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Biodiversity and health

A knowledge synthesis and analysis of the complex connections between biodiversity and health highlighting the relevant EU policies projects and initiatives.

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Contents	
Abstract.....	1
Acknowledgements.....	2
1 Introduction.....	3
1.1 State of knowledge on biodiversity and human health: a brief overview	3
1.2 Complexity of relationships and research challenges.....	6
1.2.1 Terminology and variables.....	6
1.2.2 Methodological considerations.....	6
1.2.3 Diversity of perspectives and expertise	6
2 EU action on biodiversity and health.....	8
2.1 EU policies relevant for biodiversity and health.....	8
2.1.1 Biodiversity and health in EU policy.....	8
2.1.1.1 Biodiversity and health in the evolution of the EU's overarching environmental policy framework.....	8
2.1.1.2 Mainstreaming health in EU biodiversity policies	8
2.1.2 Other EU policy areas relevant for biodiversity and health.....	9
2.1.2.1 Pollution and waste: air, water and soil.....	9
2.1.2.1.1 Overarching EU policy framework on pollution and waste.....	9
2.1.2.1.2 Air quality.....	10
2.1.2.1.3 Water.....	10
2.1.2.1.4 Soil.....	12
2.1.2.1.5 Waste.....	12
2.1.2.2 Agriculture, food systems and nutrition.....	12
2.1.2.3 Climate change and disaster risk reduction.....	13
2.1.2.4 Disease prevention, medicines and wellbeing.....	14
2.1.2.4.1 Disease prevention.....	14
2.1.2.4.2 Mental, physical and cultural wellbeing.....	16
2.1.2.4.3 Medicines	16
2.2 EU support for projects and initiatives relevant to biodiversity and health.....	18
2.2.1 EC Research & Innovation initiatives.....	18
2.2.1.1 FP7 (2007-2013) programmes.....	18
2.2.1.2 Horizon 2020 (2014-2020) programmes.....	19
2.2.1.3 Horizon Europe (2021-2027) ongoing calls/programmes.....	19
2.2.2 CINEA support.....	20
3 Conclusions.....	21
References	23
List of abbreviations and definitions.....	38

List of figures 39

Abstract

Biodiversity and health are inextricably connected, directly as well as indirectly. Nature and biodiversity directly enhance health and wellbeing by improving the quality of our air, water and soil, and providing indispensable medicines, food and nutrients. Anthropogenic drivers of biodiversity loss and ecosystem change such as pollution, agricultural intensification and climate change affect both biodiversity and health, and are in turn aggravated by the loss of biodiversity and ecosystem services. The connections are complex and involve many feedback loops, calling for reinforced attention from many policy domains as part of a systemic approach. In this report we chart out these connections and the relevant policy domains, as well as the corresponding EU policies, projects and initiatives. The main aim is to improve awareness on the strong, complex and manifold connections between nature conservation and human health with a view to enhancing win-win solutions in policymaking.

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1 Introduction

This study is part of a series initiated by the Knowledge Centre for Biodiversity (KCBD) to raise awareness on the importance of embedding biodiversity concerns in all relevant policy domains. The series describes the efforts of the European Union in this direction, key to effecting transformative change and a green transition. The content targets a wide audience, prioritising accessibility for the layperson as well as interest for specialists, policymakers and researchers. All the reports in the series follow a common structure, which was originally designed for the thematic pages of the website of the KCBD¹, and determined collectively with other knowledge centres as part of the Knowledge for Policy (K4P) initiative of the European Commission. This report focuses on the direct as well as indirect connections between biodiversity and health, and describes the relevant EU policies, projects and initiatives.

1.1 State of knowledge on biodiversity and human health: a brief overview

Increasingly, the contribution of biodiversity² to human health³ and well-being is being recognised in peer-reviewed literature [1, 2, 3] and by international governments and organisations such as the Convention of Biological Diversity (CBD) and the World Health Organization (WHO) [4]. Biodiversity underpins ecosystem functioning, providing a wide range of goods and services that ensure our health and wellbeing. It improves the quality of the air we breathe and the water we drink, regulates temperature in cities, and provides medicines, food and nutrients that maintain our health. Biodiversity is indispensable for the planet's capacity to both regulate and adapt to environmental change – especially climate change and natural disasters.

A growing amount of research has been published in the past two decades on the contribution of biodiversity to human health, including topics like medicine, food and nutrition, analysing benefits and harms in terms of physical and mental health and wellbeing, and within the context of climate change [1, 2, 3]. An extensive literature has also focused on the contribution of green spaces to physical and mental health [5, 6]. Guegan et al. [7], Loreau et al. [8], and Kopnina et al. [9] have developed societal and ecological perspectives including issues of public health, social-environmental equity and education.

Based on a broad literature review, Sandifer et al. [10] identified a wide range of mental and physiological benefits from contact with nature such as, among others, reduced anxiety and depression, improved cognitive function, reduced cardiovascular and circulatory diseases, reduced sympathetic/increased parasympathetic nerve activity, faster healing after illness, surgery or trauma, and positive influence on diabetes. Green spaces are reported to be beneficial for child brain (cognitive and behavioural) development [11]. Mental health⁴ and psychological wellbeing⁵ benefits relate notably to stress reduction and relaxation, e.g. through the calming effect of greenery and birdsongs and the quietness and fresh air induced by a walk in the woods [12]. The recognition of benefits of contact with nature is slowly contributing to the integration of human health and wellbeing objectives into the management of some biodiverse areas of high conservation value [13], like in the case of urban nature parks supporting migratory birds while playing a role in improving air quality and moderating air temperature [14] or in initiatives such as the Biophilic Cities network⁶.

Lindley et al. [15] looked in particular at physical health and highlighted the following links with biodiversity: *i*) at the level of the human body's own ecosystem, natural environments with diverse biota enrich the human microbiome through exposure to beneficial symbiotic microbes, and the decline in people's contact with nature contributes to the development of dysbiosis, which may result in a negative cycle of ill-health, including problems associated with the integumentary (skin/hair), digestive and urinary/renal systems as well as disorders in the respiratory and cardiovascular systems [16, 17]; *ii*) specific physiological positive outcomes from contact with nature are shown for the circulatory/cardiovascular, endocrine and immune systems and protection from chronic inflammatory disorders, however with mixed evidence [18]; *iii*) at the broader level of landscape biodiversity, a correlation has been shown between biodiversity (including vegetation diversity and

¹ https://knowledge4policy.ec.europa.eu/biodiversity_en

² Biological diversity: *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* (CBD, 1992)

³ Human health: *a state of complete physical, mental and social well being and not merely the absence of disease or infirmity* (WHO 1948)

⁴ Mental health: *a state of wellbeing in which an individual realizes their own abilities, can cope with the normal stresses of life, can work productively and is able to make a contribution to their community* (World Health Organisation, 2018 at <https://www.who.int/news-room/fact-sheets/detail/mental-health-strengthening-our-response>)

⁵ Psychological wellbeing: *a combination of positive affective states such as happiness (the hedonic perspective) and functioning with optimal effectiveness in individual and social life (the eudaimonic perspective)* (Winefield et al., 2012)

⁶ <http://biophiliccities.org/>

species richness) and positive respiratory health [19]; *iv*) many ecosystem processes contribute to food nutritional quality and diversity, which are important for ensuring good physical health [20]. Biodiversity also affects human health by making (e.g. agricultural) ecosystems more resilient (e.g. pest regulation) and possibly more productive for food (e.g. crop pollination, fish stocks). Van den Bosch and Sang [21] have underlined the direct and indirect pathways linking physiological health and exposure to nature. Emphasis could be on ecosystem regulatory functions (e.g. modification of environmental stressors) or on provisioning functions (such as the use of ecosystems by people for food, freshwater, fuel and medicines) [15]. Direct pathways include for example the health benefits from the consumption of nutritious food while indirect pathways include the benefits from increased physical activity in nature.

Among others, Müller et al. [22] and Morand and Lajaunie [23] have clarified the academic debates on what role biodiversity and its loss play in vector-borne diseases (VBDs)⁷. Epidemiological dynamics of VBDs are complex interactions of the vector species, the pathogen and the host; it is now well established that the transmission of infectious or parasitic agents depends on abiotic factors, climatic factors (temperature and rainfall) and the degree of biodiversity (e.g. landscape heterogeneity, species richness, reservoir host diversity) as well as its loss or alteration. However, important knowledge gaps remain on e.g. the context-dependence of VBD processes, seasonal and spatial distributional changes of vector species under climate change, and the correlation of species richness and composition in explaining the dilution effect (i.e. decreased disease risk with increasing diversity within a given ecological community - for example the effect was reported in the case of Lyme disease) [24].

When identifying factors impacting human health, researchers also point out the inter-relationships of biodiversity (and its loss) and climate (and its changes). They stress the urgent need for action in the light of recent climate change projections, on-going biodiversity losses and public health demands [2, 3]. The 2016 Global Environment Outlook (GEO-6) assessment for the pan-European region [25] identified biodiversity as a key environmental determinant of human health. But many gains in human development over the last century have come at the cost of biodiversity and the state of the natural environment, both within and outside Europe, and the later effects of this now cause health problems. Environmental factors cause an estimated 1.4 million deaths per year in the region [26]. These factors include *inter alia* air pollution, poor water quality and climate change, which have interlinkages with biodiversity loss and ecosystem degradation, as have other factors influencing the spread of non-communicable as well as infectious diseases [see Section 2.1.2]. The VBD issue is of increasing concern since on average, 77,000 people living in Europe fall sick from VBDs every year⁸, and numbers are predicted to increase as more vector species emerge (e.g. the Asian tiger mosquito, *Aedes albopictus*) or re-emerge (e.g. the yellow fever mosquito, *Aedes aegypti*). Globally, every year there are more than 700,000 deaths from zoonotic vector-borne diseases such as malaria, Lyme and dengue.

