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Biodiversity, a guarantee of health?

A natural or nearly natural environment has a positive effect on human health in many ways. This means that a natural environment can also help meet public health challenges. These include obesity, certain chronic, infectious and non-communicable diseases, depression and anxiety, and also child development and cognitive aging. In order to give everyone contact with and access to high-quality nature, it is advisable to strengthen the development and conservation of green spaces and natural landscapes with rich biological diversity. This requires close cooperation at local and national level between public health, urban development, spatial planning and nature conservation. At the same time, inter- and transdisciplinary research is needed to increase knowledge about the links between health and biodiversity.

A major challenge worldwide is to ensure healthy lives and promote well-being for all humans of all ages.[1] In industrial countries, increased urbanisation and environmental change pose significant challenges to human health. They lead among others to a rise in non-communicable diseases associated with modern lifestyles (e.g. obesity and cardiovascular disease), mental disorders, diseases associated with pollution as well as allergic and non-infectious inflammatory disease.[2]

The natural and near-natural environment with its biodiversity and the ecosystem services it supports have clear linkages to health and well-being.[2–8] Therefore, the massive and continuous loss of biodiversity that is taking place in Switzerland and across the world is likely to have a negative impact on health.[3, 9, 10] Some well-known examples are provision of pharmaceuticals, food and nutrition security, clean air, freshwater purification, climate regulation and sequestration of pollutants. Less known are the linkages between the exposure to natural or near-natural environments and mental as well as physical health, and the linkages between biodiversity, infectious, allergic and inflammatory disease and the relationship of the microbiome to health.

Human Health is the state of complete physical, mental and social well-being and not merely the absence of disease or infirmity.[11]

Biodiversity is the diversity of life. It covers the diversity of genes (breeds or varieties of wild and domestic species), species (animals, plants, fungi, microorganisms) and ecosystems (habitats such as water, forest, alpine space) and their interactions.[12]

Ecosystem services are the benefits people obtain from ecosystems and their biodiversity. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services, such as nutrient cycling, that maintain the conditions for life on Earth.[13]

The microbiome is defined as all microorganisms (composed of bacteria, bacteriophages, fungi, protozoa and viruses) that live inside and on the human body and their interactions with the environment.

The environment or landscape is **natural or nearly natural** if it takes into account the requirements of nature and is not shaped exclusively by man. Natural or near-natural environments include urban parks, schoolyards and playgrounds, gardens and other green spaces in urban areas, structurally rich agricultural lands, forests and other natural spaces favorable for biodiversity.

Linkages between natural environment and mental as well as physical health

There is growing scientific evidence that exposure to nature contributes positively to health and well-being by reducing mortality (especially cardio-vascular mortality)[14,15] and cognitive aging[16], improving mental health and well-being (e.g. reduction in stress, fatigue, anxiety and depression)[14,17,18], supporting attention restoration[19], raising birth weights[20,21], lowering obesity rates[22] and increasing self-rated health.[3,14,23–29] There is also evidence that interaction with natural landscape is linked with more favourable heart rates, blood pressure, vitamin D levels, recuperation rates, cortisol levels, reduction in type 2 diabetes prevalence[26] as well as human immune function.[30] A green space potentially facilitates social contact and enhances social cohesion (e.g. reducing loneliness, providing opportunities to build social support systems and produce feelings of social safety) with significant benefits for health and well-being.[26,28] Besides urban green areas, green school yards[31–33], gardens, agricultural zones and forests, water bodies seem relevant as well.[34,35]

Three main mechanisms are involved in the health benefits of contact with nature. Natural and near-natural landscapes provide areas in which people can be physically active, socialise with family and friends and facilitate relaxation, mental restoration and stress reduction.[28,36]

However, generalisation requires caution as the benefits offered are influenced by many interacting or confounding factors.

