



The Green Prescription: Health and wellbeing through Biodiversity Conservation

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ABSTRACT: The remarkable diversity of life, encapsulated by biodiversity at various levels, faces significant threats underscoring the urgent need for conservation efforts and sustainable practices to safeguard human health and well-being. Habitat alteration, pollution, encroachments, unsustainable practices and climate change are major threats to biodiversity, posing risks to global health and contributing to the increased occurrence of infectious diseases. The convention on biological diversity and its Kunming-Montreal Global Biodiversity Framework exemplify global efforts towards biodiversity conservation, with goals to ensure the sustainable existence of ecosystems, prevent species extinction and promote fair benefit-sharing from genetic resources. India's Biological Diversity Act 2002 and the initiatives of the Kerala State Biodiversity Board illustrate national and local responses, emphasizing agrobiodiversity, threatened species conservation and the integration of traditional knowledge. These coordinated efforts highlight the critical role of biodiversity in maintaining ecosystem stability, supporting sustainable food systems, advancing healthcare and fostering a resilient society. The integration of biodiversity conservation with holistic health frameworks underscores the interconnectedness of human, animal and ecosystem health, advocating for collaborative solutions to global health challenges.

Key Words: Health and Biodiversity, Biodiversity Board, Biodiversity Conservation

INTRODUCTION

Biodiversity or biological diversity encompasses the wide variety of life forms present on earth, spanning three primary levels: genetic diversity, which indicates variations within species; species diversity, reflecting the abundance and types of living organisms; and ecosystem diversity, encapsulating a multitude of habitats, biological communities, and ecological processes. The biodiversity, comprising the multitude of species, genotypes and ecosystems, is intertwined with human health. It serves as a vital source of nutrients and medicines, contributing to ecosystem resilience and human well-being. At the genetic level, variation within and between species is essential for adapting to changing environmental conditions and mitigating the spread of pathogens. Genetic diversity also enables populations to

exhibit a range of observable traits, enhancing their ability to respond to environmental challenges and ensuring agricultural productivity. On the other hand, the diverse ecosystems, forests, grasslands, ponds and rivers harbour diverse communities of organisms that offer essential ecosystem services such as pollination, water purification and carbon sequestration, which are crucial for human well-being. Moreover, ecosystems regulate critical processes such as the water cycle, influencing water flow, sedimentation and water quality, thereby safeguarding important water resources.

Biodiversity is fundamental to providing food and vital nutrients, discovering and developing medicines and medicinal compounds, supplying fuel and energy, supporting livelihoods, and enriching cultural and spiritual experiences. Furthermore, biodiversity significantly contributes

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to ecosystem stability through its intricate role in maintaining food webs. Its social and cultural value influences activities such as recreation, tourism and artistic inspiration. The pathways through which biodiversity contributes to human health and well-being encompass psychological benefits of green spaces, physiological advantages of microbiome diversity, regulation of infectious diseases transmission, provision of nutritious food, clean air and water, as well as the development of traditional and modern medicines. Lastly, biodiversity serves as a cornerstone for scientific research and education, fostering a deeper understanding of life processes, genetic materials and other aspects of the natural world.

Biodiversity and human health

Health, as defined by the World Health Organization in 1948, represents a holistic state encompassing not only the absence of disease but also the attainment of complete physical, mental and social well-being, acknowledging the intricate interplay of various factors influencing health outcomes, including individual characteristics, behaviours, environmental conditions and socioeconomic status.^[1] One health, along with holistic frameworks such as eco health and planetary health, recognizes the intricate interplay between human health and the overall health of the planet, encompassing all living organisms, ecosystems and the broader environment. It represents a comprehensive approach that acknowledges the interdependence of human, animal and ecosystem health, highlighting the interconnected nature of global health challenges and the need for collaborative, interdisciplinary solutions.^[2,3]

