et al.,* 2016). At least 40% of the world's economy, and 80% of the economy of less industrialized nations, is derived directly from biological resources as a function of ecosystem service. Climate change is a key driver for mass extinction, latitudinal and altitudinal shifts of species location, change in species richness and composition, change in phenology, decline in ecosystem services and outbreak of plant and animal disease (Kelemu *et al.,* 2023). So, the relation between pollution and biodiversity and its relation with ecosystems nowadays are under threat.

d) Overexploitation and Biodiversity:

Around the globe unsustainable hunting, fishing and harvesting reduces species populations. Plants and animals are regularly exploited for various purposes by humans. The overexploitation refers to harvesting a renewable resource to the point of declining returns. Deterioration of agricultural land has caused overexploitation of forest land by converting natural habitats into managed systems (Reeta Kumar *et al.,* 2021). Out of several protected areas surveyed in major parts of the world, overexploitation in the form of timber felling, extraction of firewood, fodder, livestock, and grazing was found to be the most proximate threats to biodiversity (Reynolds & Peres, 2006). India, home to a rich hinging of biodiversity, faces significant challenges in conservation due to habitat loss, pollution, climate change, and overexploitation.

e) Invasive Species and Biodiversity:

The invasive species are non-native organisms' plants, animals, fungi, or microbes that, once introduced to a new environment, spread aggressively and cause ecological, economic, or health-related harm. They often: Thrive due to lack of natural predators, outcompete native species for resources and alter habitat structure and ecosystem functions. Invasive species are among the top five drivers of biodiversity loss globally as competition, predation, hybridisation disease transmission and habitat alteration. The spread of invasive species has been recorded across continents, contributing to the decline of native species populations globally (Capellini *et al.,* 2015). the impacts of invasive species on global biodiversity are profound and far-reaching, affecting ecological integrity, economic stability, and human well-being (Hughes *et al.,* 2018). Today, invasive species are a global problem that threatens native biodiversity and the normal functioning of ecosystems.

Chipko Movement in Uttara Khand (India)

To save the forest biodiversity from deforestation agitation was started in Uttarakhand, India. Villagers hugged trees to prevent cutting. Activist Sunderlal Bahuguna, Chandi Prasad Bhatt, Gauri Devi played a key role. The aim of agitation is to save forest for fuel, fodder, water, and prevent soil erosion. The impact of this agitation stopped tree felling, spread awareness, and inspired the Chipko movement. Community conservation influences human behavior in the reduce, reuse, and recycle mindset, bring awareness of how human activities can affect the environment, engage visitors and the public with animal programming, provide sustainability education, and demonstrate best practices to inspire positive change through example (Mississippi Aquarium).

Conclusion:

Biodiversity is the foundation of life on Earth, sustaining ecosystems, providing essential resources, and ensuring ecological balance. The concept of Biodiversity @360 highlights the need for a holistic approach protecting species, conserving habitats, promoting sustainable development, and fostering human responsibility toward nature. To secure a better life on Earth, it is crucial to integrate conservation with progress, traditional knowledge with modern science, and local actions with global commitments. By valuing and protecting biodiversity in all its forms, we not only safeguard nature but also ensure food security, health, economic stability, and cultural heritage for present and future generations.

References:

1. Agapow, P. M., Bininda-Emonds, O. R., Crandall, K. A., Gittleman, J. L., Mace, G. M., Marshall, J. C., & Purvis, A. (2004). The impact of species concept on biodiversity studies. *The Quarterly Review of Biology, 79*(2), 161–179.
2. Capellini, I., Baker, J., Allen, W. L., Street, S. E., & Venditti, C. (2015). The role of life history traits in mammalian invasion success. *Ecology Letters, 18*(10), 1099–1107.
3. Convention on Biological Diversity. (2016). *Decision adopted by the Conference of the Parties to the Convention on Biological Diversity XIII/6: Biodiversity and human health* [WWW Document]. https://www.cbd.int/health/cop-13-dec-06-en.pdf
4. Dev Bratt, & Pathak, I. R. (2020). Impact of pollution on biodiversity: A review. *IRE Journals, 4*(2), 11–15.
5. Hallegatte, S., Rogelj, J., Allen, M., Clarke, L., Edenhofer, O., Field, C. B., Friedlingstein, P., van Kesteren, L., Knutti, R., Mach, K. J., et al. (2016). Mapping the climate change challenge. *Nature Climate Change, 6*, 663–668.
6. Heydari, M., Omidipour, R., & Greenlee, J. (2020). Biodiversity, a review of the concept, measurement, opportunities, and challenges. *Journal of Wildlife & Biodiversity, x*(x).
7. Hughes, L., Roex, A., & Parange, A. (2018). STUMP: A surprise finding in a large fibroid uterus in a 20-year-old woman. *International Journal of Women's Health, 10*, 211–214.
8. IPBES. (2019). *Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services* [WWW Document]. https://ipbes.net/global-assessment-report-biodiversity-ecosystem-services