The key regional drivers [4] of biodiversity loss are linked to increased land-use change: agricultural intensification including livestock, urbanisation and habitat fragmentation. Other pressures include unsustainable direct exploitation of biological resources and invasive species. These drivers and pressures affect human health by causing biodiversity loss, the degradation of ecosystem services and deterioration of food quality, as well as via other impacts such as increasing pollution and waste, and climate change. The latter impacts further undermine ecosystem services and biodiversity, and are in turn aggravated by their loss. The same drivers contribute globally to the emergence and spread of infectious diseases and are considered to lie at the root of many recent pandemics [27, 28]. A variety of mechanisms are at play here: for instance, habitat loss and fragmentation force wild animals out of their natural habitat and into closer contact with humans, augmenting the likelihood of human exposure to zoonotic infections and the possible spread of these diseases. While proximity to host species is not sufficient *per se* to increase zoonotic disease risk, as it needs to be considered along with other factors affecting transmission related to the host species, the pathogen itself and the local environment and species communities (e.g., pathogen prevalence and transmission route/s, human behaviour, type and frequency of contacts between animals and humans, landscape structure, etc.) [29, 30], anthropogenic changes in land use are undoubtedly expanding hazardous interfaces between people, livestock and wildlife reservoirs of zoonotic diseases [31, 32]. Morand and Lajaunie [23] brought evidence on the link between global deforestation and outbreaks of zoonotic and vector-borne diseases; they also found that reforestation, mostly in temperate countries, and oil palm plantations in tropical countries, may also contribute to epidemics of infectious diseases. Müller et al. [22] made recommendations to address VBD control from an interdisciplinary and trans-sectoral approach, not

⁷ vector-borne diseases (VBDs): illnesses caused by parasites, viruses or bacteria that are transmitted by a vector, such as mosquitoes, ticks, sandflies, triatomine bugs, tsetse flies, fleas, black flies, aquatic snails and lice (WHO 2017a).

⁸ <http://www.euro.who.int/en/media-centre/sections/press-releases/2014/77-000-europeans-fall-sick-every-year-with-vector-borne-diseases>

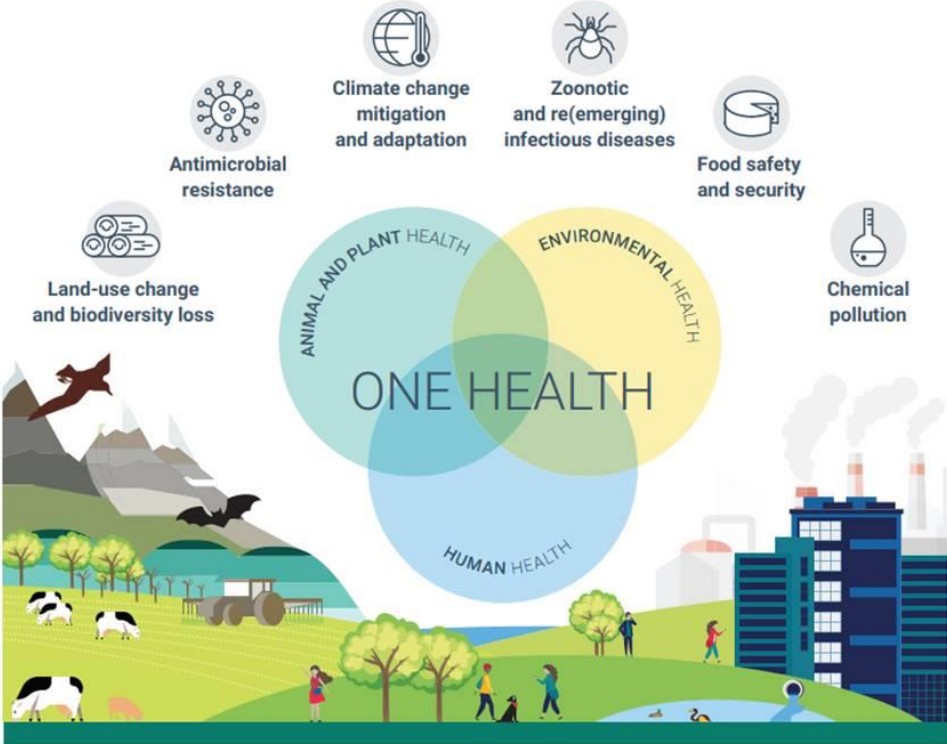
just in the health sector. Morand and Lajaunie [2] called for an international governance framework involving scientists, public health officers and policymakers to ensure the preservation of forests and the ecosystem services they provide, including the regulation of diseases. Biodiversity should be considered as well as the health risks posed by lack or mismanagement of forest ecosystems.

For Morand and Lajaunie [23], among other sources, the biodiversity and health nexus offers the unique opportunity to demonstrate how ecological, environmental, medical and social sciences can contribute to the improvement of human health and wellbeing through the conservation of biodiversity and the services it brings to societies. Cross-disciplinary approaches and collaboration are necessary for addressing these complex inter-linkages and for ensuring coherence. Towards this goal, two approaches [33] adopted at the European and global levels can be quoted:

- The planetary health approach [34], which seeks to promote human health by protecting the natural systems on which it depends. This approach investigates the effects of environmental change on human health and wellbeing, as well as the political, economic and social systems governing those effects.
- The One Health approach [35], which focuses on addressing health concerns in the animal–human–environment interface. It seeks to bring multiple sectors to communicate and work together towards better health outcomes by designing and implementing joint programmes, policies, legislation and research.

These two approaches are integral to the WHO Europe’s European Programme of Work [36], aimed at improving protection against health emergencies – including pandemics such as COVID-19 – and facilitating healthy lives and wellbeing through health-promoting local environments. The programme seeks to ensure that environmental risks affecting both humans and animals are tackled in an inter-sectoral manner, as set down in the 2017 Ostrava declaration [26] at the Sixth Ministerial Conference on Environment and Health, part of the European Environment and Health Process (EHP) [37]. In a recent joint statement [38], the relevant EU agencies expressed their commitment to support the One Health agenda in Europe.

Figure 1. Examples of issues that can be addressed through a One Health approach



Source: Cross-agency knowledge for One Health action, Joint Statement by European Union agencies, by ECDC, ECHA, EEA, EFSA and EMA, November 2023. ©EEA

1.2 Complexity of relationships and research challenges

Although there is growing appreciation and an emerging body of evidence on the important links between nature and biodiversity and human health, the research is heterogeneous in the definitions and approaches used, and there is a need to improve our understanding of the underlying mechanisms [10, 20]. Current research challenges related to the biodiversity-health nexus lie on theoretical and methodological considerations (terminology and metrics, diversity of concepts and methods, interdependence of processes), the diversity of perspectives and expertises represented, as well as the understanding of the nexus in the context of future scenarios of climatic and societal changes.

1.2.1 Terminology and variables

Biodiversity

In the body of research on biodiversity and health, many interpretations exist of the term biodiversity and the ways in which it is measured when assessing its contribution to human health [39]. This brings inconsistencies in the results. Broadly defined terms like nature, natural environments and green spaces are used: 'nature' referring to living things and associated landscapes in a wide variety of settings; 'green spaces' that may support different levels of biodiversity and may have different management objectives and public accessibility conditions, the (i.e. an urban park could be managed primarily for people while protected areas with high biodiversity value may only offer limited access to people). Marselle et al. [3] have recommended a systematic approach based on biodiversity variables organised into three levels: (i) ecosystem/habitat (e.g. landscape heterogeneity, structural diversity), (ii) species communities (e.g. species richness, perceived species richness, abundance of a specific taxonomic group), and (iii) single species level.

Health

Numerous parameters would be necessary to determine in a robust manner the health status of any one person. They should relate to individual characteristics (e.g. hereditary genetics), external factors (e.g. abundance, type and quality of the natural environment) and life experiences, both physical and social [10, 15]. To fully determine physical health, physiological variables to be measured should be associated with 11 interlinked body systems: reproductive, integumentary (skin/hair), skeletal, muscular, nervous (brain/brain activity), circulatory/cardiovascular (blood/transport of nutrients), endocrine (glands/hormones), lymphatic/immune, digestive (food), respiratory (breathing) and urinary/renal (waste). In turn, each parameter could be systematically assessed in order to establish underlying mechanisms for the influence of nature. On the psychological side, mental wellbeing variables should more systematically include attention restoration, recovery from stress, emotion/mood, and quality of life/life satisfaction, while "mental health" is another variable to be recorded individually for e.g. cognitive function.

1.2.2 Methodological considerations

Inconsistencies in terminology and incomplete sets of variables affect the quality of systematic search process and data mining for knowledge synthesis. Difficulties are further encountered when selecting inclusion/exclusion criteria of terms qualifying biodiversity and health. This has an impact on the robustness of the evidence built on the biodiversity-health relationships. The diversity of methodologies applied to link biodiversity and health may lead to inconsistencies and an incohesive body of evidence [40]. Analyses are complex and should take into account direct and indirect pathways, relevant controls and the interdependencies between psychological and physiological processes [15].

The inter-relationships between biodiversity and climate present additional challenges for building and testing hypotheses and exploring future scenarios. Climate and biodiversity act as important 'boundary conditions' for human health and wellbeing, influencing other factors that affect human health through the natural environment, and the full extent of health impacts from biodiversity losses thus remains unclear [15].

1.2.3 Diversity of perspectives and expertise

Knowledge syntheses on the biodiversity and health nexus draw from a variety of disciplines ranging from ecology, geography and animal health to environmental psychology, public health and medical science and encompassing nature conservation and land/urban planning. Such research is multi-layered and inherently multi-disciplinary; links are multiple, interconnected, multi-scale and interdependent.