Reflecting this interconnected perspective, the biodiversity hypothesis,^[4,5] elucidates the intricate interplay between microbial diversity and human immune function, suggesting that diminishing biodiversity precipitates alterations in immune responses and the onset of inflammatory diseases. The old friend's hypothesis^[6] also states that poor exposure to environmental microbiota is one of the key factors influencing immune-mediated diseases.^[7] Exposure to a diverse range of microbiota from the environment is deemed

essential for the regulation of human immune function, as elucidated by Rook^[12] and Roslund *et al.*^[8] Microbes inhabit every conceivable habitat where life thrives, including various human microbiotas, such as those in the gut, skin, airway, oral cavity, and genito-urinary tract.^[9,10] Beneficial connections between microbiota and host health have been observed, influencing bodily development, mood, and stress responses.^[11,12,13,14] With essential metabolic, immune and nutritional functions, the human intestinal microbiota has been likened to a “super-organism”.^[15]

In addition to microbial diversity, green spaces are vital to urban environments, mitigating many harmful effects of rapid urbanisation on health.^[16] The Biophilia hypothesis,^[17] suggests that humans have an inherent connection to nature and a healthy natural environment including green spaces is essential for human brain development, particularly during sensitive periods like the prenatal and early postnatal stages. On the other hand, the Stress Recovery Theory^[18] provides insights into how exposure to biodiverse environments can enhance mental and physical health by promoting stress reduction and attention restoration.^[19] Urban environments, lacking in greenery, have been associated with heightened risks of neuro developmental disorders like ADHD and autism spectrum disorders.^[20,21] Encouraging physical activity through access to green spaces also emerges as a crucial strategy for mitigating the burden of non-communicable diseases (NCDs) and promoting overall well-being, particularly given the rising prevalence of sedentary lifestyles associated with ailments like Type 2 diabetes. Complementing the benefits of green spaces, spiritual traditions worldwide also demonstrate a profound interconnection with biodiversity. Sacred natural sites, such as groves and forests dedicated to local deities, serve as vital repositories of biodiversity, often safeguarded through religious taboos against ecological harm. This deep connection with nature, as articulated in spiritual traditions, has been linked to numerous health benefits, including reduced stress, improved mental well-being and enhanced overall quality of life.^[22]

Medicines from Biodiversity

The Indigenous peoples living in harmony with nature, often reliant on local biodiversity for healthcare and livelihoods, hold essential knowledge about their environments, emphasizing the importance of equitable access to biodiversity resources. With an estimated 50,000 to 70,000 species of medicinal plants utilized worldwide, these botanical remedies have been integral to traditional healing practices for centuries, gaining increasing recognition in modern healthcare due to their validated efficacy.^[23] The vast array of biologically active compounds produced by various organisms over billions of years presents an endless reservoir of potential medicines for human ailments. Plants, for instance, have yielded invaluable compounds such as morphine from the Opium Poppy (*Papaver somniferum* L.), aspirin from the White Willow Tree (*Salix alba*), paclitaxel from the Pacific Yew tree (*Taxus brevifolia*), anti-diabetic medications like metformin from the French Lilac (*Galega officinalis* L.), Quinidine derived from the bark of South American Cinchona tree (*Cinchona* sp.) for the treatment of cardiac arrhythmias, vinblastine from periwinkle plant (*Catharanthus roseus* (L.) G. Don) to fight Hodgkin's disease, vincristine is also derived from the same plant used for acute childhood leukemias^[24] and etoposide from the American Mayapple plant (*Podophyllum hexandrum* Royle), underscoring the indispensable role of plant-derived medicines in modern healthcare. Similarly, medicines derived from animals, such as captopril from the venom of the Brazilian Pit Viper (*Bothrops jararaca*) and exenatide from the saliva of the Gila monster (*Heloderma suspectum*), hirudin from the saliva of leeches (*Hirudinaria*), cytarabine, derived from a Caribbean sponge (*Xestospongia muta*) used for the treatment of acute leukemia highlight the diverse contributions of fauna to medicinal science. Microbes, meanwhile, have bestowed humanity with life-saving antibiotics like erythromycin from *Streptomyces erythraeus* and vancomycin from *Amycolatopsis orientalis*, as well as immunosuppressants like cyclosporine from *Tolypocladium inflatum* and anti-cancer

agents like bleomycin from *Streptomyces verticillus*. This symbiotic relationship between biodiversity and human health is further emphasised by the concept of the “dilution effect,” where declining species diversity diminishes the pool of potential medicines available to humanity, thereby hindering our ability to combat diseases effectively.^[25,26,27,28] Therefore, biodiversity conservation is paramount not only for safeguarding human health but also for advancing pharmaceutical innovation and healthcare advancement in the face of emerging health challenges.