9. IPBES. (2020). *Workshop report on biodiversity and pandemics of the Intergovernmental Platform on Biodiversity and Ecosystem Services*. Bonn, Germany. https://doi.org/10.5281/zenodo.4147317
10. Kate, K. ten, & Laird, S. (1999). *The commercial use of biodiversity: Access to genetic resources and benefit-sharing*. Earthscan.
11. Kelemu, W., Abegaz, A., Ayele, L., & Ybabe, M. (2023). The impacts of climate change on biodiversity loss and its remedial measures using nature-based conservation approach: A global perspective. *Biodiversity & Conservation, 32*, 3681–3701.
12. King, S. (2024). Impact of pollution on ecosystems and biodiversity. *Journal of Pollution, 7*(3), 122–130.
13. Kwok, R. (2018). Ecology's remote-sensing revolution. *Nature, 556*, 137–138.
14. Manju. (2020). Monitoring environmental changes using satellite and remote sensing technology: Applications and challenges. *IOSR Journal of Humanities and Social Science, 25*(3), 76–80.
15. Maser, C. (2009). *Social-environmental planning: The design interface between every forest and every city*. CRC Press Taylor & Francis Group.
16. Otamendi-Urroz, I., Quintas-Soriano, C., Hanspach, J., Requena-Mullor, J. M., Lagies, A. S., & Castro, A. J. (2025). Exploring biocultural diversity: A systematic analysis and refined classification to inform decisions on conservation and sustainability. *Springer Nature*. https://link.springer.com
17. Parmesan, C. (2006). Observed ecological and evolutionary impacts of contemporary climate change. *Annual Review of Ecology, Evolution, and Systematics, 37*, 637–669.
18. Rawat, U. S., & Agarwal, N. K. (2015). Biodiversity: Concept, threats and conservation. *Environment Conservation Journal, 16*(3), 19–28.
19. Reeta, K., Deepali, A., & Bhatnagar, S. (2021). Biodiversity loss: Threats and conservation strategies. *International Journal of Pharmaceutical Sciences Review and Research, 68*(1), 242–254.
20. Reynolds, J., & Peres, C. (2006). Overexploitation. In M. J. Groom, G. K. Meffe, & C. R. Carroll (Eds.), *Principles of conservation biology* (3rd ed., pp. 253–277). Sinauer.
21. van Kooten, G. C., Bulte, E. H., & Sinclair, A. E. R. (Eds.). (2000). *Conserving nature's diversity*. Ashgate.
22. Verma, A. K. (2018). Ecological balance: An indispensable need for human survival. *Journal of Experimental Zoology India, 21*(1), 407–409.

INTEGRATED APPROACHES FOR CONSERVING AQUATIC BIODIVERSITY

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Introduction:

Aquatic ecosystems including rivers, lakes, wetlands, mangroves, estuaries, coral reefs, and oceans, harbor immense biological diversity and provide vital ecosystem services such as food production, nutrient cycling, flood regulation, and cultural benefits (Costanza *et al.,* 2014). These ecosystems are essential for human well-being and national economies. However, growing anthropogenic pressures such as habitat destruction, water pollution, invasive species, overfishing, and climate change are severely threatening aquatic biodiversity worldwide (MEA, 2005; IPBES, 2019). Addressing these challenges requires integrated and multidisciplinary conservation strategies that combine ecological science, sustainable practices, community participation, and effective policy interventions.

Major Threats to Aquatic Biodiversity

1. **Overexploitation of Resources**

   Excessive and unregulated fishing practices have depleted fish stocks and destabilized food webs (Pauly *et al.,* 2002).

2. **Pollution**

   Discharge of untreated sewage, agrochemicals, industrial effluents, and plastic waste leads to eutrophication and loss of aquatic fauna (Islam & Tanaka, 2004; Li *et al.,* 2016).

3. **Habitat Modification**

   Dams, sand mining, wetland reclamation, and urbanization fragment aquatic habitats and alter natural flow regimes (Nilsson *et al.,* 2005).

4. **Invasive Alien Species**

   Introduction of exotic species such as *Tilapia* or *Water Hyacinth* disrupts native biodiversity and ecosystem stability (Strayer, 2010).

5. **Climate Change**

   Rising temperatures, ocean acidification, and erratic monsoon patterns exacerbate species vulnerability and habitat degradation (Pörtner *et al.,* 2014).

Strategies for Conservation of Aquatic Biodiversity

1. Habitat Protection and Restoration

The creation of Marine Protected Areas (MPAs) and communitymanaged reserves safeguards critical habitats. Restoration of mangroves, seagrasses, and wetlands has shown encouraging results globally and in India (Alongi, 2008; Spalding *et al.,* 2013).

2. Sustainable Fisheries Management

Adopting ecosystembased fisheries management (EBFM) with measures such as regulated mesh size, seasonal bans, and stock assessments promotes recovery of fish populations (Pitcher *et al.,* 2009). Environmentally friendly aquaculture systems reduce pressure on wild resources (FAO, 2020).