Important green spaces

It is generally agreed that nearby green spaces support human health and that this proximity matters.[37,38] There does not seem to be empirical support for a specific distance cut-off value though because green areas further than 200–300 m away have also been associated with health benefits. While larger areas with more natural vegetation might offer greater or deeper psychological restoration, even small green areas nearby help to improve mental health. Therefore, a cumulative opportunity indicator taking all the green spaces of any size within a certain distance into account seems more consistently positively related to health than distance alone.[37] Moreover, in times of decreasing daily interaction of urban people with nature, a positive relationship was noted between daily nature 'dose' and mental health.[39–41]

Research has so far focused on the visual aspects of nature experience. Non-visual avenues, in particular auditory (e.g. bird songs[42]), but also smell (e.g. phytoncides[30,43]), taste and touch, are potentially important for delivering health benefits from nature experience, but the evidence base is still weak.[44–47]

A growing body of research demonstrates associations between a strong personal nature connection (the mix of feelings, attitudes, beliefs and behaviours that people have towards nature), and a variety of positive health and well-being outcomes or mediating factors.[40,48–50]

The health benefits from use of green spaces often differ across sociological, demographic and cultural groups. Although the linkages are often inconclusive or not yet systematically explored, they seem particularly relevant in urban populations having limited contact with natural or near-natural environments.[14,24,26,28,51–55] The differences seem particularly important between gender and age.[50,53,56,57] A small body of research suggests that contact with nature in childhood can provide cumulative benefits with far reaching developmental significance. For example, contact with nature may improve attention function in children diagnosed with attention deficit disorder, improve self-discipline[28] and cognitive development in children[58–61] and reduce the risk of a later mental illness.[62] There is some evidence that benefits from contact with nature may be most significant in lower socioeconomic groups.[54,63]

Does biodiversity matter?

The role of biodiversity in green spaces for health effects is complex. A systematic literature review indicated that exposure to or use of more biodiverse environments can generally relate to better mental health outcomes and increased health-promoting behaviours. Overall though, the evidence was inconclusive, partly because the definitions of health, well-being and biodiversity were not well-articulated in the included studies.[64] The positive relationships were most evident following immediate encounters or repeated exposure with a biodiverse environment at a local scale. Another review evidenced positive association between species diversity (plants, birds and butterflies were the most studied groups) and well-being (psychological and physical) and between ecosystem diversity and immune system regulation.[65]

Spending time in a diversified natural environment promotes relaxation and reduces stress.

Other studies show a general positive influence on mental health and well-being from time spent in forests[66–69], although the structure matters: walks in tended urban forests balancing dense growth and open views had greater restorative and well-being effects than walks in wild forests with large amounts of dead wood[70,71] probably because for most people urban forests are more familiar and thus feel more secure.

It is acknowledged that people's aesthetic preference is contributing to well-being and health by influencing the site satisfaction and the frequency, time and activity passed in natural settings. A systematic review of 200 studies on people's perception and valuation of urban biodiversity in terms of habitat concluded that people prefer moderately dense vegetation over settings that are very open or very dense[55]. This evidence supports results from the BiodiverCity project[72], a national survey in Switzerland, concluding that city dwellers prefer varied vegetation of loosely scattered shrubs and trees in meadows with unmowed sections rather than cleared green areas.

Other studies found a prevailing positive valuation of species richness, although results of mixed or no effect were also common.[55,73] Field studies and experiments in Switzerland and the UK found that perceived plant diversity increased aesthetic appreciation for the plant communities and thus the well-being.[40,74,75] Additionally, it was observed that species richness is related to a considerable proportion of activities in parks e.g. with the picking of edible or decorative plants, or with observing species.[73,76]

