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Reviewing planetary health in light of research directions in One Health

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Abstract

Climate change significantly impacts our planet's health, ecosystems, plants, animals and humans, increasing extreme weather events and the incidence and prevalence of infectious diseases, including zoonotic diseases. We reviewed the environmental changes affecting human, animal and planetary health and conducted a bibliometric analysis from 2012 to 22 that included these components. We identified 448 publications published on the topic throughout that period. Then, we reflected on the Research Directions question: How can we improve and facilitate multi-sectoral collaboration in warning and response systems for infectious diseases and natural hazards to account for their drivers, interdependencies and cascading impacts? The bibliometric analysis of planetary health has shown increasing interest among researchers since 2017, peaking in 2022. Lancet Planetary Health was the journal with more published articles; The London School of Hygiene and Tropical Medicine was the best-placed institution, and The United States led in topic-related publications. On the other hand, the climatic and pandemic global environmental crises demand fostered surveillance, which should concentrate on the drivers of disease, giving signals that account for human and animal health and environmental degradation. In response to global crises, higher education curricula should integrate One Health and Planetary Health approaches to achieve transdisciplinary thinking, allowing transcend knowledge, research and observation into action.

Introduction

The international community must now recognise that, despite their differences, the planet's and humans' health are inextricably linked to one another and, taken as a whole, offer a critical path for mitigation (Demaio and Rockström, 2015). Considering these two aspects, which, as stated prima facie, look unrelated, human health is possibly the best recognised. Regarding planetary health, this one is more likely to be identified with global health. By contrast, global health per se does not fully contemplate the setting we live in, the Earth itself (Horton, 2013). In this context, the Rockefeller Foundation–Lancet Commission on Planetary Health defined planetary health as the accomplishment of the utmost achievable level of healthiness, welfare and fairness at the global level via thoughtful attentiveness to the social–political–economic systems that outline humanity's future as well as the Earth's natural systems, which outline the healthy environmental limits within which humanity may prosper. In simpler words, the state of human civilisation and the natural systems it depends on is called planetary health (Horton and Lo, 2015; Jones et al., 2022). Alternatively, the Canmore Declaration understands planetary health as the inter-dependent vitality of all natural and anthropogenic ecosystems, emphasising that achieving planetary health depends on the interconnected systems of life and our approach to living (Jones et al., 2022). The philosophy of planetary health relies on the understanding that thriving natural systems and intelligent governance of such systems are essential for human health and civilisation. Nonetheless, natural systems are being degraded to a certain extent, which has never been seen in human history (Whitmee et al., 2015).

Planetary health emphasises the effects of anthropogenic disruptions on Earth's natural systems, that is limited resources, land-use changes, climate change and biodiversity loss. Food insecurity, the spread of vector-borne diseases and high heat- and air-related mortality rates are just a few of the effects of these disturbances. According to the World Health Organization (WHO), environmental degradation is responsible for nearly one-fourth of all deaths and diseases worldwide (Hampshire et al., 2022).

The 2016 UN Climate Change Conference highlighted that climate affects disease patterns, death rates, human living conditions, nutrition, water and hygiene, resulting in an upward trend in temperatures, sea levels and extreme events. Flooding, which can increase the risk of water-related illnesses and vector-borne illnesses; food manufacturing – both in terms of lengthened dry spell cycles and decreased micronutrients in staple crops – and the contaminants linked to carbon emissions – all of which are detrimental to human health (COP22,). Climate change also influences human and animal health by altering the conditions for pathogens and vectors of zoonotic diseases, posing new challenges to maintaining human and animal health (Leal Filho et al., 2022).