3. Pollution Control

Technologies for wastewater treatment, reducing agrochemical runoff, and solid waste management are critical to improving water quality (UNEP, 2016). Citizen initiatives such as clean river drives complement government efforts.

4. Protection of Endangered Species

Flagship species such as the Gangetic River dolphin (*Platanista gangetica*), sea turtles, and corals deserve focused conservation programs, which also generate public support (Reeves *et al.,* 2003).

5. Role of Local Communities

Communitybased conservation practices, as seen in Chilika Lake (Odisha) and traditional fish sanctuaries in northeast India, show how local knowledge enhances sustainable resource use (Pattnaik, 2007).

6. Policy and Legislative Frameworks

India's Wildlife Protection Act (1972) and Biological Diversity Act (2002) provide a legal backbone for biodiversity protection. Globally, agreements such as the Convention on Biological Diversity (CBD) and the Ramsar Convention are significant (CBD, 2020).

7. Technology in Conservation

Remote sensing, GIS, environmental DNA (eDNA), and genetic barcoding have improved monitoring and identification of aquatic species (Thomsen & Willerslev, 2015).

8. Climate Change Mitigation

Blue carbon ecosystems such as mangroves and seagrasses serve as natural carbon sinks, making their protection vital for climate adaptation (McLeod *et al.,* 2011).

Conclusion:

Aquatic biodiversity conservation demands an integrated approach that combines ecological restoration, sustainable resource use, pollution control, species protection, and strong community engagement. In the Indian context, conservation of rivers, wetlands, and coastal ecosystems requires greater emphasis on local participation alongside scientific innovations. Aligning biodiversity conservation with climate change adaptation and the UN Sustainable Development Goals will ensure resilience of aquatic ecosystems for future generations.

References:

1. Alongi, D. M. (2008). Mangrove forests: Resilience, protection from tsunamis, and responses to global climate change. *Estuarine, Coastal and Shelf Science, 76*(1), 1–13.
2. CBD (2020). *Convention on Biological Diversity: Global Biodiversity Outlook 5*. Montreal: Secretariat of the CBD.
3. Costanza, R., de Groot, R., Sutton, P., van der Ploeg, S., Anderson, S., Kubiszewski, I., Farber, S., & Turner, R. K. (2014). Changes in the global value of ecosystem services. *Global Environmental Change, 26*, 152–158.
4. FAO. (2020). *The state of world fisheries and aquaculture 2020: Sustainability in action*. Rome: Food and Agriculture Organization.
5. IPBES. (2019). *Global assessment report on biodiversity and ecosystem services*. Bonn: Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.
6. Islam, M. S., & Tanaka, M. (2004). Impacts of pollution on coastal and marine ecosystems including coastal and marine fisheries. *Marine Pollution Bulletin, 48*(7–8), 624–649.
7. Li, W. C., Tse, H. F., & Fok, L. (2016). Plastic waste in the marine environment: A review of sources, occurrence, and effects. *Science of the Total Environment, 566–567*, 333–349.
8. McLeod, E., Chmura, G. L., Bouillon, S., Salm, R., Björk, M., Duarte, C. M., ... & Silliman, B. R. (2011). A blueprint for blue carbon: Toward an improved understanding of the role of vegetated coastal habitats in sequestering CO_2. *Frontiers in Ecology and the Environment, 9*(10), 552–560.
9. MEA. (2005). *Ecosystems and human well-being: Biodiversity synthesis*. Washington, DC: World Resources Institute.
10. Nilsson, C., Reidy, C. A., Dynesius, M., & Revenga, C. (2005). Fragmentation and flow regulation of the world's large river systems. *Science, 308*(5720), 405–408.
11. Pauly, D., Christensen, V., Dalsgaard, J., Froese, R., & Torres, F. (2002). Fishing down marine food webs. *Science, 279*(5352), 860–863.

12. Pattnaik, A. K. (2007). Management of coastal wetlands: Lessons from Chilika Lake, India. *International Journal of Ecology and Environmental Sciences, 33*(2), 117–128.
13. Pitcher, T. J., Kalikoski, D., & Pramod, G. (2009). Evaluations of compliance with the FAO (UN) Code of Conduct for Responsible Fisheries. *Fisheries Centre Research Reports, 17*(2). University of British Columbia.
14. Pörtner, H. O., Karl, D. M., Boyd, P. W., Cheung, W. W., Lluch-Cota, S. E., Nojiri, Y., ... & Zavialov, P. O. (2014). Ocean systems. In *Climate change 2014: Impacts, adaptation, and vulnerability. IPCC AR5*.
15. Reeves, R. R., Smith, B. D., Crespo, E. A., & Notarbartolo di Sciara, G. (2003). *Dolphins, whales, and porpoises: 2002–2010 conservation action plan for the world's cetaceans*. Gland: IUCN.
16. Spalding, M. D., McIvor, A. L., Beck, M. W., Koch, E. W., Möller, I., Reed, D. J., ... & Tolhurst, T. J. (2013). Coastal ecosystems: A critical element of risk reduction. *Conservation Letters, 7*(3), 293–301.
17. Strayer, D. L. (2010). Alien species in fresh waters: Ecological effects, interactions with other stressors, and prospects for the future. *Freshwater Biology, 55*(Suppl. 1), 152–174.
18. Thomsen, P. F., & Willerslev, E. (2015). Environmental DNA—An emerging tool in conservation for monitoring past and present biodiversity. *Biological Conservation, 183*, 4–18.
19. UNEP. (2016). *Marine plastic debris and microplastics: Global lessons and research to inspire action and guide policy change*. Nairobi: United Nations Environment Programme.