Linkages between biodiversity, infectious disease and non-communicable disease

Infectious disease

Two main mechanisms influence the effect of biodiversity on the transmission of infectious disease.[77] The first, the 'dilution effect' argues that an increase in species diversity leads to a decrease in pathogen prevalence. At the local level, the assumption is that greater species diversity reduces the success of pathogens switching between hosts, leading to a decrease in pathogen transmission rate and prevalence. The pathogens are more likely to encounter resistant or less sensitive species. This leads to a decrease in transmission rate and disease frequency.[78] Theoretical models, laboratory experiments and field studies support this effect[79], but generalisability is still debated.[80,81] The second mechanism, the 'amplification effect' is the converse of the dilution, describing a positive correlation between species diversity and disease risk or infection prevalence.[82]

According to the available studies, a number of drivers are postulated to influence both mechanisms. Several impact community composition, structure and interactions, including for example encounter reduction[83], susceptible host regulation through interspecific competition or predation limiting competent host abundance[82], and competition for food.[84] These factors ultimately regulate host abundance and population density[85], and can also be affected by human-induced landscape changes.[86]

Scale has an outsized impact on the results in the context of infectious disease.[87] It is only possible to untangle and understand causal mechanisms for diversity-disease relationships

when data are spatially and temporally related to relevant outcomes[84, 88–90]. One example: although species diversity may increase disease risk at local scale (amplification), the mechanism of encounter reduction could operate at larger scales resulting in an overall dilution effect.[90, 91] Habitat properties (land use, fragmentation) play an additional role in driving the mechanisms of dilution versus amplification[92], further supporting the argument for careful consideration of scale.

Non-communicable disease

The links between biodiversity and non-communicable diseases can be broadly grouped within two topics: allergic and inflammatory disease and the relationship of microbiomes to health.

The 'hygiene hypothesis' proposes that modern lifestyles do not expose people to the microbial diversity in which the human immune system evolved and which is required for its normal maturation.[51, 93, 94] Studies suggest that microbe-rich environments such as farm environments are protective against inflammatory and autoimmune disease.[95–98] Recent work proposes that declining biodiversity increases the chance of human immune dysfunction.[97–100] This extends to the 'biodiversity hypothesis', which suggests that lack of exposure to natural environment and associated microbial diversity leads to microbial imbalance in human commensal microbiota, immune dysfunction and clinical disease.[101–104] Support for this hypothesis comes from work indicating that the gut microbiome interacts with the immune system to maintain immune function[105]. For example factors in the neonatal period, such as caesarean delivery[106], duration of breastfeeding and antibiotic use affect the gut microbiome and are associated with increased incidences of asthma and allergies. Debate continues about the relative importance of sources of microbial exposure, including microbe diversity and key species, both during early development and later life[99, 100, 102], as well as co- and multiple strain infections.[107, 108] Investigations indicate heritability also plays a role in the intestinal microbiome, unlike that of the skin.[109]

The intestinal microbiome supports a variety of functions, many of which are not yet fully understood. Strong evidence indicates a child's early environment, including maternally transferred prenatal signals, affects immune maturation, modifying later disease risk.[100] Gut, skin and respiratory tract microbes activate innate and regulatory networks of cells and proteins which contribute to healthy immune function.[99, 110] Experimental work supports the view that early postnatal intestinal colonisation with microbiome self-induces temporal activation of bacterial sensors influencing intestinal barrier function and humoral immunity.[111] Commensal microbes use toll-like receptor signals to maintain mucosal homeostasis[112]; regulation of intestinal permeability is affected by microbial shifts associated with low-grade inflammation.[94] Animal models indicate that cellular communication occurs through protein inducers, but understanding of the role of microbial colonisation dynamics is limited.[113]

In addition to environment and dietary influence, studies have also documented bi-directional communication between the gut microbiome and brain as well as the skin microbiome and lung, including direct and indirect immune, humoral and neural mechanisms.[95, 110, 114] The nervous system and pulmonary immune responses play important signalling roles related to normal function versus disease states, but current experimental studies have only investigated single microbial niches despite likelihood that microbial complexity affects multiple niches.[95, 115]

Challenges, opportunities and risks

A main challenge in assessing links between biodiversity and health is the diversity of the two research areas in their approaches, methods and ways of thinking. There is wide variation in the definitions used for health and for biodiversity[51, 64, 78], which makes comparisons difficult or impossible depending on the aspects considered. Another important heterogeneity encompasses study methods, with very few laboratory-based experiments and applied field studies in natural systems, few longitudinal studies and generally small sample sizes.