Complexities are compounded due to differing perspectives on issues, for example with some researchers using health as a primary starting point and other researchers starting from the perspective of environmental or ecological processes. The different perspectives are important for developing fuller understanding, but still make the challenges of integrating all the research more demanding, especially at the science-practice interface [15]. Different disciplines have unique perspectives to offer, and further efforts in interdisciplinary collaboration are needed to contribute to a cohesive body of evidence, to inform strategies or policies that aim for win-win scenarios for both biodiversity conservation and physical and mental health and wellbeing.

Action is needed due to climate projections, biodiversity losses and health demands. New research agendas demand ambitious, multi-disciplinary and cross-sector approaches. A holistic approach in policy and practice is as important as it is in scientific research [15]. Practical questions are essential to address, such as done in Eclipse multi-stakeholders consultations⁹ on biodiversity in an urban context or biodiversity and pandemics: What habitat types and elements of biodiversity in green and blue spaces in urban areas help promote physical health? How can these types and elements be considered within the planning process and within health and social care systems? What are on-the-ground actions (failures and successes) aiming at understanding the emergence of zoonotic and infectious diseases and their prevention? What are relevant indicators (including social) for biodiversity and climate change to help prevent future pandemics? How to translate information to stakeholders and the young generation?

⁹ <http://www.eclipse.eu/>

2 EU action on biodiversity and health

Under EU action we consider EU policies and EU-funded projects and initiatives relevant to biodiversity and health. As biodiversity is essential for human and planetary health, any EU action to reverse biodiversity loss benefits our health, directly or indirectly. In addition, many drivers of biodiversity loss, such as pollution and climate change, also severely affect human health. Actions that mitigate their impacts are thus beneficial to both biodiversity and health, as are many actions taken in other domains such as food systems and disease prevention. Section 2.1.2 on EU policies in these domains (pollution, food systems, climate change, disease prevention, etc.) also explains how these domains are closely linked to biodiversity and health.

2.1 EU policies relevant for biodiversity and health

In Section 2.1.1 we summarise connections with health issues in the EU's biodiversity and overarching environmental policies, whilst Section 2.1.2 deals with other policy domains that are closely linked to both biodiversity and health.

2.1.1 Biodiversity and health in EU policy

Section 2.1.1.1 describes how biodiversity and health, and the linkages between them, have been integrated in the EU's overarching environmental policy. Section 2.1.1.2 summarise the incorporation of health issues in EU biodiversity and nature-based policies.

2.1.1.1 Biodiversity and health in the evolution of the EU's overarching environmental policy framework

The EU's environmental and climate policymaking is guided in pluri-annual environment action programmes that define a common long-term vision towards ensuring coordinated action of the EU and its Member States. The EU's 6th Environment Action Programme (EAP) (2002-2012) [41] identified four main priority areas: climate change; nature and biodiversity; environment and health; natural resources and waste. The final assessment (2011) [42] of the 6th EAP reported that targets were met only for climate change. Key challenges on nature and biodiversity remained unaddressed, and a coherent approach on environment and health was lacking. Targets on natural resources and waste were only partially met. The 7th EAP (2013-2020) [43] had three thematic priorities: to protect, conserve and enhance the Union's natural capital; to turn the Union into a resource-efficient, green, and competitive low-carbon economy; and to safeguard the Union's citizens from environment-related pressures and risks to health and wellbeing. The Commission's evaluation of the 7th EAP (2019) [44] reported that – while there has been progress across the board – major challenges remain: we face a global ecological crisis as we cross-planetary boundaries, this crisis affects human health, and the EU is not on track to meet its biodiversity targets. The Communication (2019) [45] on the European Green Deal (EGD) prioritised swiftly achieving climate and environmental targets while protecting people's health and wellbeing from environmental risks and impacts, and ensuring a just and inclusive transition.

The proposal for an 8th EAP (October 2020) [46] stated that decisive further action is required for addressing biodiversity loss and ecosystem services degradation, climate change, unsustainable use of resources, pollution and associated risks to human health and wellbeing, nature, ecosystems, and the economy. It acknowledged that the current growth model has exacerbated environmental pressures that are expected to increase further, with direct and indirect effects on human health. It called for an accelerated transition to a regenerative growth model, envisioning a regenerative economy by 2050 where a healthy environment underpins our health and wellbeing, where biodiversity thrives and natural capital is protected, restored and valued, thereby also enhancing resilience to climate change and other environmental risks. The General Union Environment Action Programme to 2030 (8th EAP, adopted in 2022) [47] emphasised that economic activity should develop in a way that protects, restores and improves the state of the environment, including by halting and reversing biodiversity loss, prevents environmental degradation, and protects health and wellbeing from negative environmental risks and impacts, preventing and minimising pollution. It aimed to fully integrate the One Health approach across all levels of policymaking. Pursuing zero pollution is one of its six priority objectives.

2.1.1.2 Mainstreaming health in EU biodiversity policies

The evaluation (2022) [48] of the EU Biodiversity Strategy to 2020 concluded that its targets were not achieved. Despite increased efforts, the EU fell short of achieving its headline target to halt and reverse

biodiversity loss in the EU by 2020, and did not fully achieve any of the other targets. However, progress was made in certain areas despite continuing pressures. Health was not directly addressed. In 2020 the EU adopted the Biodiversity Strategy for 2030 (EU-BDS 2030) [49], underscoring the importance of nature for our mental and physical wellbeing, as well as for our society's ability to cope with global change, health threats and disasters. EU-BDS 2030 addresses multiple drivers of biodiversity loss, most of which also impact human health. The older Habitats [50] and Birds Directives [51] also include considerations of public health. The 2013 EU Strategy on Green Infrastructure (GI) [52] recognises that GI delivers health-related benefits such as better air and water quality, and that healthy ecosystems also reduce the spread of vector-borne diseases. It aims to ensure the protection and enhancement of GI via strategic spatial planning. It was supplemented and reviewed [53] in 2019, specifically with a view to mainstreaming in other EU policies such as nature protection, agriculture, climate, water and scientific research. In addition, nature-based solutions [54], which support several major EU policies [55], including the European Green Deal, EU-BDS 2030 and the climate adaptation strategy, are known for their multiple health benefits [56].

2.1.2 Other EU policy areas relevant for biodiversity and health

EU policies in several other areas are relevant to the connection between biodiversity and health. These include policy domains such as pollution, agriculture and climate change, which impact both biodiversity and human health – and are in turn impacted by the loss of biodiversity and ecosystem services. Another relevant domain is that of medicine, health and wellbeing, which relies heavily on biodiversity. The following sections 2.1.2.1 to 2.1.2.4 are devoted to these policy domains. Each section firstly explains how the selected domain relates to biodiversity and health, and secondly describes the relevant EU policies.

2.1.2.1 *Pollution and waste: air, water and soil*

The declining quality of air, water and soil severely harms human health as well as biodiversity. On the other hand, ecosystems and biodiversity help maintain and improve air, water and soil quality, thereby enhancing human health. Pollution causes heart and pulmonary disease, diabetes, mental and neurological conditions and other ailments. In 2015 pollution caused [57] an estimated 9 million premature deaths worldwide – three times more than AIDS, tuberculosis, and malaria combined, and 15 times more than war and aggression. It causes 1 in 8 deaths annually in the EU [58]. Pollution – in particular pesticides, endocrine disruptors and loading of nitrogen and phosphorus [59] from agriculture and transport – is also one of the main drivers of biodiversity loss and the ongoing extinction of species.

2.1.2.1.1 Overarching EU policy framework on pollution and waste

The EU's Zero Pollution Action Plan or ZPAP (2021) [60] is based on the following vision for 2050:

Air, water and soil pollution is reduced to levels no longer considered harmful to health and natural ecosystems and that respect the boundaries our planet can cope with, thus creating a toxic-free environment.

Its targets for 2030 include a reduction by 55% of health impacts (premature deaths) of air pollution; by 30% of the share of population chronically disturbed by transport noise; by 25% of the EU ecosystems where air pollution threatens biodiversity; by 50% of nutrient losses, use and risk of chemical pesticides, use of the more hazardous ones, and the sale of antimicrobials for farmed animals and in aquaculture; by 50% of plastic litter at sea and by 30% microplastic release into the environment; by 50% of residual municipal waste and significantly total waste generation. The ZPAP hierarchy emphasises the precautionary principle, preventive action, rectification of environmental damage at source, and the 'polluter pays' principle. It includes a 'flagship' to reduce the EU's external pollution footprint.

The Sustainable Use of Pesticides Directive (SUD) (2009) [61] aimed at reducing risks to human health and the environment via alternative approaches such as Integrated Pest Management, an approach to preventing and/or suppressing pests aiming to keep the use of plant production products to levels that are justified both economically and ecologically, encouraging the use of non-chemical alternatives for sustainable crop protection. The Commission proposal (2022) [62] transforms the existing Directive into a Regulation on the Sustainable Use of Plant Protection Products, namely the Sustainable Use Regulation (SUR), which will be directly binding for the EU Member States (MS). It includes strengthened provisions as well as targets to reduce by 50% at EU level the use and risk of chemical pesticides and the use of the more hazardous pesticides by 2030, in line with the EU-BDS 2030 [49] and the EU-Farm to Fork (F2F) [63] strategies, new measures to promote an environmentally friendly system of pest control, and a ban of pesticides in any ecologically sensitive area to be preserved for threatened pollinators. In January 2023, the Commission

published a staff working document¹⁰ on the drivers of food security, showing that biodiversity loss is among the main drivers, and that pesticide use reduction is expected to exert positive effects on soil health and biodiversity. At the European Parliament, the Commission proposal was referred to the Committee on the Environment, Public Health and Food Safety (ENVI). In November 2023, the Parliament rejected the proposal at the first reading¹¹. The Council still has to decide on its position to determine whether the proposal is definitively rejected or will return to Parliament for a second reading.