SACRED FLORA: PLANTS AT THE HEART OF RITUALS AND CEREMONIES

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Introduction:

Since ancient times, plants have carried deep symbolic meanings, conveying emotions, spiritual values, and humanity's connection with nature. In many cultures, specific species are revered for their sacred and symbolic significance. Since the Vedic period people of the Indian subcontinent have developed rituals to honour and preserve elements of nature (Harshberger, 1896). Similarly, many indigenous cultures worldwide have practiced conservation-based traditions, preserving biodiversity through sacred beliefs and ceremonial practices (Chandraasian, 2022; Kavitha *et al.,* 2019). The Vedas and other scriptures mention numerous plant species used in worship, and this knowledge has been preserved and transmitted across generations (Mandal *et al*., 2020, Sneh Lata, *et al.,* 2022). However, despite its cultural and ecological importance, systematic scientific study of these practices remains limited (Kolte *et al*., 2012). The use of plants in local religious and ceremonial contexts reflects the richness of cultural heritage and the deep interconnection between humans and nature.

Across the globe, plants have been central to festivals and rituals, embodying purity, prosperity, protection, and spiritual connection (Sahay, 2022). Documenting these practices not only preserves traditional knowledge but also highlights the role of biodiversity in cultural and spiritual life. Academic research on how plants shape rituals, community practices, and cultural experiences is still limited. This offers valuable opportunities for research in botany, anthropology, and ecology with their cultural symbolism, medicinal properties, and conservation status. In Hindu tradition, every ritual associated with the stages of human life is deeply connected with plants and animals. In fact, no ceremony is considered complete without their involvement (Shende *et al*., 2021). This reflects a beautiful way of expressing gratitude towards nature, recognizing it as the ultimate provider. At the same time, it represents a wise and practical system of biodiversity conservation, where worship becomes a means of protecting and sustaining natural resources (Geng *et al*., 2017). Through such practices, respect for nature is instilled across generations, ensuring cultural continuity as well as ecological balance. Moreover, sacred plants and animals serve as powerful symbols of purity, prosperity, fertility, and protection in rituals ranging from birth ceremonies to marriage and even funeral rites. Thus, Hindu traditions embody a unique integration of spirituality, cultural identity, and environmental stewardship (Karle *et al*., 2025).

Maharashtra state, covers an area of approximately 308,000 km², the third-largest state in India, located between 15º 35′ to 22º 2′ north latitude and 72º 40′ to 80º 30′ east longitude. The state shares borders with Gujarat, Chhattisgarh, Madhya Pradesh, Andhra Pradesh, Karnataka, and Goa, as well as Union Territory of Dadra and Nagar Haveli. Arabian Sea at the west, bounded by the forming an extensive coastline. (Khare *et al*., 2020). In the present work, plants used in various rituals in Maharashtra, connected to human life events are documented, including their common names, botanical families, plant parts utilized, and specific purposes in rituals. This not only highlights their spiritual and cultural value but also emphasizes their ecological and medicinal significance.

Materials and Methods:

1. Data Collection:

Through Interviews data was collected using a random sampling method. Participants were selected based on their long experience in customs. It was focused on collecting information on the common names of plants, plant parts used, specific roles in festival rituals, associated medicinal properties, and their significance to conservation. Interviews with local community members provided valuable ethnobotanical knowledge and the cultural importance of various plant species in religious and celebrations.

2. Taxonomic Identification:

The Botanical names, family, classifications and taxonomic citations of the plant species were verified using the Flora of Bombay Presidency, Flora of Marathwada and International Plant Names Index (IPNI) database to confirm standardization. Information of the traditional uses of plants in religious and cultural perspectives was cross-referenced with historical literature, including the book Sanvar Vrat, Vaikalya.

3. Data Organization and Statistical Analysis:

The collected data was systematically organized in tabular format for clarity and ease of interpretation. Statistical analyses were conducted using MS Excel.