Regarding zoonosis, it is an infectious disease that has jumped from a non-human animal to humans (WHO, 2021). In other words, it is a direct infection acquired naturally from animals causing disease. Zoonotic diseases can be caused by pathogens that can spread to humans through direct or indirect contact with animals, vector-borne transmission, foodborne transmission or waterborne transmission (CDC, 2021). A zoonotic pathogen can undergo replication and mutation under selective pressure within a human host, enabling the pathogen to acquire the ability to efficiently transmit from person to person, subsequently leading to an emerging infectious disease in human populations unrelated to its zoonotic origins (Escudero Pérez et al., 2023). Noteworthy recent examples include the 2022 global outbreak of Mpox (formerly known as Monkeypox) and likely the COVID-19 pandemic (Haider et al., 2020; Orviz et al., 2022; Sharif et al., 2023). The complex links between human, animal and environmental health require coordinated multidisciplinary and multipronged collaboration to address the threats from zoonotic diseases, and the global public health community needs to act decisively now. Therefore, the importance of One Health, defined by the quadripartite WHO-WOAH-FAO-UNEP as an integrated, unifying approach that aims to sustainably balance and optimise the health of people, animals and ecosystems – It recognises the health of humans, domestic and wild animals, plants and the wider environment (including ecosystems) are closely linked and interdependent. The approach mobilises multiple sectors, disciplines and communities at varying levels of society to work together to foster well-being and tackle threats to health and ecosystems while addressing the collective need for clean water, energy and air, safe and nutritious food, taking action on climate change and contributing to sustainable development (WOAH, 2021). Hence, One Health is critical to addressing zoonotic public health threats, environmental issues and neglected tropical diseases to attain sustainable development goals (WHO, 2022).

However, implementing planetary health initiatives at the local level presents many challenges, some overlapping with those encountered in implementing One Health programmes (Bordier et al., 2020). In this regard, Mwatondo et al. (2023) stated a need to increase domestically available financial resources for national and subnational One Health Networks.

Human health is currently at its highest quotas, with increased life expectancy and decreased global mortality rates in children under five. Over the past quarter-millennium, humans have been highly successful, performing a "great escape" from extreme dearth. Despite the upsurge in the total population of less developed countries, the overall number of people living in extreme poverty has dropped over the last 30 years, followed by unparalleled advancements in public health, healthcare, education, the human rights legislation framework and industrial evolution that have brought humanity innumerable benefits – despite their unfairness – and untold benefits (Whitmee et al., 2015). On the other hand, the state of the rest of the biosphere is the worst it has ever been in human history. Climate change may threaten human health in a variety of ways, primarily direct and indirect ones, that is extreme weather events; communicable diseases that are mediated by environmental, social and demographic changes and military conflicts, which are intervened by more dispersed and complex social disruptions (Arber et al., 2020). Further, several environmental factors can potentially affect agricultural production, such as freshwater provision and sanitation, burning of biomass fuels and atmospheric air emissions, the occurrence and spread of diseases that are sensitive to climate change, and nutrient and waste absorption and detoxification (Haines et al., 2014).

The Industrial Revolution's intensification of human activities in the late 19th century caused soil, rivers and the air we breathe to become contaminated, harming our health and the natural systems supporting us. Afterwards, the gases created by pollution, burning fossil fuels and deforestation significantly changed the entire planet's atmosphere, being the cause of global climate change that became apparent about 75 years ago (Arber et al., 2020). Climate change would then respond by impacting and threatening human and planetary health. This chain reaction accelerated biodiversity loss worldwide, raising population morbidity and mortality rates.

Every region worldwide will likely experience further increases in climate hazards shortly, increasing multiple risks to ecosystems and people. A rise in heat-related human mortality and morbidity, food-, water-, and vector-borne illnesses, difficulties with mental health, flooding in coastal and other low-lying cities and regions, biodiversity loss in the land, freshwater, and ocean ecosystems, and a decline in air quality are among the dangers and risks anticipated in the near terms (Lee and Romero, 2023).

A bibliometric analysis of climate change and zoonosis (Leal Filho et al., 2022) found that the top four author keywords were "climate change," "zoonosis," "epidemiology" and "One Health," and the authors' keywords' largest node of the bibliometric map contained the following: infectious diseases, emerging diseases, disease ecology, One Health, surveillance, transmission and wildlife. The research also revealed that zoonotic diseases, documented in the literature in the past, have evolved, especially during 2010–15, as evidenced by a sharp augmentation and peaking in 2020 with the COVID-19 outbreak, an emerging disease with a probable zoonotic origin.