Chemical manufacturing is the EU's fourth largest industry. The EU Chemicals Strategy for Sustainability (2020) [64], which is part of the zero-pollution ambition, recognises the negative impacts of hazardous chemicals on human health and the environment, as well as the need for the existing EU chemicals policy to evolve and respond more effectively to challenges posed by hazardous chemicals. Key points to tackle included, among others, the need to address risks derived from exposure to mixture of chemicals, which may lead to cumulative and synergistic effects, and to cover data gaps still existing for many substances, as the information currently required in registration dossiers does not allow for a comprehensive hazard assessment, including for carcinogenicity, neurotoxicity, immunotoxicity and endocrine disruption. To this end, the Registration, Evaluation, Authorisation and Restriction of Chemicals or REACH (2007) Regulation [65] is being revised to align it with EC ambition on protecting health and the environment, following a public consultation [66] launched by the Commission in 2022. Different policy options for possible amendments of REACH to modify requirements for registration of low tonnage substances (1-10t/year) and to increase new approach methodologies (NAMs)-based information on critical hazards at all tonnage levels were proposed by the JRC in 2021. The Commission formulated options that are currently under discussion, taking into consideration results from comprehensive impact assessments [67]. The proposal in preparation for the REACH revision is expected to introduce more stringent provisions on information requirements, hazard classification and risk management of chemicals of concern, including substances causing carcinogenicity, neurotoxicity, immunotoxicity and endocrine disruption, as well as persistent, mobile and bio-accumulative substances.

2.1.2.1.2 Air quality

Air pollution harms both human health and ecosystems. It is now the single largest risk to human health in Europe, annually causing hundreds of thousands of premature human deaths (over ten times more than road traffic accidents) [68, 69] and is a leading cause of respiratory and cardiovascular disease. More than 6 million new cases of cardiovascular disease [70] are diagnosed in Europe every year. Fine particulate matter, carbon monoxide, ozone, nitrogen dioxide and sulphur dioxide are the main pollutants of concern for human health. Air pollution also impacts both vegetation and wildlife, threatening almost two-thirds of Europe's ecosystems¹² [69]. Excess nitrogen deposition [59] is a major cause of species loss, ecosystem dysfunction and eutrophication. Conversely, ecosystems benefit air quality [4] in many ways: for instance via removal of air pollution and meteorological regulation.

The Clean Air Policy Package for Europe was adopted in December 2013 based on an extensive review of EU air policy to date. Its Clean Air Programme [71] aimed to achieve full compliance with existing air quality standards across the EU as soon as possible, and set objectives for 2020 and 2030. As set out in the subsequent (2018) communication [72], the EU's wide-ranging policy efforts towards clean air for all rest on three main pillars aimed at preventing or reducing harmful effects on human health and the environment as a whole. The first pillar comprises the ambient air quality standards set out in the Ambient Air Quality Directive [73] for ground-level ozone, particulate matter, nitrogen oxides, dangerous heavy metals and a number of other pollutants. Member States (MS) are required to adopt air quality plans to adhere to these standards. The second pillar consists of national emission reduction targets established in the National Emissions Ceiling Directive [74] for the most important trans-boundary air pollutants: sulphur oxides, nitrogen oxides, ammonia, volatile organic compounds and fine particulate matter. The third pillar comprises emissions standards for key sources of pollution, from vehicle and ship emissions to energy and industry.

2.1.2.1.3 Water

Water is a precondition for life and health, and plays a fundamental role in climate regulation. Ecosystems facilitate the water cycle by regulating nutrient cycling and soil erosion [75], and managing pollution [76].

¹⁰ https://commission.europa.eu/publications/analysis-main-drivers-food-security_en

¹¹ : [No majority in Parliament for legislation to curb use of pesticides | News | European Parliament \(europa.eu\)](#)

¹² <https://www.eea.europa.eu/publications/air-quality-in-europe-2022/impacts-of-air-pollution-on-ecosystems>, in EEA, 2022 [39]

Species loss hinders ecosystem services such as pollutant filtration and nutrient uptake [77]. Many protected areas were established to protect human water supply. But human activity is now threatening freshwater ecosystems [78], resulting in water quality decline. The main anthropogenic drivers are increased freshwater consumption for agriculture, mining, energy generation, industry and households. Nutrient discharge [79] into water bodies leads to eutrophication, widely recognised as a major threat to both human health and ecosystems. Excess nitrogen (in agricultural runoff, etc.) and phosphorus (in detergents, etc.) are the main culprits, with multiple impacts including cyanotoxin outbreaks [80] in humans and animals, and oxygen depletion of ecosystems. Apart from direct health impacts (such as water-related illness), degradation caused by human activity affects access to sanitation and water resources, and the capacity for food production. Maintaining or restoring ecosystems is a cost-effective and sustainable way [81] to improve water quality, delivering substantial benefits for biodiversity and health.

EU water legislation shares an overarching objective of protecting human health and the environment from the combined effects of toxic and/or persistent pollutants, in light of increasing pressure on Europe's water resources [82]. The Water Framework Directive (WFD) [83] adopted in 2000 is the most comprehensive instrument of EU water legislation. It was supplemented in 2006 by the Groundwater Directive [84] and amended in 2008 by the Directive on environmental quality standards in water policy [85]. The water blueprint (2013) [86] facilitated its implementation by identifying remaining obstacles and ways to overcome them. The WFD applies an integrated river basin approach to managing fresh, coastal and transitional waters while respecting the integrity of whole ecosystems that are key to safeguarding water resources. Its main objective was to achieve 'good status' (ecological and chemical) for all EU waters by 2015, in tandem with a number of other directives on specific aspects. But later reports [87, 88] show that the WFD's objectives were not achieved: in 2019 only 40% and 38% of EU surface water bodies had good ecological and chemical status respectively, despite improvements for individual substances. With respect to groundwater, 74% and 89% of groundwater area had good chemical and quantitative status respectively.

The Urban Wastewater Treatment Directive (1991) [89] aimed at protecting the environment from adverse effects of wastewater discharge. Its forthcoming review will consider permanent monitoring of health-relevant factors in wastewater with a view to improve preparedness for new epidemic threats. The Nitrates Directive (1991; amended in 2003 and 2008) [90] aimed at mitigating water pollution caused by nitrates from agricultural sources in order to protect human health and aquatic ecosystems, and to safeguard other legitimate uses of water. The Priority Substances Directive (2013) [91] aimed at preventive action and rectification at the source of the adverse effects of surface water pollution: impacts on the aquatic environment such as acute and chronic toxicity in aquatic organisms, accumulation of pollutants in ecosystems and loss of habitats and biodiversity, as well as the threat to human health. Since January 2023, the recast Drinking Water Directive (2020) [92] provides higher human health protection via more stringent quality standards. Furthermore, the Marine Strategy Framework Directive (2008) [93] noted the mounting pressure on the EU's natural marine resources and called for an ecosystem-based approach to managing these resources to phase out pollution (substances and human-induced underwater noise) and reduce risks to marine biodiversity and ecosystems, human health and legitimate uses of the sea. With freshwater and marine biodiversity being a source of food, the bioaccumulation of chemical pollutants in aquatic organisms can lead to human dietary exposure to such substances. The Commission is reviewing the Marine Strategy Framework Directive since the related report (2020)¹³ that assessed the first cycle highlighted that biodiversity loss was not halted in European seas.

EU water legislation includes lists of pollutants and quality standards, and requirements for their regular review. The 2019 fitness check [88] confirmed the need to update these lists and to improve the effectiveness, efficiency and coherence of water legislation. This led in October 2022 to a Commission proposal to amend the WFD and its daughter directives [94]. The proposal's general objectives are to increase the protection of EU citizens and natural ecosystems in line with the EU-BDS 2030, ZPAP and the EGD, and to increase the effectiveness and reduce the administrative burden of water legislation, enabling the EU to respond more quickly to emerging risks.

¹³ COM(2020) 259 final. Report from the Commission to the European Parliament and the Council on the implementation of the Marine Strategy Framework Directive (Directive 2008/56/EC) {SWD(2020) 60 final at <https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX%3A52020DC0259>

2.1.2.1.4 Soil

Soil is an essential ecosystem containing more than 25% [95] of all living organisms on the planet. It provides food, biomass and fibres, and regulates water, carbon and nutrient cycles, making life possible. Soil pollution is rampant in the EU: about 2.8 million sites are potentially contaminated [96], of which 390,000 are expected to require remediation. About 65,500 sites had been remediated by 2018. Pesticide residues in soil are widespread in the European agricultural soils (74.5% according to [97]) and this raises concern regarding their known negative impact on soil biodiversity [98]. Consequently, the loss on biodiversity leads to a decrease in organic matter and alteration of nutrient cycling which in turn affect the soil productivity.

The new EU soil strategy for 2030 [95] replaces the former EU Thematic Strategy for Soil Protection (2006) [99], aiming to achieve healthy soils by 2050, with concrete objectives for 2030. Its key actions include sustainable soil management, boosting the circular economy by enhancing land reuse and reaching no net land take by 2050, restoring degraded soils and remediating contaminated sites, preventing desertification, increasing research (data and monitoring), and mitigating and adapting to climate change. A new Soil Health Law has been proposed [100] by the Commission in 2023 to ensure a level playing field and a high level of environmental and health protection. Public feedbacks¹⁴ on this proposal have been collected till November 2023 in order to then proceed towards the adoption of a Directive on this topic. Under the novel Horizon Europe initiative EU Missions [101], the mission A Soil Deal for Europe [102] aims to lead the transition to healthy soils by 2030. The BDS 2030 and F2F strategies [Section 2.1.2.2] also cover many aspects of soil health, such as nutrient pollution and erosion control.

2.1.2.1.5 Waste

Total annual EU waste generation [103] amounts to 2.2 billion tonnes, or 4.8 tonnes per capita a year. Waste electrical and electronic equipment (WEEE) continues to be one of the EU's fastest growing waste streams. Discarded devices contain hazardous materials that can cause major environmental and health problems if not managed properly.