3. Results:

Table 1: Plants used in different life ceremonies

Sr. No.	Botanical Name	Common Name	Family	Plant Part Used	Use
	1. Pachavi pujan (Birth Ceremony)				
1	*Cocos nucifera* L.	Coconut	Arecaceae	Fruit	Worshipping Food
2	*Areca catechu* L.	Areca nut	Arecaceae	Seeds	Worshipping
3	*Triticum astivum* L.	Wheat	Poaceae	Seeds	Worshipping Food
4	*Oryza sativa* L.	Rice	Poaceae	Seeds	Worshipping Food
5	*Piper betel* L.	Betel leaf	Piperaceae	Leaves	Worshipping
6	*Curcuma longa* L.	Turmeric	Zingiberaceae	Rhizome	Worshipping Food
7	*Citrus limon* (L.) Osbeck	Lemon	Rutaceae	Fruit	Worshipping
8	*Opuntia elatior* Mill.	Cactus	Cactaceae	Leaves	Worshipping
9	*Spinach oleracea* L.	Spinach	Amaranthaceae	Leaves	Food
10	*Phoenix dactylifera* L.	Dates palm	Arecaceae	Fruit	Worshipping
11	*Prunus amygdalus* Batsch.	Almond	Rosaceae	Seeds	Worshipping Food
12	*Gossypium hirsutum* L.	Cotton	Malvaceae	Fruit	Worshipping
13	*Ferula assa-foetida* L.	Asafoetida	Apiaceae	Root	Worshipping Food
14	*Saccharum officinarum* L.	Sugarcane	Poaceae	Stem	Worshiping Food
	2. Munj				
1	*Ficus religiosa* L.	Sacred fig	Moraceae	Leaves	Worshipping
2	*Senegalia catechu* (L.f)J.H.Hurter and mabb.	Cutch tree	Fabaceae	Leaves	Worshipping

3	*Ficus racemosa* L.	Cluster fig	Moraceae	Leaves	Worshipping
4	*Butea monosperma* (Lam.) Kuntze	Flame tree	Fabaceae	Leaves	Worshipping
5	*Santalum album* L.	Sandalwood	Santalaceae	Leaves	Worshipping
6	*Mangifera indica* L.	Mango	Anacardiaceae	Leaves	Worshipping Food
7	*Prosopis cineraria* (L.) Druce	Shami	Fabaceae	Leaves	Worshipping
8	*Curcuma longa* L.	Turmeric	Zingiberaceae	Rhizome	Worshipping Food
9	*Areca catechu* L.	Areca nut	Arecaceae	Seeds	Worshipping Food
10	*Oryza sativa* L.	Rice	Poaceae	Seeds	Worshipping Food
	3. Vastupooja (Home Warming Ceremony)				
1	*Ocimum sanctum* L.	Basil	Lamiaceae	Leaves	Worshipping
2	*Cynodon dactylon* (L.) Pers.	Bermuda grass	Poaceae	Leaves	Worshipping
3	*Piper betel* L.	Betel leaf	Piperaceae	Leaves	Worshipping Food
4	*Aegle marmelos* L. Correa	Golden apple	Rutaceae	Leaves	Worshipping
5	*Mangifera indica* L.	Mango	Anacardiaceae	Leaves	Worshipping
6	*Ficus racemosa* L.	Cluster fig	Moraceae	Leaves	Worshipping
7	*Musa acuminata* L.	Banana	Musaceae	Leaves	Worshipping Food
8	*Oryza sativa* L.	Rice	Poaceae	Seeds	Worshipping Food
9	*Prosopis cineraria* (L.) Druce	Shami	Fabaceae	Leaves	Worshipping
10	*Calotropis procera* (L.) R.Br	Giant Milkweed	Apocynaceae	Leaves	Worshipping
11	*Syzygium cumini* (L.)	Black plum	Myrtaceae	Fruit	Worshipping Food
12	*Citrus sinensis* (L.) osbeck	Orange	Rutaceae	Fruit	Food

13	*Citrus limetta* Risso	Sweet lime	Rutaceae	Fruit	Food
14	*Malus domestica* (Suckow) Borkh.	Apple	Rosaceae	Fruit	Food
15	*Psidium guajava* L.	Guava	Myrtaceae	Fruit	Food
	4. Marriage Ceremony				
1	*Mangifera indica* L.	Mango	Anacardiaceae	Leaves, Fruit	Worshipping Food
2	*Ocimum sanctum* L.	Basil	Lamiaceae	Leaves	Worshipping
3	*Curcuma longa* L.	Turmeric	Zingiberaceae	Rhizome	Worshipping Food
4	*Areca catechus* L.	Areca nut	Arecaceae	Seeds	Worshipping Food
5	*Oryza sativa* L.	Rice	Poaceae	Seeds	Worshipping Food
6	*Triticum astivum* L.	Wheat	Poaceae	Seeds	Worshipping Food
7	*Phoenix dactylifera* L.	Dates palm	Arecaceae	Fruit	Worshipping Food
8	*Prunus amygdalus* Batsch.	Almond	Rosaceae	Seed	Worshipping Food
9	*Cocos nucifera* L.	Coconut	Arecaceae	Fruit	Worshipping Food
10	*Musa acuminata* L.	Banana	Musaceae	Leaves	Worshipping Food
11	*Piper betel* L.	Betel leaf	Piperaceae	Leaves	Worshipping Food
12	*Cynodon dactylon* (L.) Pers	Bermuda grass	Poaceae	Leaves	Worshipping
13	*Citrus limon* (L.) Osbeck	Lemon	Rutaceae	Fruit	Worshipping Food
14	*Saccharum officinarum* L.	Sugarcane	Poaceae	Stem	Worshipping
15	*Santalum album* L.	Sandalwood	Santalaceae	Leaves	Worshipping
16	*Tagets erecta* L.	Marigold	Asteraceae	Flower	Decoration Worshipping
17	*Chrysanthemum morifolium* Ramat.	Chrysanthemum	Asteraceae	Flower	Decoration Worshipping