Besides, the global crises COVID-19 pandemic and the human-induced impact on Earth's life-support systems and planetary boundaries have reinvigorated the One Health and planetary health concepts, which build on equivalent systemic principles (Ruiz de Castañeda et al., 2023). The increased attention to One Health after the COVID-19 pandemic is an opportunity to focus efforts and resources on areas that need them most (Mwatondo et al., 2023).

This review combines:

1. An exploration of the recent literature on environmental changes affecting human, animal and planetary health.
2. A bibliometric analysis to understand better the quantitative evaluation of planetary health, health and climate change from 2012 to 22.
3. A reflection on the Research Directions One Health question: How can we improve and facilitate multi-sectoral collaboration in warning and response systems for infectious diseases and natural hazards to account for their drivers, interdependencies and cascading impacts? Our search addressed one and planetary health interactions, warning and surveillance, and capacity building in higher education institutions.

In 1 and 3, we complemented our search with the help of artificial intelligence (AI).

The structure of this review is as follows: In section "Methods", we describe the methodological approaches. Section "Reviewing the environmental changes affecting human, animal and planetary

Table 1. Scopus search approach

Search query/ Identified doc.	Excluded doc.	Doubled doc.	Doc. in the bibliometric analysis
(TITLE-ABS-KEY (“planetary health“) AND TITLE-ABS-KEY (health) OR TITLE-ABS-KEY (wellbeing) OR TITLE-ABS-KEY (well-being) AND TITLE-ABS-KEY (“climate chang*“) OR TITLE-ABS-KEY (“climate variab*“))	Non-English documents not yet in the publication phase Written before 2012 and after 2022		
n = 707	n = 257	n = 2	n = 448

health” summarises the state of the art of the environmental challenges on human and planetary health. Section “Results of the bibliometric analysis” presents the results of the bibliometric analysis from 2012 to 22 with a discussion. In section “Addressing the Research Directions question”, we address the Research Directions question. Finally, we summarise and conclude in section “Overall Summary and Conclusion”.

Methods

We combined qualitative and quantitative approaches. First, we explored the recent literature and comprehensive search on Planetary Health and One Health (section 3). We identified several articles and reports supporting climate change’s influence on the environment in which we live, human health and planetary health. In this context, comprehensive information was made available by exploring PubMed, Google Scholar and ScienceDirect databases for published journal articles and reports in English over the last decade. Also, we searched the websites of international organisations, that is the WHO, Intergovernmental Panel on Climate Change, Convention on Biological Diversity, World Wildlife Fund, Global Nutrition Report and United Nations Environmental Programme (UNEP).

Besides, we conducted complementary research with the help of the Microsoft AI tool, Copilot, to answer questions and identify sources related to our research topic. Copilot is an AI companion that provides information, answers questions and generates content using natural language processing and web search technologies (Harvard Online, 2023).

Second (Section 4) involved a bibliometric analysis to quantitatively assess the literature about the relationship between planetary health, health and climate change. In this research, we used the Scopus database by applying the following query: (TITLE-ABS-KEY (“planetary health”) AND TITLE-ABS-KEY (health) OR TITLE-ABS-KEY (well-being) OR TITLE-ABS-KEY (well-being) AND TITLE-ABS-KEY (“climate chang*”) OR TITLE-ABS-KEY (“climate variab*”)) AND PUBYEAR>2011 AND PUBYEAR <2023 AND (LIMIT-TO (LANGUAGE, “English”)) AND (LIMIT-TO (PUBSTAGE, “final”)). We identified 448 publications from 2012 to 2022, after removing doubled documents. For additional data analysis, we utilised the VOSViewer software. Table 1 provides summarised information about the search approach.

Thirdly (section 5), we addressed the Research Directions question, focusing on animal, human and planetary health interactions, warning and surveillance, and capacity building in higher education institutions.

Reviewing the environmental changes affecting human, animal and planetary health

This section summarises the main environmental changes affecting human, animal and planetary health based on a targeted literature review of recent publications, including the state of the art of heat, extreme weather events and air pollution (Table 2).