The Waste Framework Directive (2008) [104] aimed at protecting the environment and human health by preventing or reducing waste generation and its adverse impacts, and improving resource use efficiency. The RoHS Directive regulating 'Restriction of Hazardous Substances' in electrical and electronic equipment [105] and the WEEE Directives regulating their waste [106] (2011-12) specifically target WEEE. But despite EU efforts, the amount of waste generated has not decreased. The EU's First Circular Economy Action Plan [107] (2015) was completed by 2019. Though recycling of municipal waste increased in that period, recycled materials still meet less than 12% [108] of EU demand for materials.

The new Circular Economy Action Plan (2020) [109] proposes a revision of EU legislation on batteries, packaging, end-of-life vehicles, and hazardous substances in electronic equipment with a view to preventing waste, increasing recycled content, promoting safer and cleaner waste streams, and ensuring high-quality recycling. In addition, the EC will put forward waste reduction targets for specific streams as part of stronger measures on waste prevention and a review of the Waste Framework Directive. However, less than 40% of electronic waste is recycled in the EU. Its informal recycling in developing countries exposes people to numerous harmful substances [110], such as lead and mercury, with a major impact on children. The EC will support initiatives via the Basel Convention to better monitor international trade for these waste-streams and improve their management, as well as explore a global initiative to end informal recycling of used lead acid batteries. The European Commission is currently evaluating the WEEE Directive to address the need for its revision and an on-line public consultation¹⁵ was open until the end of September 2023.

2.1.2.2 Agriculture, food systems and nutrition

Agricultural intensification is one of the main causes [111, 112] of biodiversity loss in Europe, and also directly impacts human health. On the other hand, biodiversity in and around agricultural systems is of key importance for food security and health [4]. It is the source of the components of production (crops, livestock, farmed fish), and the genetic diversity within these [113] that ensures continuing improvements in food production, allows adaptation to current needs and ensures adaptability to future ones. A diversity of species and varieties, as well as wild sources, underpins dietary diversity [114] and good nutrition. Biodiversity is also

¹⁴ https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13350-Soil-health-protecting-sustainably-managing-and-restoring-EU-soils_en

¹⁵ https://environment.ec.europa.eu/topics/waste-and-recycling/waste-electrical-and-electronic-equipment-weee_en

essential for agricultural production systems, underpinning ecosystem services such as pollination, pest control, nutrient cycling, erosion control and water supply. While agriculture and food systems rely on biodiversity in many ways, biodiversity also relies on agriculture [112]: it is estimated that 50% of all species in the EU rely upon agricultural habitats. Diversity loss in agro-ecosystems has increased the vulnerability and reduced the sustainability of production systems, as well as having negative impacts on human health. It has also weakened regulating and supporting ecosystem services, thus making these systems more dependent on additional chemical inputs and creating negative feedback loops. The use of chemical inputs, particularly pesticides, has had severe consequences for wildlife, human health and agricultural biodiversity.

The EU Farm to Fork Strategy (F2F) [63] proposes a transition to a more sustainable food system. It aims to comprehensively address the challenges involved while recognising the inextricable links between healthy people, healthy societies and a healthy planet. It recognises the urgent need to reduce dependence on pesticides and antimicrobials, reduce excess fertilisation, increase organic farming, improve animal welfare, and reverse biodiversity loss. Both BDS 2030 and F2F go beyond the Pesticides Directive in including specific targets for halving the use and risk of chemical pesticides in agriculture and the use of more hazardous pesticides by 2030, as well as enhanced provisions on integrated pest management and safe alternative ways to protect harvests from pests and diseases. F2F and BDS 2030 also have specific targets for reducing nutrient pollution (halving nutrient loss and reducing fertiliser use) and expanding organic farming to 25% of EU agricultural area, as well as an integrated nutrient management plan to address nutrient pollution at source. The EU has a comprehensive legal framework [115] based on official controls in MS to ensure a high level of health protection and trust in the areas of food and feed safety; animal and plant health; animal welfare; organic farming, and other factors, throughout the food and feed chain, from farm to fork, and appropriate monitoring. Regarding animal welfare, a Eurobarometer¹⁶ was run back in 2016 and a public consultation run in 2021 by the EC has highlighted the need to update the current law and align it to recent scientific evidence and societal expectations (e.g. on-farm rearing, transport, slaughter and labelling) also recalling the ambition of the EU as a global leader on animal welfare. Intensive animal agriculture is booming in many countries outside the EU (e.g. Brazil, Argentina, China, India) that are main exporters of animal products to the EU and where only vague and/or non-binding farmed animal welfare standards apply, causing animal welfare problems, but also being environmentally unsustainable and a threat to public health.

The Common Agricultural Policy (CAP) for 2023-2027 [116] seeks to provide more targeted support to enhance the contribution of agriculture to EU environmental and climate goals and allow greater flexibility for Member States in adapting the measures to local conditions. It is intended as a key tool for achieving the ambitions of the F2F and EU-BDS 2030. Four of the new CAP's nine specific objectives relate directly or indirectly to 'biodiversity and agriculture'. In line with the recommendations from previous evaluations, a number of changes have been introduced that are expected to achieve a greener CAP with regard to biodiversity objectives. These include notably: a more strategic approach to improve targeting, as both pillars are combined under a single CAP Strategic Plan (SP) for each MS, which must explicitly take into account key EU environmental legislation; improved monitoring and tracking of the impact of CAP expenditure on biodiversity; higher ambition to be demonstrated in each CAP SP on environment and climate action compared to the previous programming period; stronger support and incentives for farmers, as at least 25% of the budget for direct payments is allocated to eco-schemes, and under pillar 2 (rural development), MS have to spend at least 35% of allotted funds on measures to support climate, biodiversity, environment and animal welfare; and stronger conditionality rules linked to CAP payments such as a new obligation to protect wetlands and peatlands and a minimum share of at least 4% of arable land devoted to non-productive features (the share can be reduced to 3% if farmers commit to reach 7% through eco-schemes).

2.1.2.3 *Climate change and disaster risk reduction*

Climate change impacts health and biodiversity directly as well as indirectly [117], and the connections are complex. Heat waves and other climate-related disasters have direct impacts on human health [118] and ecosystems, while several indirect impacts on human health are mediated by climate impacts on ecosystems and biodiversity [119]. These range from less resilient food systems to the spread of water-related, food-related, and vector-borne disease. There are many feedback loops: for instance, climate change can reduce water and air quality, damaging human health as well as ecosystems and biodiversity, which in turn affects water and air quality. Climate change accelerates biodiversity loss, which in turn reduces the resilience of ecosystems and agriculture against climate change, as well as their capacity to adapt to it. Climate change

¹⁶ https://data.europa.eu/data/datasets/s2096_84_4_442_eng?locale=en

also affects agricultural production, food and water security, the nutritional content of food, and the distribution and abundance of fish stocks, all of which impact human health. It is also likely to amplify the impact of other drivers [117] such as land use change, pollution, and invasive species on both human health and biodiversity. As interplay, air pollution is one of the main cause of climate change, and industrial farming, livestock production as well as deforestation accelerate both climate change and biodiversity loss, with significant health impacts.

Ecosystem degradation and the collapse of ecosystem services can precipitate disasters including disease epidemics, floods, storms and wildfires, with adverse consequences for human health and for ecosystems. Climate-related disasters are on the rise [120], and ecosystem degradation increases the vulnerability of human populations to such events. The creation of disaster-resilient societies will be essential, and is dependent on resilient ecosystems and their sustainable and secure delivery of goods and services: not only those associated with disaster resilience, but also those that normally support communities. Long-term health is an important indicator of community resilience against disasters.

The 2021 EU climate adaptation strategy [121] noted that climate-related health threats are increasing in Europe. These include death and injury from heat, floods or wildfires; threats to food and water safety and security, and the emergence and spread of infectious diseases and allergens from geographical shifts in vectors and pathogens. EU public health systems will be affected. The European Climate and Health Observatory [122] was launched in 2021 to address knowledge gaps on climate change impacts on human health. Recognising that human health is inextricably linked to animal and environmental health, the Commission has adopted the 'One Health' approach in analysing and preventing climate change impacts, including via the One Health European Joint Programme [123]. The EC proposal for the 8th Environment Action Programme [46], as well as the 8th EAP [47], called for strengthening the links between climate and health policies, and specifically mentioned the need to address the impacts and risks of climate change to human health and wellbeing. The EC proposal on a European Health Union [124] addresses serious cross-border threats including those from environmental and climatic conditions.

The EU climate adaptation strategy also emphasises nature-based solutions [125] for building climate resilience and sustaining healthy water, oceans and soils in a cost-effective way: by protecting and restoring wetlands, peatlands, coastal and marine ecosystems; developing urban green spaces; promoting and sustainably managing forests and farmland. Nature-based solutions are particularly effective for boosting climate resilience against water impacts. Climate change is aggravating situations of either too much or not enough water in Europe, as well as threats to water quality: it increases the risk of contaminated freshwater due to low river flows, high water temperatures, flooding and forest loss. In order to ensure sustainable freshwater supply and quality, the Commission is prioritising the Common Implementation Strategy of the Water Framework Directive [83] and the Floods Directive (2007) [126]. The latter aims at reducing flood-related impacts on human health, the environment, cultural heritage and economic activity.

2.1.2.4 Disease prevention, medicines and wellbeing

Biodiversity plays an indispensable role in sustaining human health by containing and preventing the occurrence and spread of diseases, enhancing mental and physical wellbeing, and providing resources that enable innovation in modern medicine as well as the maintenance of traditional systems of medicine.

2.1.2.4.1 Disease prevention

Recent research is increasingly focusing on the significant role played by the loss of biodiversity and natural habitats in the rise of several non-communicable as well as infectious diseases, including global pandemics.