18	*Citrus sinensis* (L.) osbeck	Orange	Rutaceae	Fruit	Food
19	*Citrus limetta* Risso	Sweet lime	Rutaceae	Fruit	Food
20	*Malus domestica* (Suckow) Borkh	Apple	Rosaceae	Fruit	Food
21	*Psidium guajava* L.	Guava	Myrtaceae	Fruit	Food
	5. Satynarayan pooja (Post Wedding Ceremony)				
1	*Musa acuminata* L.	Banana	Musaceae	Leaves Fruit	Worshipping Food
2	*Mangifera indica* L.	Mango	Anacardiaceae	Leaves Fruit	Decoration Food
3	*Saccharum officinarum* L.	Sugarcane	Poaceae	Stem	Worshipping
4	*Phoenix dactylifera* L.	Dry dates	Arecaceae	Fruit	Worshipping Food
5	*Prunus amygdalus* Batsch	Almond	Rosaceae	Seed	Worshipping Food
6	*Cocos nucifera* L.	Coconut	Arecaceae	Fruit	Worshipping Food
8	*Oryza sativa* L.	Rice	Poaceae	Seeds	Worshipping Food
9	*Triticum astivum* L.	Wheat	Poaceae	Seeds	Worshipping Food
10	*Areca catechu* L.	Areca nut	Arecaceae	Seeds	Worshipping Food
11	*Piper betel* L.	Betel leaf	Piperaceae	Leaves	Worshipping Food
12	*Ocimum sanctum* L.	Basil	Lamiaceae	Leaves	Worshipping
13	*Santalum album* L.	Sandalwood	Santalaceae	Leaves	Worshipping
14	*Tagets erecta* L.	Marigold	Asteraceae	Flower	Decoration Worshipping
15	*Chrysanthemum morifolium* Ramat.	Chrysanthemum	Asteraceae	Flower	Decoration Worshipping
16	*Curcuma longa* L.	Turmeric	Zingiberaceae	Rhizome	Worshipping
17	*Hibiscus rosa sinensis* L.	Hibiscus	Malvaceae	Flower	Decoration Worshipping

18	*Canna indica* L.	Kardal	Cannaceae	Flower, Leaves	Worshipping
	6. Jagran Gondhal (Post Wedding Ceremony)				
1	*Sorghum bicolor* (L.) Moench	Jowar	*Poaceae*	Seeds	Worshipping Food
2	*Curcuma longa* L.	Turmeric	Zingiberaceae	Rhizome	Worshipping Food
3	*Oryza sativa* L.	Rice	Poaceae	Seeds	Worshipping Food
4	*Triticum astivum* L.	Wheat	Poaceae	Seeds	Worshipping Food
5	*Cocos nucifera* L.	Coconut	Arecaceae	Fruit	Worshipping Food
6	*Piper betel* L.	Betel leaf	Piperaceae	Leaves	Worshipping Food
7	*Phoenix dactylifera* L.	Dry dates	Arecaceae	Fruit	Worshipping Food
8	*Prunus amygdalus* Batsch	Almond	Rosaceae	Seeds	Worshipping Food
9	*Saccharum officinarum* L.	Sugarcane	Poaceae	Stem	Worshipping
10	*Aegle marmelos* (L.) Correa	Golden apple	Rutaceae	Fruit, Leaves	Worshipping
11	*Curcuma longa* L.	Turmeric	Zingiberaceae	Rhizome	Worshipping
12	*Citrus limon* (L.) Osbeck	Lemon	Rutaceae	leaves	Worshipping
	7. Antyavidhi (Funeral)				
1	*Ocimum sanctum* L.	Basil	Lamiaceae	Leaves	Worshipping
2	*Azadirachta indica* A. Juss	Neem	Meliaceae	Leaves	Worshipping
3	*Ficus religiosa* L.	Sacred fig	Moraceae	Leaves	Worshipping
4	*Curcuma longa* L.	Turmeric	Zingiberaceae	Rhizome	Worshipping
5	*Oryza sativa* L.	Rice	Poaceae	Seeds	Food
6	*Triticum astivum* L.	Wheat	Poaceae	Seeds	Food