Table 3 summarises other relevant environmental changes.

Finally, we comment on the surveillance system from the One and Planetary Health perspectives.

Heat, extreme weather events and air pollution

Rising atmospheric temperatures harm the health of all plants, animals and people who live on Earth (Sampath et al., 2023). Data analysis from 65 million deaths and temperature estimates in nine countries indicates that 17 causes of death are linked to extreme heat or cold, with the majority being cardiorespiratory or metabolic diseases. Extreme heat and cold were responsible for 17% of all deaths worldwide in 2019, of which 356,000 were related to heat (Lancet, 2021). Evidence suggests climate change has accelerated the spread of infections in the northern hemisphere because the global climate crisis can also alter the nature of zoonotic infections through its effect on temperature and precipitation (Sipari et al., 2021).

Available data indicate that the rise in temperature and extreme weather events significantly impact vectors, rodents and foodborne pathogens. Numerous vector-borne diseases, such as dengue, chikungunya, visceral leishmaniasis and Lyme disease, are experiencing an increase in both incidence and geographic distribution (Stone et al., 2017; Wahid et al., 2017; Pasquali et al., 2019; Brady and Hay, 2020; Vandekerckhove et al., 2021; Yang et al., 2021). Although other factors related to global change, including urbanisation, land-use change and international travel, may be related (Tatem et al., 2012; Wilke et al., 2019; Swei et al., 2020), the rise in mean temperatures play a crucial role in the increased prevalence of vector-borne diseases. This is attributable to an accelerated life cycle of the vector, heightened blood-feeding activity, a shorter extrinsic incubation period of the pathogens and increased fecundity facilitated by warmer temperatures (Hlavacova et al., 2023; Rivas et al., 2014; Mordecai et al., 2019; Winokur et al., 2020; Wiskel et al., 2023). Moreover, extreme events like floods can elevate the incidence of mosquito-borne diseases due to the proliferation of potential breeding sites and increased humidity, contributing to higher vector survival (Coalson et al., 2021; Nosrat et al., 2021). Conversely, these events can reduce the risk of tick-borne diseases by creating a hostile environment for tick survival (Weiler et al., 2017; Bidder et al., 2019). On the other hand, drought could increase the risk of certain mosquito-borne diseases by augmenting the number of breeding sites through the proliferation of water storage tanks and other containers near households (Chretien et al., 2007; Trewin et al., 2013).

Furthermore, rodents are crucial reservoir hosts for zoonotic pathogens such as Leptospira and Hantaviruses. Also, they serve as potential reservoirs for emerging infectious diseases (Han et al., 2015).

Heavy rainfall and high temperatures in the winter can significantly impact the epidemiology of rodent-borne pathogens by altering the food resources available and, thus, the population

Table 2. Summary of the most significant environmental challenges to human, animal and planetary health posed by heat, extreme weather events and air pollution