Environmental microbial diversity and non-communicable diseases (NCDs)

NCDs are on the rise globally, and Europe is the most affected [25]. NCDs cause over 80% of the disease burden in the EU [127, 128] and 90% of all deaths [129]. There is mounting evidence that many (autoimmune diseases, type 1 diabetes, multiple sclerosis, allergies, eczema, asthma, etc.) can be linked to depleted microbial diversity in the human microbiome [130]. Recent research also points to links between altered microbial diversity and mental disorders [131, 132]. The diversity of bacteria, viruses, fungi, archaea and protozoa contained in microbes, and microbial interaction within the complex human microbiome, influence both the physiology of disease and susceptibility to it. Microbial interchange with environmental microbial ecosystems diversifies the human microbiota [133] and helps regulate the immune system as well as enhances the adaptability of human microbiota (in digesting new foods, for instance). Failing

immunoregulatory mechanisms [134], partly attributable to reduced contact with the natural environment and biodiversity, can also lead to poor control of background inflammation.

Furthermore, many mechanisms that regulate our immune systems were co-created via human co-evolution with other organisms [130]. Some of these mechanisms have negative health effects and are eliminated by modern medicine, especially in high-income settings like Europe. This emphasises the importance of the immunoregulatory role of the microbial environment especially in these settings [134].

The human and financial costs of NCDs are high and expected to grow, also considering the EU's ageing population. Moreover, people suffering from NCDs can be more affected by other diseases, as COVID-19 has shown. From 2018 to 2022 the Steering Group on Health Promotion, Disease Prevention and Management of Non-Communicable Diseases [135] provided expertise to the Commission on developing and implementing activities for health promotion, and NCD prevention and management, promoting coordination between MS in addressing these challenges. From 2022 onwards its work is being continued under the broader framework of the expert group on public health [136], which expands these activities to include other new public health challenges, including communicable diseases. The EU Green Infrastructure Strategy [52] promotes increased exposure to nature and its attendant benefits for NCD mitigation.

Infectious diseases

Infectious diseases cause over a billion human infections and millions of deaths per year globally. They also affect plants and animals, undermining food and water supply, with additional impacts on human health. Two-thirds [4] of known human infectious diseases are shared with animals, and the majority of recently emerging diseases are associated with wildlife [137]. Anthropogenic practices [138] such as land-use change and antimicrobial use damage ecosystems, leading to increased infectious disease transmission risks and impact. For instance, loss of natural habitat forces wild animals into human-inhabited areas, facilitating the spread of zoonotic diseases [28]; these constitute 60% of emerging infectious diseases, of which 72% originate in wildlife [137]. Whilst high-biodiversity areas may have more pathogens, biodiversity also protects against pathogen exposure via regulating functions such as host species competition. Biodiversity loss is seen as a key driver of emerging infectious diseases, while biodiversity conservation can provide additional habitats for species, reducing the potential contact between wildlife, livestock and humans, and thus modulating the risk and emergence of zoonotic disease in humans [139, 140]. There are however still important knowledge gaps and academic debates regarding the relationship between biodiversity and infectious disease risk, due to the variety and complexity of the mechanisms involved in disease transmission and emergence [2, 22, 141]. The dynamics of infectious diseases can be indeed affected by genetic diversity within host populations, species diversity within host communities, and diversity among communities. Field studies of plants, aquatic invertebrates, amphibians, birds, and mammals demonstrate that the phenomenon of the so-called "dilution effect" (decreased disease risk with increasing species diversity within a given ecological community) does occur in many natural systems. However, in a multi-host disease system, the reduction of a species can potentially cause either the increase or the decrease of the transmission of a certain disease, depending on the role of those species as hosts, and on many other factors [24]. The ability to predict when and where the dilution effect occurs remains poor, in particular on whether species richness or species composition (both being metrics of biodiversity) drives disease risk, or maybe the correlation of both.

At the same time, pathogen dynamics are also changing: global travel, climate change and antimicrobial use are rapidly affecting pathogen movement, host ranges, and persistence and virulence. Beyond direct infection risks, such changes also impact food security and medicine. Infectious diseases not only threaten humans, but also wild and domesticated species, as pathogen spill-over can occur both ways. An area of increasing concern in this sense is represented by wildlife trafficking. A key issue in terms of animal welfare, wildlife trafficking can also increase the risk of introduction and/or the spread of infectious diseases, either zoonotic or relevant to wild or farmed animal populations [142, 143]. Building on the previous EU Action Plan against wildlife trafficking (2016-2020), the Commission adopted in November 2022 a revised Action Plan, which foresees four main priorities: the prevention of wildlife trafficking addressing its root cause, the strengthening of the legal and policy framework, the enforcing of regulations and policies to fight wildlife trafficking effectively, and the strengthening of the global partnership of source, consumer and transit countries [144]. Trafficked species, if voluntarily or accidentally released in the environment, may also become invasive. The introduction of invasive alien species [145] via trade and travel has been a phenomenon constantly increasing during the last decades [146], with impacts on both biodiversity conservation and human/animal health, as these species can alter population and infectious disease dynamics in the areas where they are introduced through several mechanisms [147, 148, 149].

The agenda for a European Health Union (2020) [124] was presented in the midst of widespread occurrence of COVID-19. Of the people affected globally, 25% were living in Europe at the time. The agenda describes long-term trends such as pressures on biodiversity, climate change and antimicrobial resistance as factors aggravating the spread of infectious diseases worldwide and in Europe. Underscoring the crucial role of improved preparedness against increasing outbreaks, it cites climate change mitigation and adaptation, biodiversity preservation and restoration, improved diets and lifestyles, and pollution reduction and removal from the environment as important elements. The amended proposal for a European Centre for Disease Prevention and Control [150] recommends a One-Health approach that recognises the interconnections between human and animal health and the environment. The activities of the expert group on public health [136] cover infectious diseases as well as NCDs.

2.1.2.4.2 Mental, physical and cultural wellbeing

It is well established that biodiversity is central to many cultures and traditions, and that mental and physical health benefit from exposure to nature and biodiversity [151]. Given that 74% of the EU's population is urban (55% globally) [152], there is a rising trend for people to be separated from nature and its health benefits. The resulting alienation or "extinction of experience" [153] also exacerbates a cycle of disaffection towards nature.

Studies of populations [4] in developed countries show that access to natural green spaces and biodiversity has significant health benefits [154], stemming notably from increased physical activity, exposure to microbial diversity [155, 156] as well as psychosocial factors. These benefits include [132] lower incidence and risk of mental illness (such as depression, anxiety and stress), cardiovascular diseases and NCDs, improved immune function, and reduced overall mortality. Reduced recuperation times and improved recovery outcomes in hospital patients have also been reported. Exposure to nature is especially important for childhood development and health [157-161]. Children who grow up close to nature are more likely to conserve nature themselves as adults [162-163], while those in developed countries increasingly suffer from "nature-deficit disorder" due to lack of outdoor activity [164].

In terms of cultural wellbeing [4], species, habitats, ecosystems and landscapes inspire forms of music, language, art, literature and dance. They are essential to food production systems, culinary traditions, traditional medicine, rituals, worldviews and social systems.

Green infrastructure (GI), as laid out in the EU Strategy on Green Infrastructure [52, 53] is key for providing increased exposure to nature, especially in nature-deprived urban environments. The European Parliament's pilot project on BiodiverCities [165] aims to engage citizens in vision-building towards enhancing urban biodiversity, and to assess how urban GI can provide local and regional benefits. Further GI development is being informed by reports on the impact of nature-based solutions [166] and the health and social benefits of nature and biodiversity [167] in the EU. These indicate multiple benefits for physical, psychological and social wellbeing at the individual and community level: ranging from social cohesion to improved mental health and reduced cardiovascular and respiratory diseases.

2.1.2.4.3 Medicines

Modern pharmaceuticals

Most diseases that afflicted or killed people a century ago are today curable or preventable thanks to modern medicines, many of which are derived from biodiversity and natural products [4]: one of the most direct links between biodiversity and medicine. Antibiotics that greatly improved human health in the 20th century derive from microorganisms: the penicillins, as well as nine of thirteen other major classes of antibiotics. Nature-derived antimicrobials (antibacterials, antivirals, antiparasitics, antifungals) constituted more than 75% [168] of those approved by the Food and Drug Administration of the United States (USFDA) between 1981 and 2010. Despite substantial advances in synthetic drug design, biodiversity continues to be crucial for the development of new drugs and treatments, as well as for providing new insights into human health. Most of the medicinal potential of nature has yet to be tapped [1]: plants have been the single greatest source, but the majority have not yet been studied [169] for medicinal potential. Microbial and marine organisms, studied only since recently, hold vast potential [1]. Finally, of even greater importance than the medicinal potential of individual species is the insight that biodiversity and ecology provide into how infections are tackled by natural means. Yet many of these crucial organisms, species and habitats are increasingly endangered with extinction [1] by human action.

On the other hand, the release of pharmaceuticals both from human and veterinarian use into the environment [170] presents dangers for biodiversity as well as human health. A range of active pharmaceutical ingredients or APIs (active pharmaceutical ingredients such as hormones, antimicrobials and anti-depressants) have been detected in rivers and streams [171] across the world. Designed to interact with a specific target (receptor, enzyme or biological process) in humans and animals, they also affect organisms in the natural environment. APIs can be released via aquaculture and pasture animals and via manufacturing processes, sewage systems, surface water or soils [171, 172-174]. Limiting antimicrobial use would provide biodiversity and health co-benefits; excessive use alters the human microbiome and cultivates antimicrobial resistance (AMR) [175]; highly resistant bacterial strains in plants, animals and humans, increasing the risk of disease and death. Endocrine-disrupting chemicals [176] and non-steroidal anti-inflammatory drugs have also had adverse effects on ecosystems, wildlife and human health.

Directive 2008/105/EC [85] (amended by the Priority Substances Directive 2013/39/EU [91]) on environmental quality standards in water policy requires the European Commission to develop a strategic approach to water pollution from pharmaceutical substances, and to address the environmental impact.