Agricultural biodiversity

Building upon the vital role of biodiversity in human health, agricultural biodiversity emerges as a solution to address the complex challenges of malnutrition and food insecurity facing populations worldwide. Micronutrient deficiencies afflict over two billion individuals, impairing growth, development and productivity, while rising rates of overweight and obesity affect another two billion people globally. Moreover, countries are fighting with the complex coexistence of undernutrition, micronutrient deficiencies, overweight and obesity within the same populations, leading to what is termed the “double burden” of malnutrition.^[29] In this scenario, agricultural biodiversity offers a solution to mitigate these health crises and enhance food security. The maintenance of genetic diversity within production systems is indispensable for providing ecosystem services such as pest and disease control, pollination and soil health, thereby enhancing agricultural sustainability and supporting human health.^[30]

Agricultural biodiversity, encompassing the diverse array of animals, plants and microorganisms within agroecosystems, constitutes fundamental components of global food production systems and significantly impacts human health and well-being. Managed and influenced by farmers, pastoralists, fishers and forest dwellers, agricultural biodiversity underpins the stability, adaptability and resilience of farming systems worldwide. Apart from the agricultural food source, wild foods are also an essential component of human nutrition,

contributing significantly to dietary diversity and nutritional adequacy. Across various ecosystems, from forests to coastal regions, a plethora of wild plant and animal species offer a rich array of nutrients, including essential vitamins, minerals, and proteins.

Threats to biodiversity

The remarkable diversity of life, encapsulated by biodiversity at various levels, faces significant threats underscoring the urgent need for conservation efforts and sustainable practices to safeguard the rich biodiversity for human well-being. Habitat alteration, pollution, encroachments, cattle grazing, collection of firewood, mass tourism and pilgrimage, poaching, unscientific collection of non-timber forest produce, unsustainable mining and quarrying, forest fires, illicit felling, invasive species and other anthropogenic activities, along with climate change, are acting as major threats to biodiversity.^[31] The escalating loss of biodiversity, driven by various aforementioned factors, poses risks to global health. Furthermore, biodiversity loss has been implicated in the heightened occurrence of infectious disease outbreaks, exemplified by the COVID-19 pandemic. The emergence of infectious diseases like Ebola, HIV/AIDS, SARS, MERS and COVID-19 underscores the intricate connections among biodiversity, global environmental changes and human health. On the other hand, Vector-borne diseases (VBDs) are also now a significant health concern globally, caused by parasites, viruses, or bacteria transmitted by vectors like mosquitoes, ticks and sandflies. The dynamics of VBDs involve intricate interactions among vectors, pathogens and hosts, with climatic changes and biodiversity playing crucial roles. Efforts to understand the complex interactions between ecosystem services, human activities, and well-being are imperative to mitigate the adverse impacts of biodiversity loss on human health.^[33] It emphasises the imperative for integrated, transdisciplinary approaches such as One Health and other holistic methodologies to address the complex interplay between the health of people, animals, plants and the shared environment. Moreover, Global cooperation is

crucial to address environmental challenges, conservation of biodiversity and maintain ecosystem health for human health (CBD, 2021).^[32]