Environmental challenges, impacts and regions	References
Heat and extreme weather events	
From 2000 to 2016, the number of people exposed to heat waves amplified by about 125 million.	(Naumann et al., 2020; Sampath et al., 2023)
About 175 million added persons were exposed in 2015 to hot spells compared to average years. In numerous European locations, extreme heat waves broke all-time temperature records from June to July 2019. Climate change will likely increase the occurrence and intensity of extreme weather events. Under a scenario with 3°C global average warming, the number of EU and UK residents exposed to heatwaves will increase 30 times from the average 1981–2010, affecting more than half the EU population. In the absence of adaptation, this could lead to 96,000 annual deaths from extreme heat, up from the current annual death toll of 2,750. Achieving global warming of 1.5°C would reduce the number of people who die each year from extreme heat to about 30,000.	(Naumann et al., 2020)
Heat can affect work productivity. The probability of experiencing occupational heat stress was 4.01 times higher among persons performing single work shifts under high temperatures than those working under neutral thermal environments. Of those persons performing under high temperatures, 35% underwent occupational hyperthermia, while 30% registered productivity losses. Lastly, 15% of persons who usually performed upon heat stress reported suffering from kidney disease or acute renal failure.	(Flouris et al., 2018)
The International Labour Organization estimates that more than a billion workers, not all employed during the summer, are reportedly exposed to high heat episodes. However, these figures are probably conservative based on projections of future socio-economic development.	(Ebi et al., 2021)
The diurnal temperature variation (DTV) index is a death risk factor. A multi-country modelling study conducted across 445 communities and 20 nations revealed that DTV increased mortality. In the unalleviated climate change scenario, the upcoming median DTV will intensify (0.4 to 1.6°C), predominantly in the USA, Central and Southern Europe, Mexico, and South Africa, leading to extra deaths between 0.2%–7.4%. Besides, in the long term, it is expected that a 0.05% additional DTV mortality risk per 1°C rise in median temperature and the DTV-related surplus deaths will likely rise in all countries by 1.4%–10.3% over 2090–99.	(WHO, 2022)
The recurrence and strength of unusual climate events are expanding, with around 90% of hydro-meteorological disasters. Over 2008–2017, 84.2% of the 3751 usual threats recorded in the Emergency Events Database EM-DAT were weather-related (e.g., heatwaves, surges, storms and dry spells), recording approximately 2 billion individuals and an overall financial disaster of 1658 billion USD. These occasions cause serious fatalities, which through a cascade reaction may affect well-being and welfare, reckoning contaminant diseases, mental sickness, starvation, struggle and populace movement. Extreme events might harm the obliterated physical health organisation, leading to the closure of healthcare service provider institutions and other health challenges.	(Ebi et al., 2020)
Air pollution	
Particulate matter $PM_{2.5}$ is now the leading environmental contributor to the global disease burden. Moreover, long-term exposure to $PM_{2.5}$ is linked to early death from several illnesses, including lung cancer, cardiovascular disease and lower respiratory infections. Indeed, 92% of the world's population lives in places where atmospheric $PM_{2.5}$ concentrations surpass the WHO guideline, particularly in China, Bangladesh, India, Pakistan and Nigeria.	(Turner et al., 2020; Southerland et al., 2022; Guinto et al., 2022)
Global population-weighted average NO_2 concentrations increased at an annual rise of 0.9% from 1996 to 2012. High-income countries across the Asia Pacific, Western Europe and North America had the largest population-weighted mean concentrations. However, a declining pattern varied from 2.1% to 4.7% per annum. Reportedly, East Asia had the largest population-weighted mean concentrations and was annually growing at the fastest rate of 6.7%. In 2017, the global population-weighted mean O_3 concentration was the same as in 1990.	(Turner et al., 2020)
Air pollution significantly impacts animal health, particularly in birds, leading to respiratory distress, impaired reproduction and increased susceptibility to infections upon exposure to airborne pollutants. Urban wildlife, companion animals and zoo animals exposed to air pollution demonstrate elevated rates of anthracosis, affecting their health.	(Ahasan et al., 2010; Bettini et al., 2010; Barton et al., 2023; Leya et al., 2023; Torres-Blas et al., 2023)
Animal health	
Climate change and land-use alterations can modify the geographical range, interactions and abundance of various animal species and their pathogens, thereby facilitating spillover events.	(Hoberg and Brooks, 2015; Williams et al., 2022)
Emerging infectious diseases driven by anthropogenic global changes pose a significant threat to the conservation of endangered animal species, such as certain amphibians and marine turtles.	(Cohen et al., 2019; Manes et al., 2022)
Climate change effects, particularly rising temperatures, can affect the health and welfare of food-producing animals by increasing heat stress, elevating the risk of metabolic diseases, inducing oxidative stress and impairing immune function.	(Lacetera, 2019)

Table 3. Summary of the environmental challenges to human and planetary health posed by food security and undernutrition, water scarcity and sanitation, vector-borne and zoonotic diseases, biodiversity loss and agriculture and deforestation