Antimicrobial resistance (AMR) causes 35,000 deaths every year in the EU, and leads to high costs, including €1.5bn annually for healthcare systems [175]. In November 2020, the new Commission Implementing Decision (EU) 2020/1729 [177] on the monitoring of AMR in zoonotic and commensal bacteria was published, as part of the 2017 EU One Health Action Plan against Antimicrobial Resistance [178]. In June 2023 the Council adopted the Recommendation on stepping up EU actions to combat antimicrobial resistance in a One Health approach [179]. The EU4Health regulation [180] establishing the new EU4Health programme (2021-27) includes the specific objective of "supporting the prudent and efficient use of medicinal products, in particular antimicrobials, and actions to support the development of medicinal products that are less harmful for the environment, as well as the environmentally friendly production and disposal of medicinal products." The Farm to Fork Strategy aims to halve overall EU sales of antimicrobials for farmed animals and in aquaculture by 2030.

Traditional medicine

Millions of people rely on traditional medicine [181] based on biological resources, well-functioning ecosystems and the context-specific knowledge of local health practitioners. Plants used in traditional medicine are crucial for local healthcare, but also for global innovations in healthcare [182] and the associated international trade. They enter global commodity chains based on information gathered from their use in traditional medical pharmacopeia. Many of these plant and animal resources are on the verge of extinction [183], mainly due to overharvesting, habitat alteration and climate change. This also threatens livelihoods [4] of practitioners and collectors, who are often poor. Traditional medical knowledge often inspires industrial R&D processes in bio-resource based sectors, necessitating mechanisms to secure attribution and sharing of rights and benefits with knowledge holders, as set out in the Nagoya Protocol from the Convention on Biological Diversity (CBD) [184] on access to genetic resources and equitable sharing of benefits arising from their utilization, to which the EU is a signatory.

The simplified registration procedure for traditional herbal medicinal products introduced by EU Directive 2004/24/EC [185] clarifies uncertainties in the status of these products and facilitates their free movement through harmonised rules. It was intended for herbal medicinal products with a long tradition of medicinal use which do not fulfil "well established use" requirements for marketing authorisation, i.e. published scientific literature on recognised efficacy and safety. The Committee for Herbal Medicinal Products (HMPC) [186], set up in 2004 at the European Medicines Agency (EMA), was tasked with establishing monographs for traditional herbal medicinal products. A new HMPC work plan [187] was adopted in January 2023.

Figure 2. Biodiversity and health infographic as displayed by the EC Knowledge Centre for Biodiversity



Source: Emilie Weynants

2.2 EU support for projects and initiatives relevant to biodiversity and health

2.2.1 EC Research & Innovation initiatives

A variety of EC initiatives under the FP7 (2007-13)¹⁷ and Horizon 2020 (2014-20)¹⁸ programmes have supported research and innovation relating to biodiversity and health. Over this time period, a list of 150 EU-funded relevant projects was extracted through a projects' mining exercise based on selected terms qualifying biodiversity and health with a focus on animal health, animal welfare and zoonoses. Results are available at the dedicated EU research project-policy link explorer page¹⁹. Queries based on other terms could be run freely at the EU research project-policy link explorer page²⁰ from the KCBD website. Regarding the new Horizon Europe programme (2021-27)²¹, calls under the second phase (2023-24) are ongoing (HE work programme for 2023-24²²) and a list of calls can be consulted for the HE work programme for 2021-22²³.

2.2.1.1 FP7 (2007-2013) programmes

Specific Programme "Cooperation": Food, Agriculture and Biotechnology (FP7-KBBE) aimed at advancing knowledge in the sustainable management, production and use of biological resources (microbial, plant and

¹⁷ FP7: Seventh framework programme of the European Community for research and technological development including demonstration activities. <https://cordis.europa.eu/programme/id/FP7>

¹⁸ Horizon 2020 - EU Framework Programme for Research and Innovation.

https://ec.europa.eu/environment/integration/research/2020_en.htm

¹⁹ https://www.timanalytics.eu/TimTechPublic/dashboard/index.jsp#/space/s_1713?ds=156446

²⁰ https://knowledge4policy.ec.europa.eu/biodiversity/topic/eu-research-project-policy-link-explorer_en

²¹ Horizon Europe – Research and innovation funding programme until 2027.

https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe_en

²² https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/horizon/wp-call/2023-2024/wp-1-general-introduction_horizon-2023-2024_en.pdf

²³ https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/horizon/wp-call/2021-2022/wp-1-general-introduction_horizon-2021-2022_en.pdf

animal) towards safer, healthier, eco-efficient and competitive products and services for agriculture, fisheries, feed, food, health, forest-based and related industries.

Specific Programme "Cooperation": Environment (including Climate Change) (FP7 - Environment) aimed at improving the sustainable management of environmental resources by advancing knowledge on interactions between the climate, biosphere, ecosystems and human activities via multidisciplinary research. Environment and health, and natural hazards were covered as sub-topics under the area "Climate change, pollution and risks."

Specific Programme "Cooperation": Health (FP7-Health) aimed at improving the health of European citizens, and strengthening the competitiveness and innovative capacity of European health-related industries and businesses.

2.2.1.2 Horizon 2020 (2014-2020) programmes

Pillar III (SOCIAL CHALLENGES): "Health, demographic change and wellbeing" (H2020-EU.3.1) aimed at improving the lifelong health and wellbeing of all. Among its actions most relevant for biodiversity were "Preventing disease" (H2020-EU.3.1.2) and "Health care provision and integrated care" (H2020-EU.3.1.6) under topics such as "Innovative actions for improving urban health and wellbeing - addressing environment, climate and socioeconomic factors" (SC1-BHC-29-2020) and "Setting the priorities for a European environment, climate and health research agenda" (SC1-HCO-13-2018).

Pillar III (SOCIAL CHALLENGES): "Food security, sustainable agriculture and forestry, marine, maritime and inland water research, and the bioeconomy" (H2020-EU.3.2) aimed to secure sufficient supplies of safe, healthy and high-quality food and other bio-based products by developing productive, sustainable and resource-efficient primary production systems, fostering related ecosystem services and the recovery of biological diversity. Among its actions most relevant for biodiversity and health were "Sustainable and competitive agri-food sector for a safe and healthy diet" (H2020-EU.3.2.2), "Healthy and safe foods and diets for all" (H2020-EU.3.2.2.2), "Sustainable and competitive bio-based industries and supporting the development of a European bio-economy" (H2020-EU.3.2.4), "Sustainable agriculture and forestry" (H2020-EU.3.2.1), and "Increasing production efficiency and coping with climate change, while ensuring sustainability and resilience" (H2020-EU.3.2.1.1).

Pillar III (SOCIAL CHALLENGES): "Climate action, Environment, Resource Efficiency and Raw Materials" (H2020-EU.3.5) aimed to achieve a resource- and water-efficient and climate change-resilient economy and society, protect and sustainably manage natural resources and ecosystems, and ensure a sustainable supply and use of raw materials. Among its actions relevant to biodiversity and health was "Protection of the environment, sustainable management of natural resources, water, biodiversity and ecosystems" (H2020-EU.3.5.2). This action also co-funded the European partnership on biodiversity or BiodivERsA3, including 10 research projects²⁴ under the call on "Biodiversity and its influence on animal, human and plant health."

Pillar I (EXCELLENT SCIENCE): Marie Skłodowska-Curie Actions (H2020-EU.1.3) and European Research Council (H2020-EU.1.1) also include several topics relevant to biodiversity and health.

2.2.1.3 Horizon Europe (2021-2027) ongoing calls/programmes

Horizon Europe's Pillar II on Global Challenges and European Industrial Competitiveness covers both health and biodiversity as major topics under Cluster 1 and Cluster 6.

Under Cluster 1, devoted to health, the HE Work programme (2021-22), and the HE Work programme (2023-24) include the following destinations covering themes relevant for ecosystems and biodiversity:

Destination 2 "Living and working in a health-promoting environment" covers calls on "Environment and health" and "Partnerships in health." These include the topics "European partnership for the assessment of risks from chemicals" (HORIZON-HLTH-2021-ENVHLTH-03-01), "Health impacts of climate change, costs and benefits of action and inaction" (HORIZON-HLTH-2021-ENVHLTH-02-03) and "Methods for assessing health-related costs of environmental stressors" (HORIZON-HLTH-2022-ENVHLTH-04-01).

Destination 3 "Tackling diseases and reducing disease burden" covers calls on "Tackling diseases," including the topics "Pandemic preparedness" (HORIZON-HLTH-2021-DISEASE-04-06 and HORIZON-HLTH-2022-

²⁴ Joint BiodivERsA call (2018-19) on "Biodiversity and its influence on animal, human and plant health."
<https://www.biodiversa.eu/2019/10/07/2018-2019-joint-call/>

DISEASE-07-02) and "A roadmap towards the creation of the European partnership on One Health antimicrobial resistance (OH AMR)" (HORIZON-HLTH-2021-DISEASE-04-05).

Under Cluster 6 on "Food, Bioeconomy, Natural Resources, Agriculture and Environment," the HE Work programme (2021-22) and the HE Work programme (2023-24) include the following destinations covering topics relevant to health and biodiversity:

Destination "Fair, healthy and environmentally-friendly food systems from primary production to consumption" encompasses impact areas of the HE strategic plan (2021-24) on climate change mitigation and adaptation, enhancing ecosystems and biodiversity on land and water, sustainable food systems from farm to fork on land and sea, good health and high-quality accessible healthcare, and clean and healthy air, water and soil. It covers topics relevant to food systems, health, biodiversity and agro-ecology under calls HORIZON-CL6-2021-FARM2FORK-01, HORIZON-CL6-2022-FARM2FORK-01 and HORIZON-CL6-2022-FARM2FORK-02.