Policies and international initiatives for biodiversity conservation

In this context, the Convention on Biological Diversity (CBD) emerges as a comprehensive legally binding international agreement that addresses all aspects related to biodiversity. Adopted at the Earth Summit in Rio de Janeiro in 1992, the CBD has three main objectives: conservation of biodiversity, sustainable use of its components and fair and equitable sharing of benefits arising from the use of these resources. The Conference of the Parties (CoP) is the governing body of the CBD, comprising representatives from member countries. The 15th Conference of the Parties (COP 15) to the UN Convention on Biological Diversity in 2022 adopted the historic Kunming-Montreal Global Biodiversity Framework (KMGBF). KMGBF includes 4 main goals to be achieved by 2050 and 23 targets to be achieved by 2030. Goal (a) Ensure the sustainable existence of ecosystems, significantly increase natural habitat areas by 2050, prevent human-induced extinction of species and conserve genetic diversity. (b) Use biodiversity sustainably, assess and improve the contribution of ecosystem functions and services, and achieve the Sustainable Development Goal by 2050 for present and future generations, with a focus on the restoration of threatened ecosystems. (c) ensure fair and equitable sharing of benefits from genetic resources and traditional knowledge with indigenous peoples and local communities, including appropriate protection of traditional knowledge for biodiversity conservation and sustainable use in accordance with international agreements; (d) Bridging the financial gap of \$700 billion in annual appropriations for biodiversity conservation. In line with the KMGBF, the Indian Government is in the process of setting the national goals and targets and the Kerala State Biodiversity Board is also in the process of updating the Kerala State Biodiversity Strategy and Action Plan incorporating state goals and targets similar to

KMGBF. These efforts will check the biodiversity loss to some extent and which will in turn result in maintaining the ecosystem health.

Policies and national initiatives for biodiversity conservation

India is a Party to the Convention on Biological Diversity (CBD), and the Ministry of Environment, Forest and Climate Change (MoEFCC) serves as the nodal Ministry for implementing the CBD in the country. In line with the CBD, India has framed the Biodiversity Act (2002) and Regulations (2004) to ensure effective management, conservation and sustainable use of India's rich biological resources, intellectual property rights related to biological resources and to fully implement the responsibilities vested in it as a member state of the Convention on Biological Diversity. Consisting of 12 chapters and 65 sections, the Biodiversity Act is a powerful legislative framework for the conservation and sustainable use of India's biodiversity.

The Biodiversity Act contains key provisions for the conservation of biodiversity and the well-being of human health. The Act establishes the National Biodiversity Authority (NBA), State Biodiversity Boards (SBBs), and Biodiversity Management Committees (BMCs), detailing their powers, functions, finance and audit procedures. Thus, it is a three-tier system to implement the provisions of the Biodiversity Act in our country and coordinate conservation activities. The Act contains provisions for the creation of National, State and Regional Biodiversity Funds to finance conservation activities through various grants and resource utilisation (Sections 27, 32, and 43). To ensure biodiversity conservation and sustainable use, Section 36 mandates the development of National Biodiversity Strategies and Action Plans, fulfilling obligations under the Convention on Biological Diversity (CBD). The state government can identify and notify important biodiversity areas as Biodiversity Heritage Sites, engaging local communities in conservation efforts without restricting indigenous practices (Section 37). The Act also contains provisions to declare species as endangered or threatened, prohibiting or restricting their collection and taking steps for their rehabilitation (Section 38).

To ensure the conservation and sustainable utilisation, the Act also regulates the unauthorised access for commercial utilisation, research, bio-survey and bio-utilization of biological resources and traditional knowledge from India, requiring foreign nationals, Non-Resident Indians (NRIs), and foreign-controlled entities to obtain prior approval from the National Biodiversity Authority (NBA) for these activities (Sections 3, 4, and 5). Additionally, the transfer of research results on Indian biological resources or traditional knowledge to foreign entities also requires NBA approval, with exceptions for publications and seminars approved by the Central Government. Cooperative research projects complying with Central Government guidelines are exempt from these regulations. Entities must not apply for intellectual property rights on research or discoveries related to Indian biological resources or traditional knowledge without NBA approval (Section 6). Indian citizens and organisations must inform the State Biodiversity Board before commercialising biological resources or associated traditional knowledge, with certain exemptions (Section 7). The Act allows for the imposition of fees, royalties, or other conditions, including benefit sharing, when granting permission to use biodiversity and traditional knowledge for intellectual property or industrial purposes so as to conservation of the biodiversity and protection of IPR.