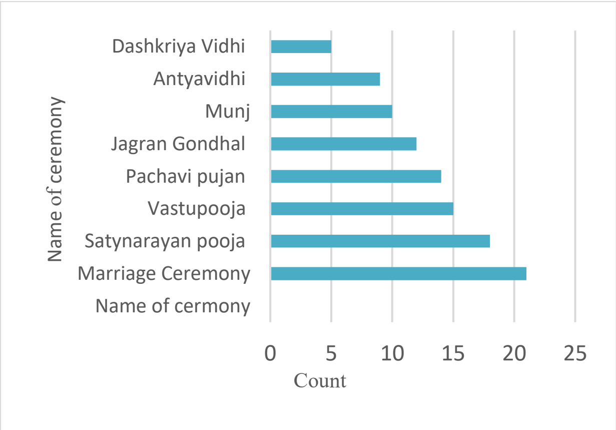
7	*Cenchrus spicatus* (L.) Cav	Pearl millet	Poaceae	Seeds	Food
8	*Santalum album* L.	Sandalwood	Santalaceae	Wood	Worshipping
9	*Aegle marmelos* (L.) Correa	Golden apple	Rutaceae	Fruit	Worshipping
	8. Dashkriya Vidhi (Post Funeral)				
1	*Oryza sativa* L.	Rice	Poaceae	Seeds	Worshipping, Food
2	*Ocimum sanctum* L..	Basil	Lamiaceae	Leaves	Worshipping
3	*Cynodon dactylon* (L) Pers	Bermuda grass	Poaceae	Leaves	Worshipping
4	*Sesamum indicum* L.	Sesame	Pedaliaceae	Seeds	Worshipping
5	*Triticum astivum* L.	Wheat	Poaceae	Seeds	Food

Table 2: Frequency of plants used in different ceremonies

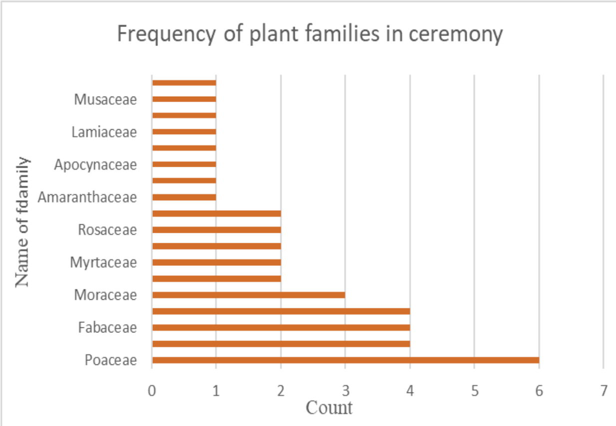
Sr. No.	Name of Ritual	No
1	Pachavi pujan (Birth ceremony)	14
2	Munj (Thread ceremony)	10
3	Vastupooja (home warming ceremony)	15
4	Lagna (Marriage Ceremony)	21
5	Satynarayan pooja (Post Wedding)	18
6	Jagran gondhal (Post Wedding)	12
7	Antyavidhi (Funeral)	09
8	Dashkriya Vidhi (Post Funeral)	05

Table 3: Plant part used in different ceremonies

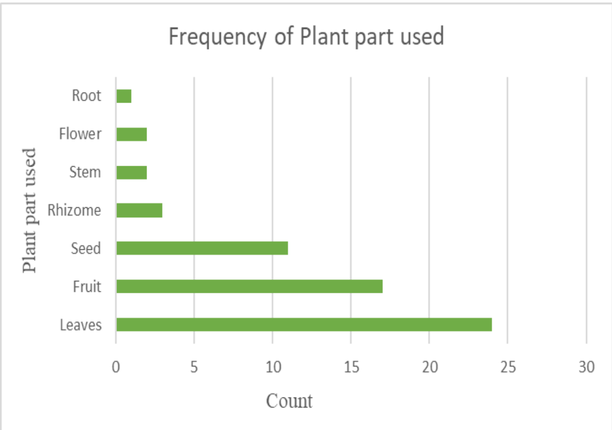
Sr. No	Plant Part Used	No.
1	Leaves	42
2	Seeds	22
3	Fruit	17
4	Rhizome	06
5	Stem	03
6	Flower	03
7	Root	01
8	Wood	01