Destination "Resilient, inclusive, healthy and green rural, coastal and urban communities" encompasses impact areas of the HE strategic plan (2021-24) on climate change mitigation and adaptation, enhancing ecosystems and biodiversity on land and water, sustainable food systems from farm to fork, and good health and high-quality accessible healthcare. Topics under this destination are covered under calls HORIZON-CL6-2021-COMMUNITIES-01, HORIZON-CL6-2022-COMMUNITIES-01 and HORIZON-CL6-2022-COMMUNITIES-02-two stage.

Destination "Biodiversity and ecosystem services" is co-funding the European partnership on biodiversity²⁵ or BiodivERSA+ under call HORIZON-CL6-2021-BIODIV-02. Its main objectives include several objectives relevant for health, and it emphasises the rollout of nature-based solutions. It is also funding call HORIZON-CL6-2023-BIODIV-01-1 on impacts of chemical pollution on terrestrial biodiversity.

Pillar I (Excellent Science) programmes, Marie Skłodowska-Curie Actions and Research Infrastructures, also continue under HE. Both include topics relevant to biodiversity and health.

2.2.2 CINEA support

The European Climate Infrastructure and Environment Executive Agency (CINEA)²⁶ runs programmes that fund projects relevant to biodiversity and health. These include the LIFE programme²⁷ for environment and climate action, programmes in the maritime sector, and others.

The LIFE programme

In 2021 the Commission approved an investment package of more than €290 million for 132 new projects under the LIFE programme (2021-27), which will mobilise a total investment of €562 million. Putting Europe's biodiversity on a path to recovery by 2030 is one of its main goals. It consists of four sub-programmes, one of which is devoted to Nature and Biodiversity. The Nature and Biodiversity sub-programme, and includes projects relevant for biodiversity and health. It will fund 39 projects with a total budget of €249 million, of which the EU will pay €134 million. Earlier LIFE programmes also covered projects relevant to biodiversity and health, which can be searched in the [LIFE public database](#).

²⁵ BiodivERSA+: The European Biodiversity Partnership. <https://www.biodiversa.eu/>

²⁶ CINEA – The European Climate Infrastructure and Environment Executive Agency. https://cinea.ec.europa.eu/our-projects_en

²⁷ The LIFE Programme. https://cinea.ec.europa.eu/programmes/life_en

3 Conclusions

Our main conclusion is that the connections between biodiversity and health are complex and manifold, a fact that calls for urgent attention in policymaking, and requires a multidisciplinary and multi-sectoral approach, involving researchers and policymakers from the fields of human health, animal health, environmental science and social sciences. Scientific disciplines range from the evolutionary ecology of infectious and non-infectious diseases to ethics, law and politics [2]. Biodiversity and health offers the unique opportunity to demonstrate how ecological, environmental, medical and social sciences can contribute to the improvement of human health and wellbeing through the conservation of biodiversity and the services it brings to societies. There is still a knowledge gap to fill between the ecology of health and the concepts supported by international initiatives such as One Health or Planetary Health. Section 1 briefly summarised the state of research and touched on theoretical and methodological challenges, including the diversity of perspectives and expertise to involve.

The benefits of biodiversity for human health include the regulatory services provided by ecosystems that improve the quality of the air, water and soil, the provisioning services that underpin most of our food and medicines, as well as the cultural services that support our mental health. Interaction with biodiverse environments is integral to our health and wellbeing. Biodiversity also supports health by contributing to climate change mitigation and adaptation, and the recognition of climate change as an important factor influencing biodiversity as well as health brings new aspects in the current debate, encouraging collaboration and transdisciplinary working [3]. Biodiversity loss and the resulting disruption of ecosystem services have far-ranging consequences for our health and wellbeing, directly as well as through other impacts of human activities.

In sections 1 and 2.1.2.1 to 2.1.2.3 we have elaborated on the connections between biodiversity and health and the domains of pollution, climate change and agriculture and on EU policies in these domains. Human activities that cause climate change and pollution, and undermine the resilience of food systems and agriculture, also adversely affect biodiversity and health. The complex connections involved call for deepening our understanding of the direct and indirect pathways through more focused investigation. However, there is already a substantial body of evidence confirming that biodiversity loss has both exacerbated, and been exacerbated by, pollution and climate change. Pollution and climate change, which are among the five main direct drivers of biodiversity loss, also have a huge direct impact on human health. Agricultural intensification contributes to both pollution and climate change, as well as to other drivers of biodiversity loss. Of all human activities, unsustainable agriculture poses the highest threat to biodiversity. The resulting biodiversity loss in turn weakens the ability of ecosystems to mitigate pollution impacts and climate change, to adapt to climate change, and to boost the resilience and sustainability of agriculture and food systems. The multiple self-reinforcing feedback loops thus generated involve adverse and often unpredictable consequences for human health, and could get out of control if not addressed in a timely and coherent manner. EU policies in these domains, which have been reinforced over the years and are at the core of the European Green Deal, will impact both biodiversity and human health - and are in turn impacted by the loss of biodiversity and ecosystem services.

Biodiversity loss has many other important consequences for health. As described in sections 1 and 2.1.2.4, recent research shows that biodiverse surroundings enhance human microbial diversity, thus boosting our immunoregulatory functions and helping to prevent many non-communicable diseases. In a broader context, interaction with nature and access to green spaces profoundly influence mental and physical health and wellbeing, especially in children. As regards infectious diseases, the loss of natural habitat contributes to the spread of infectious zoonotic diseases. Last but certainly not the least, biodiversity lies at the root of the medicines that keep us alive: both the development of modern pharmaceuticals and the maintenance of traditional systems of medicine depend on a wide range of plants, animals and microorganisms, without which they cannot be effective.

Loreau et al. [8] reminded us that the idea that changes in biodiversity can impact how ecosystems function has, over the last quarter century, gone from being a controversial notion to an accepted part of science and policy. As the field matures, it is high time to review progress and look ahead to the implementation of this knowledge. Some pathways for the biodiversity and health nexus are provided in [7, 188, 189] on the necessity of combining ecology and public health:

- Refoundation of traditional disciplines is recommended, with teaching in medicine and biology that better considers the reality of infectious diseases as complex systems, necessitating integrative and transversal thinking and better collaboration between disciplines.
- There is a need for change in governance methods that are now outdated. Gautier [188] argues that the biodiversity/health nexus challenges the governance of the present biomedical- and technical expertise-based health system and calls for shaping a real integrated policy of “bio-diverse health” as the basis of a One Health Approach. Human health problems involving wild fauna and flora (Lyme disease, allergies, etc.) are provoking conflicts of expertise and evaluation methods between ecology professionals, human health professionals, and animal health professionals, and the health field is being shaken up by the irruption of new knowledge and new ways of thinking.

The multiple and complex interlinkages described above – and the associated risks for human health – call for coordinated intervention in all relevant policy domains: from pollution to climate change and disaster risk reduction to agriculture and food systems to medicine. With this synthesis we hope to draw attention to all these factors and more, as well as to the EU policies and initiatives, including on research and innovation, which address them. Whilst health concerns are gaining increasing attention in EU policies on biodiversity and nature conservation, especially in the wake of Covid-19, it will be equally necessary to embed the importance of biodiversity in EU health policies. The multiple policy domains described in this report need to be better integrated in a comprehensive, systemic One Health approach that prioritises win-win actions for health and biodiversity.

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List of abbreviations and definitions

AIDS	Acquired ImmunoDeficiency Syndrome
AMR	AntiMicrobial Resistance
APIs	Active Pharmaceutical Ingredients
CAP	European Union Common Agricultural Policy
BDS 2030	European Union Biodiversity Strategy for 2030
CBD	Convention on Biological Diversity
CINEA	European Climate Infrastructure and Environment Executive Agency
COVID-19	Coronavirus disease 2019
EAP	European Union Environment Action Programme
EGD	European Green Deal
EHP	European Environment and Health Process
EMA	European Medicines Agency
ENVI	European Parliament's Committee on Environment, Public Health and Food Safety
EU4Health	Programme for the European Union's action in the field of health
F2F	Farm to Fork Strategy of the European Union
FP7	Seventh framework programme of the European Community for research and technological development (2007-2013)
KCBD	Knowledge Centre for Biodiversity, established by the European Commission
HE	Horizon Europe, EU funding programme for research and innovation (2021-2027)
HMPC	Committee for Herbal Medicinal Products
K4P	Knowledge for Policy, EU Commission's platform for evidence-based policymaking
GEO-6	Sixth Global Environment Outlook from the United Nations Environment Programme
GI	Green Infrastructure
MS	European Union Member States
NAMs	New Approach Methodologies
NCDs	Non-Communicable Diseases
REACH	Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals
RoHS	EU Directive on 'Restriction of Hazardous Substances' in electrical and electronic equipment
RTD	Directorate-General for Research and Innovation
SUD	Sustainable Use of Pesticides Directive
SUR	Sustainable Use of Pesticides Regulation
USFDA	Food and Drug Administration of the United States
WEEE	Waste Electrical and Electronic Equipment
WFD	European Union Water Framework Directive
WHO	World Health Organization
ZPAP	Zero Pollution Action Plan of the European Union

Biodiversity: the variability among all living organisms from all sources and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems ([United Nations Convention on Biological Diversity, 2006](#)).

Health: a state of complete physical, mental and social well being and not merely the absence of disease or infirmity (WHO 1948)

Mental health: a state of wellbeing in which an individual realizes their own abilities, can cope with the normal stresses of life, can work productively and is able to make a contribution to their community ([World Health Organisation, 2018](#)).

Psychological wellbeing: a combination of positive affective states such as happiness (the hedonic perspective) and functioning with optimal effectiveness in individual and social life (the eudaimonic perspective) ([Winefield et al., 2012](#)).

List of figures

Figure 1. Examples of issues that can be addressed through a One Health approach.....5

Figure 2. Biodiversity and health infographic as displayed by the EC Knowledge Centre for Biodiversity18

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