Section 39 of the Act, authorises the Central Government to designate institutions for storing biological resources and voucher specimens, ensuring proper documentation and conservation of newly discovered taxa. Biological resources normally traded as commodities are exempt from the Act's provisions unless used for other purposes (Section 40). BMCs are empowered to conserve local biodiversity, sustain ecosystems, protect traditional breeds and knowledge, and prepare People's Biodiversity Registers (PBRs). They can levy fees on industrial users of biological resources, ensuring local community involvement and benefit (Section 41). Finally, Section 55 outlines penalties for violations of the Biodiversity Act, ensuring compliance and enforcement of its provisions. These measures collectively aim to

conserve biodiversity, promote sustainable use, and protect traditional knowledge, contributing to environmental and human health and well-being.

INITIATIVES OF KERALA STATE BIODIVERSITY BOARD

Promoting the health and well-being of humans can be achieved through the conservation of agricultural diversity, which is crucial for ensuring food security. To address this, the Kerala State Biodiversity Board (KSBB) has initiated various programs focused on conserving agrobiodiversity. One significant initiative was a flagship project supported by the Rebuild Kerala Initiative of the Government of Kerala, initiated to assess the status of agrobiodiversity and the impact of floods on agricultural diversity in eight severely affected districts of the state. Additionally, it aimed to conserve existing agrobiodiversity. As part of this project, 800 custodian farmers, with 100 from each district, were selected. Among them, 160 farmers, 20 from each district were provided support to establish farm schools. These 160 farm schools serve as platforms for sharing knowledge and best practices in agrobiodiversity conservation of the State. Furthermore, Seed Fest and seed exchange programs were conducted to facilitate the exchange of seeds, contributing to the conservation of agrobiodiversity.

Another significant initiative in this regard is the Ecological restoration and Agrodiversity conservation project of KSBB at College of Agriculture, Vellayani. Under this project State wide survey, germplasm collection of wild relatives/land races and farmers varieties of different crops and development of a digital database of agrodiversity of Kerala is in progress. Establishment of agrodiversity conservatory of wild relatives/ land races and farmers varieties of prioritized crops including rice, vegetables, fruit plants, millets, legumes, tuber crops and spices are also being done. Construction of Seed banks and Millet Museum under this project is also in progress.

KSBB has initiated a statewide project titled “Identification, Database Creation, Propagation, Conservation, and Value Addition of Wild and Underutilized Agricultural Crops in Kerala,” with

support from 18 partners, including agricultural universities and research institutes. This project aims to identify and catalog wild and underutilized agricultural crops, conserve them and develop value-added products from these resources. Many of these crops are consumed by tribal communities and are rich in carbohydrates, fats, proteins, energy, vitamins, minerals and dietary fiber. The project covers a range of wild edible fruits, vegetables, tubers, rhizomes, legumes, millets and pulses. By promoting the development of value-added products, particularly those with potential economic and nutritional benefits for tribal communities, the project aims to enhance food security and livelihoods. Through these initiatives, KSBB aims to safeguard agricultural diversity and promote sustainable food production practices in Kerala.

The decline in biodiversity has been linked to increased occurrences of infectious disease outbreaks and various human health issues. Therefore, preserving species diversity is crucial. It's essential to assess which species are under threat across different categories to address this concern effectively. In this regard, KSBB in collaboration with Jawaharlal Nehru Tropical Botanic Garden and Research Institute (JNTBGRI) Palode, has compiled a detailed report on threatened species of Kerala using the criteria of the International Union for Conservation of Nature (IUCN). This comprehensive document identifies 1274 taxa across various plant groups, including bryophytes, pteridophytes, gymnosperms, and angiosperms. Among these, 264 species of flowering plants are deemed to be facing extinction, with 44 categorized as Critically Endangered (CR), 113 as Endangered (EN) and 107 as Vulnerable (VU). Additionally, four gymnosperms, three pteridophytes and one bryophyte are also listed as ‘threatened’ in the State.