Complexity adds another challenge. Understanding of the relevant ecology is crucial for infectious diseases but generally remains incomplete due to the many interactions and dynamic nature of the systems.[88, 116] Human demographic, socioeconomic and cultural context[88] as well as global anthropogenic trends with environmental impacts, like climate change, and nutrient pollution[117, 118] determine in many ways the interrelations between people and nature and add additional complexity.[28, 119] Untangling the interactions remains a major challenge.

A number of studies note uncertainty[110, 120], lack of convincing evidence[121], lack of validation criteria[122] or failure to consider confounding factors.[118] Others describe limitations to determining causality including the need for temporal studies[123], the difficulty to decouple change in socioeconomic status from health status changes[51], and the likely non-linearity of diversity-disease risk relationships.[91, 124, 125] A further challenge, especially with regard to biodiversity and infectious diseases, is the bias towards publishing reports of a negative relationship between biodiversity and disease.[126]

Nevertheless, numerous opportunities exist to develop integrated (inter- and transdisciplinary) research, strategies and measures to realise benefits for both biodiversity and human health and well-being. Knowledge of the multiple benefits of nature experiences for physical, mental and social health supports efforts to protect and promote natural landscapes in and around settlements and to better integrate nature into the architecture, infrastructure, and public space of urban areas.[46, 56, 127, 128] Natural environments can help reduce stress associated with urban life, increase physical activity and foster social contacts. In this way, public health benefits from urban green space including e.g. street trees, green roofs, community gardens, parks and open spaces, and extensive connected pathways for walking and biking. Simultaneously, urban green space mitigates heat stress due to climate change, improves air quality and reduces noise.[2, 129] Such urban design potentially yields ecological benefits, both directly by offering and connecting habitats for plants, animals and other organisms, and indirectly through the role they play in shaping a positive human attitude toward nature and environmental protection.

Economic estimates to value health gains and avoided health care costs attributable to nature contact indicate that the con-

tact with nature will bring more benefits than cost, although precise estimates are elusive.[130–132] Importantly, assessment of the monetary value should take a life course approach: investments towards nature contact in early life may yield substantial health improvements, and avoided medical costs, later in life.[130]

The World Allergy Organization position statement promotes induction of immune tolerance as a promising strategy for prevention and treatment of allergic and immune disease, based on recent evidence that declining biodiversity contributes to human immune dysfunction.[99] Behavioural activities, such as physical exercise and healthy diet have an important impact on the burden of allergic disease and prevention of non-communicable disease. Pragmatic population-based action plans provide an important opportunity for success.[133]

In addition to human health benefits, there may be some health risks to be taken into account when designing (urban) green spaces or modifying existing management practices. For example, altering plant populations in cities can increase the prevalence of allergenic pollen or increase the emissions of volatile organic compounds (VOCs). The risk of adverse reactions is considered greater in urban areas due to the urban heat island effect compounded with air pollution.[134] Natural environments might boost the number of disease transmitting pest species, such as ticks or brown rats.[135,136] Understanding of the complex life cycles of allergens, disease agents and vectors in urban settings, the shifts likely to occur based on transmission dynamics and the effects of climate change is necessary on a contextual basis to maximise health benefits and minimise health risks.

Recommendation for action

Improving the knowledge base on the contribution of biodiversity to health and well-being.