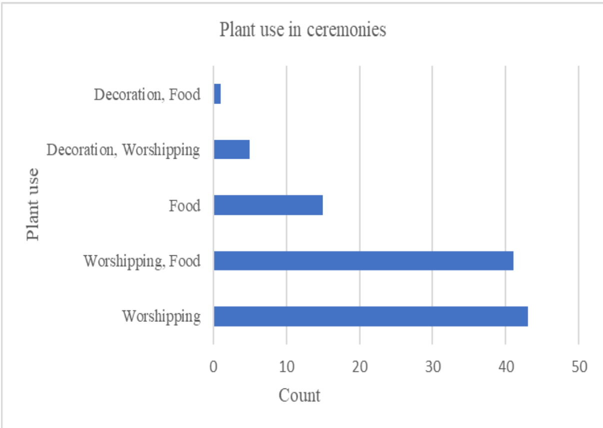
Frequency of plant used in ceremonies



Frequency of plant families in ceremonies



Frequency of plant parts used



Plant used in ceremonies

Conclusion:

The study highlights the significant role of plants in traditional ceremonies, reflecting both cultural symbolism and practical utility. Among the rituals, Pachavi Pujan (Birth Ceremony) records the highest frequency of plant use, indicating its rich botanical association.

Rice (*Oryza sativa*) is the most versatile plant, appearing in nearly all rituals except Antyavidhi, while Turmeric (*Curcuma longa*) and Coconut (*Cocos nucifera*) are also widely used across multiple ceremonies. At the family level, Poaceae, Arecaceae, and Fabaceae are dominant, emphasizing their ritualistic and dietary importance. In terms of plant parts, leaves and seeds are most frequently employed, largely for purposes of worship and food offerings. Overall, the findings reveal that plants are not merely ritual objects but serve as vital cultural symbols, sustaining traditions and linking communities with their ecological heritage.

Overall, the observed patterns highlight a strong cultural link between plants and concepts of purity, nourishment, and sanctity. The data suggest that while specific ceremonies emphasize different plant functions, food plants frequently double as worship items, thus blurring the boundary between material and spiritual needs. Furthermore, species such as basil and sandalwood transcend individual ceremonies, serving as culturally "universal" plants, deeply embedded in the collective spiritual consciousness.

References:

a. Harshberger, J.W. (1896). The purpose of Ethnobotany. *Botanical Gazette*, 21:146-154.

b. Satish Chandraasian, (2022). Documentation of the plant use in different hindu ritual in Uttarakhand India. Journal of Ethanobiology. *Asian Journal of Ethnobiology*, 19 (2): 92 101.

c. R. Kavitha, R. Pandiyalakshmi, P. Kalaimathi and A. Sarvalingam, (2019). Ritual plant used by religious cultural and rural societies of Virudhunagar district (South Tamil Nadu) India. *Trends in Kalis Research*, 12 (1):154-160.

d. R. R. Kolte, R. S. Kulkarni, P. V. Shinde, H. K. Padvekar, V. G. Magadum, S. A. Apate (2012). Studies on the ethno-medicinal plants used on the occasion of festivals with special reference to Ratnagiri district from Maharashtra state. *International Journal of Research in Engineering and Technology*, 1-5.

2. Ushashee Mandal, Monalisa Panda, Sagarika Parida and Gyanranjan Mahalik (2020). Plant Sources used for celebrating hindu ritual makar sankranti the uttarayan movement of sun. *Indian Journal of Natural Sciences,* 10(59):18548-18551.

3. Sneh Lata, Sheetal Sharma and Chitra Maurya (2022). Traditional use of plants in various rituals and ceremonies among Tharu tribe of Udham Singh Nagar, Kumaun Himalaya, Uttarakhand, India. *Plant Archives*, 22(1):334-342

4. Sahaya Mary C., Asha D. R. (2022). Traditional cuisine used during harvest festivals in India. *International Journal of Multidisciplinary Research and Development,* 9(9):77-82

5. Shende, J. J., and Dalal, L. P. (2021). Studies on the ethno medicinal plants used at the occasion of festivals in Wardha District, Maharashtra State, India. *International Journal of Innovative Research in Technology*, 8(4), 41-52
6. Geng Y., Hu G., Ranjitkar S., Shi Y., Zhang Y. and Yang Y. (2017). The implications of ritual practices and ritual plant use on nature conservation: A case study among the Naxi in Yunnan Province, Southwest China. *Journal of Ethnobiology and Ethnomedicine*, 13, 58.
7. Khare, U., Thakur, P., and Joshi, P. (2020). Temporal changes in urban population in Maharashtra state using GIS. *IOSR Journal of Humanities and Social Science (IOSR-JHSS)*, 25(10-2), 1-10.
8. Karle B. A. *et al.,* (2025). Ritual plants of Maharashtra: documentation, analysis, and cultural significance. *The Bioscan*, 20(1):114-124
9. Cooke T., (1901). The flora of Bombay Presidency vol. I –III. Botanical survey of India, Calcutta.
10. Naik V. N. (1998). Flora of Marathwada vol. I and II. Amrut Publication Aurangabad, Maharashtra.
11. https://www.ipni.org
12. https://www.tropicos.org

Biodiversity 360°: Development and Conservation

(ISBN: 978-81-992068-7-8)

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ISBN 978-81-992068-7-8

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