Based on the above findings, KSBB has initiated a significant program, supported by 21 institutes, to conserve threatened species of the state. This effort includes establishing conservatories dedicated to threatened species across Kerala and distributing planting materials, demonstrating a

proactive approach to biodiversity protection. Through strategic placement of these facilities statewide, KSBB seeks to safeguard a diverse array of species within their natural environments. Besides, a project for developing nurseries of rare, endangered and threatened plants and their propagation through Kudumbasree in Thiruvananthapuram district of Kerala has been initiated. It was aimed to provide livelihood opportunities to the Kudumbasree workers and ensure quality planting materials of threatened species. Training was provided to selected Kudumbasree workers of Thiruvananthapuram with the support of JNTBGRI and disseminated awareness on different propagation techniques, setting up of nurseries, planting operations and aftercare of selected threatened species. Seedlings/planting materials of different species, including threatened species and indigenous variety of fruit trees were also supplied to the trainees.

Climate change, along with its associated challenges such as biodiversity loss, disease outbreaks, and the rise of infectious diseases, presents significant threats to both biodiversity and public health. Therefore, there is an urgent need for strategic approaches to both mitigate and adapt to these changes. In response to this, KSBB, in collaboration with the Ministry of Environment, Forest & Climate Change and the United Nations Development Programme (UNDP), with funding from the Global Environment Facility (GEF), has updated the Kerala State Biodiversity Strategies and Action Plan for 2022-2032. This plan identifies major threats to biodiversity in Kerala across various sectors and provides policy recommendations for biodiversity conservation, along with a detailed action plan for the next decade. Key areas of focus include the restoration of degraded forest ecosystems, enhancing the carbon sink potential of forests, building resilience against climate extremes like floods, droughts and landslides.

Additionally, KSBB has launched the preparation of a Local Action Plan for Biodiversity conservation and management based on people's biodiversity registers. This initiative aims to

translate international and national biodiversity and climate change policies and targets into actionable plans at the local level. Furthermore, KSBB has initiated a unique endeavour to conduct green audits, evaluating and promoting environmental performance and sustainability initiatives across diverse sectors such as industries, educational institutions, governmental agencies, commercial establishments and residential communities. By integrating green auditing with sustainability initiatives, organizations demonstrate their commitment to environmental stewardship, inspiring others to join in the fight against climate change and contribute to a resilient and sustainable future for all.

The conservation of biodiversity is connected to the nation's health security, and endeavours that foster the conservation and sustainable utilization of biodiversity also offer a range of health benefits. In this regard KSBB has been conducting various biodiversity conservation activities. KSBB conducted a comprehensive study on tradable bioresources in Kerala, aiming to identify various floral bioresources being traded, assess their volume and economic potential and inventory bioresource-based industries operating in the state. This project covered bioresources from forests, outside forests, marine, and freshwater resources. The study aimed at consolidating data on the current status and utilization of bio-resources, depletion levels, conservation initiatives and alternate uses, as well as formulating policies for managing these resources.

KSBB has initiated the preparation of comprehensive guidelines related to Traditional Knowledge to empower Biodiversity Management Committees (BMCs) across the state. The primary aim of these guidelines is to equip BMCs with the knowledge and tools necessary to conduct comprehensive studies on the current status, collection, conservation and sustainable utilization of Traditional Knowledge (TK) associated with biodiversity, while also facilitating the implementation of Access and Benefit Sharing of TK. The guidelines will pave the way for the seamless integration of traditional knowledge into the Gramapanchayat level planning process, promoting innovation and collaboration

with research institutions in the development of new herbal drugs, nutraceuticals and plant-based products. The KSBB has recognized invasive species as a significant threat to the state's biodiversity. Consequently, organised a two-day National Seminar on bioinvasions, focusing on trends, threats and management strategies. Drawing from insights gathered during the conference and inputs from subject experts, KSBB is currently developing a comprehensive policy to control and manage invasive species in Kerala.