- Developing evidence-based answers to open questions in an interdisciplinary research program, including integrative approaches to combining different perspectives.[89,91,137,138] The program should among others identify which biodiversity provides benefits or detriments for physical, psychological and social health and well-being; investigate the required biodiversity for a positive health effect and include environmental, socio-demographic, cultural, personal and perceptive factors.[36,130,139]
- Improving and harmonising methodologies and assessment methods in the cross-cutting area of biodiversity and health. Epidemiological and longitudinal studies are necessary. Geographic and epidemiological methods should be combined to study the local level and biogeographic regionality. It takes further experimental manipulation in communities, and models which include community feedbacks across gradients that incorporate natural ecosystems.[36,119,130,139,140]
- Analysing the cost-effectiveness and cost-benefit ratios of the impact of biodiversity on human health from a life-course perspective. These can support decision-makers in politics and business.[141]
- Developing innovative, strategic solutions to improve the knowledge base through interdisciplinary and contextual approaches. The Rockefeller Foundation-Lancet Commission on planetary health[142] includes propositions to address conceptual, research, informational and governance challenges for a holistic integrated research agenda.

Effectively design and manage green spaces[143,144]

- Developing a 'common language' between relevant players in the field of green space design and management to facilitate understanding and cross-sectoral cooperation. Understanding what practitioners and policy-makers need to implement the research on biodiversity and health.
- Developing an appropriate management of small urban green spaces. It should especially promote those aspects of biodiversity potentially beneficial to human health and well-being. Enable all people to incorporate contact with natural environments into daily life.
- Designing larger green spaces and establishing green corridors from urban green spaces to rural areas to create additional opportunities for recreation and psychological restoration.
- Increasing the biodiversity of green spaces and the length of stay of people in these areas. Both aspects promote health and well-being.

Increase awareness of the health and well-being effects of natural or near-natural environments and biodiversity

- Maintaining dialogue across disciplines and effectively including the diversity of knowledge of all stakeholders. It will only then be possible to adequately address the complexity of relationships between biodiversity and health[25].
- Emphasising the contribution of biodiversity in addressing priority health issues. Identify facts and synergies on health benefits and risks.[128]
- Adapt communication on health benefits of biodiversity to the interests of different stakeholders (e.g. park managers, landscape architects and urban planners/designers, health professionals and policy-makers.)[46]

Promote synergies by increasing policy coherence

- Promote the development of knowledge in the disciplines concerned and transdisciplinary approaches that can be integrated into sustainable policies[145].
- Highlight the links between climate change, human health and biodiversity. Develop cross-sectoral approaches to exploit synergies, such as the health potential of semi-natural green spaces in the context of adaptation to climate change[128,138].
- Developing of political strategies across different spatial levels. Decisions are often made nationally, but local-scale has a big impact on public health[100,146].

Conclusion

The current state of knowledge shows that biodiversity can in many ways be a guarantee of human health. The conservation and promotion of natural or semi-natural environments has considerable preventive and therapeutic potential that is still largely untapped. In addition, the promotion of biodiversity can also offer synergies to reduce the health impact of climate change and other environmental changes. We therefore recommend that the promotion of biodiversity and human health be increasingly addressed in joint strategies and programmes in the future, and propose a range of measures to make better use of the potential of biodiversity to promote public health. To this end, it is necessary to strengthen cooperation between the public health, nature conservation and urban and spatial development sectors at national and local level.

The mechanisms linking biodiversity and health are complex and variable, and there are gaps in knowledge. To fill these gaps, an inter- and transdisciplinary approach is required to take into account the multiple socio-economic, ecological and cultural factors.

SDGs: The global Sustainable Development Goals of the UN

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'Ensure healthy lives and promote well-being for all at all ages', 'Make cities and human settlements inclusive, safe, resilient and sustainable' and 'Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss'.

> sustainabledevelopment.un.org
> eda.admin.ch/agenda2030/en/home/agenda-2030/die-17-ziele-fuer-eine-nachhaltige-entwicklung.html

1–146 The literature referenced in this factsheet is listed in the online version available at swiss-academies.ch/en/factsheets

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