CONCLUSION

Conservation of biodiversity is foundational to human health and environmental sustainability, necessitating urgent, coordinated efforts at global, national and local levels. Global frameworks like the Convention on Biological Diversity, national legislations such as India's Biological Diversity Act 2002, and local initiatives by bodies like the Kerala State Biodiversity Board collectively contribute to these efforts. KSBB's diverse projects in agrobiodiversity, threatened species conservation and integration of traditional knowledge exemplify effective, community-engaged conservation strategies. These initiatives not only promote sustainable resource use, equitable benefit sharing and resilience against climate change but also ensure food security, advance healthcare and maintain ecosystem stability. Recognizing the interconnectedness of human, animal and ecosystem health, holistic health frameworks advocate for collaborative solutions to global health challenges. Preserving biodiversity is essential for maintaining cultural values and the continued discovery of medical advancements, underscoring its irreplaceable role in fostering a healthy, resilient society.

References

1. Robinson, J., Breed, A., Camargo, A., Redvers, N., & Breed, M. (2022). Biodiversity and Human Health: A Scoping Review and Case Studies on Underrepresented Linkages. *Environmental Research* 246(9): 118115
2. World Health Organization. (2021). Nature, biodiversity and health: an overview of interconnections. University of Exeter, European Centre for Environment & Health. 32p. <https://iris.who.int/bitstream/handle/10665/341376/9789289055581-eng.pdf?sequence=1>
3. Romanelli, C., Cooper, D., Campbell-Lendrum, D., Maiero, M., Karesh, W. B., Hunter, D., & Golden, C. D. (2015). Connecting global priorities: biodiversity and human health: a state of knowledge review. World Health Organisation/Secretariat of the UN Convention on Biological Diversity.
4. Von H. L., Hanski I., Haahtela T. Natural immunity (2011). Biodiversity loss and inflammatory diseases are two global megatrends that might be related. *EMBO Rep*, 12: 1089-1093.
5. Haahtela, T. (2019). A biodiversity hypothesis. *Allergy*, 74(8): 1445-1456
6. Rook, G. A. W. (2010). 'old friends' hypothesis. *Clin. Exp. Immunol.* 160:70-79.
7. Roslund, M. I., Parajuli, A., Hui, N., Puhakka, R., Grönroos, M., Soininen, L., Rajaniemi, J. (2022). A placebo-controlled double-blinded test of the biodiversity hypothesis of immune-mediated diseases: environmental microbial diversity elicits changes in cytokines and increase in T regulatory cells in young children. *Ecotoxicology and Environmental Safety*, 242.
8. Rook, G.A (2013). Regulation of the immune system by biodiversity from the natural environment: an ecosystem service essential to health. *Proceedings of the National Academy of Sciences*, 110: 18360-18367.
9. Roslund, M. I., Puhakka, R., Nurminen, N., Oikarinen, S., Siter, N., Grönroos, M., Cinek, O., Kramná, L., Jumpponen, A., Laitinen, O. H., Rajaniemi, J., Hyöty, H., Sinkkonen, A., Cerrone, D., Grönroos, M., Hui, N., Mäkelä, I., Nurminen, N., Oikarinen, S., Sinkkonen, A. (2021). Long-term biodiversity intervention shapes health-associated commensal microbiota among urban day-care children. *Environment International*, 157
10. Liddicoat, C., Waycott, M., & Weinstein, P. (2016). Environmental change and human health: can environmental proxies inform the biodiversity hypothesis for protective microbial-human contact?. *BioScience*, 66(12): 1023-1034.
11. Haahtela, T., Bousquet, J., & Antó, J. M. (2024). From biodiversity to nature deficiency in human health and disease. *Porto Biomedical Journal*, 9(1): e245.
12. Round, J.L and Mazmanian, S.K. (2009). The gut microbiota shapes intestinal immune responses during health and diseases. *Nature Reviews Immunology* 9 (50): 313-23.
13. Jose E Belizario and Mauro Napolitano (2015). Human microbiomes and their roles in dysbiosis, common diseases and novel therapeutic approaches. *Front Microbial* 6: 6; 1050
14. Margaret McFall-Ngao, Michael G. Hadfield, Thomas C. G. Bosch and Jemnifer J. Wernegreen (2013). Animal in a bacterial world, a new imperative for the lifesciences. *Biological Sciences*, 110(9): 3229-3236.

15. Purchiaroni, F., Tortora, A., Gabrielli, M., Bertucci, F., Giganta, G., Ianiro, G., Ojetti, V., Sarpellini, E., Gasbarrini (2013). The role of intestinal microbiota and the immune system. *Eur Rev Med Pharmacol Sci* 17(3): 323-33
16. Gascon, M., Triguero-Mas, M., Martínez, D., Dadvand, P., Rojas-Rueda, D., Plasència, A., & Nieuwenhuijsen, M. J. (2016). Residential green spaces and mortality: A systematic review. *Environment International*, 86: 60–67.
17. Wilson, E. O. (1984): *Biophilia, the Human Bond With Other Species*. Harvard University Press, Cambridge (Massachusetts), 157 p
18. Ulrich, R.S., Simons, R.F., Losito, B.D., Fiorito, E., Miles, M.A. and Zelson, M. (1991) Stress Recovery during Exposure to Natural and Urban Environments. *Journal of Environmental Psychology*, 11: 201-230.
19. Donovan, G. H., Gatzliolis, D., Mannelje, A. T., Weinkove, R., Fyfe, C., & Douwes, J. (2021). An empirical test of the biodiversity hypothesis: Exposure to plant diversity is associated with a reduced risk of childhood acute lymphoblastic leukemia. *Science of The Total Environment*, 768: 144.
20. Lovell, R., Wheeler, B. W., Higgins, S. L., Irvine, K. N., & Depledge, M. H. (2014). A systematic review of the health and well-being benefits of biodiverse environments. *Journal of Toxicology and Environmental Health, Part B*, 17(1): 1-20.
21. Li, H., Jansen, R. E., Sijuwade, C., Macura, B., Giusti, M., & Jørgensen, P. S. (2024). What evidence exists regarding the impact of biodiversity on human health and well-being? A systematic map protocol. *Environmental Evidence*, 13(1): 11.
22. Kellert S R (2006); Building for Life: Designing and Understanding the Human-Nature Connection, *RENEWABLE RESOURCES JOURNAL*, 8: 24
23. Schippmann, U. W. E., Leaman, D., & Cunningham, A. B. (2006). A comparison of cultivation and wild collection of medicinal and aromatic plants under sustainability aspects. *Frontis*, 75-95
24. Alves, R2. R., & Rosa, I. M. (2007). Biodiversity, traditional medicine and public health: where do they meet?. *Journal of ethnobiology and ethnomedicine*, 3, 1-9.
25. Halliday, F. W., Rohr, J. R., & Laine, A. L. (2020). Biodiversity loss underlies the dilution effect of biodiversity. *Ecology letters*, 23(11): 1611-1622.
26. Halsey, S. J., & Miller, J. R. (2020). Maintenance of *Borrelia burgdorferi* among vertebrate hosts: a test of dilution effect mechanisms. *Ecosphere*, 11(2): e03048.
27. Strauss, A. T., Civitello, D. J., Cáceres, C. E., & Hall, S. R. (2015). Success, failure and ambiguity of the dilution effect among competitors. *Ecology letters*, 18(9): 916-926
28. Wood, C. L., McInturff, A., Young, H. S., Kim, D., & Lafferty, K. D. (2017). Human infectious disease burdens decrease with urbanization but not with biodiversity. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 372: 1722.
29. Popkin B M, Corvalan C, Grummer-Strawn L M. (2020) Dynamics of the double burden of malnutrition and the changing nutrition reality. *The Lancet*, 65-74
30. Jarvis D.I., C. Padoch, H.D. Cooper (2011) Managing biodiversity in agricultural ecosystems, *Genetic Resources and Crop Evolution* 795-796
31. Marselle, M. R., Stadler, J., Korn, H., Irvine, K. N., & Bonn, A. (2019). *Biodiversity and health in the face of climate change*, p. 481.
32. Biodiversity and health, Convention on Biological Diversity (2021)
33. Díaz, S., J. Settele, E. S. Brondízio, H. T. Ngo, M. Guèze, and J. Agard. “& Zayas, C. (2019). Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services.” Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (2020).