Environmental challenges, impacts and regions	References
Food security and undernutrition	
Guaranteeing nutrition security and suitable sustenance without compromising planetary well-being remains one of the tremendous worldwide challenges for the 21st century.	(Ebi et al., 2020; Guinto et al., 2022)
Warming temperatures, erratic rainfall patterns and extreme weather events adversely impact crop yield potential, increasing food and financial insecurity. Unsustainable food systems restrict people's access to affordable, nutrient-dense foods in this situation, increasing their risk of illness and unhygienic living conditions.	(WHO, 2021)
Worldwide starvation expanded to one out of every nine persons in 2018, requiring constant access to secure, nourishing and adequate food. Approximately 144 million children under five were low height for their age, and 38 million were overweight in 2019, with increased rates of malnourishment, comprising under/overnutrition, coexisting in numerous nations. These impacts mainly impact the low- and middle-income states.	(Ebi et al., 2020)
Rising temperatures, altered precipitation patterns and increased occurrence of extreme events adversely impact food security.	(Mbow et al., 2019)
Roughly 21%–37% of greenhouse gas emissions (GHE) are attributable to the food system chain. Besides, recent research demonstrates that climate alteration would negatively affect crops in lower-latitude areas and positively affect those in higher-latitude regions.	
With increased atmospheric CO_2 concentration, the nutritional value of some grains and legumes will also decline, increasing the risk of zinc and iron deficiency in low- and middle-income countries.	(WHO, 2021)
Climate change affected the consumption of fruit and vegetables in high-income countries and Western Pacific low- and middle-income countries, leading to non-communicable diseases (NCDs), e.g., type 2 diabetes mellitus, cardiovascular diseases and some cancers.	(Mbow et al., 2019)
Climate variation affects food security in drylands, predominantly in Africa and high mountain districts of Asia and South America. By 2050, climate change will likely further influence food security in terms of increased prices. Furthermore, the dissemination of pests and illnesses will vary, negatively affecting food production. Likewise, intensifying extreme events would risk the food system.	Myers et al., 2017b)
The success of the global increase in food production over the last six decades for public health was only feasible given our planet's natural resources. Agricultural land and meadows make up about 40% of the ice-free ground on Earth, and they are the only primary human uses of water, accounting for 66% of annual water abstractions.	(WHO, 2021)
Undernutrition causes about 45% of all deaths. Good nutrition for children under two years old promotes overall better development and lowers morbidity, mortality and the risk of chronic disease.	(Development Initiatives, 2022)
Since the COVID-19 outbreak, the number of people who suffer from hunger has increased by 24% from 2019 to 2021.	
Food insecurity increases the risk of stunting and being underweight but not wasting, particularly in children under five who are at risk for stunting. Additionally, children and adolescents in developing countries were more likely to be at high risk. Indeed, in 2020, 149 million children under five were too short for their age, and 38.9 million were overweight or obese.	(Moradi et al., 2019); WHO, 2021)
Water scarcity and sanitation	
The lack of appropriate water and sanitation causes various diseases, notably diarrhoea. Nearly 1000 children under five die daily because of diarrhoea, exacerbated by contaminated water and sanitation. The UN Sustainable Development Goals (SDGs) included a water (SDG 6) goal with ambitious objectives for equitable access to drinking water and sanitation by 2030. Under the impact of climate change, achieving affordable universal access would be a significant task for the SDG era.	(Howard et al., 2016)
The location of human settlements, socio-economic activities and the ecological environment are all influenced by water. The conservation of ecosystems and biodiversity is made more accessible by the sustainable management of water resources (Goals 14 and 15).	(Vinci et al., 2021)
Nevertheless, despite substantial progress achieved during the Millennium Development Goals period, nearly 748 million people in 2012 still relied on contaminated drinking water supplies, with 173 million drinking directly from rivers, lakes or ponds.	(Whitmee et al., 2015)
Vector-borne and zoonotic diseases	
Despite a downward trend, infectious diseases account for about 20% of the global disease burden and underpin more than 80% of foreign health threats.	(Watts et al., 2018)
Rapid climate change outweighs vector-borne diseases and has long-term effects on humans and natural ecosystems. Pests, diseases and vectors thrive in warmer climates. As a result, climate change has already improved the conditions for spreading infectious diseases, such as Lyme disease, water and foodborne illnesses, illnesses spread by mosquitoes, like malaria and dengue fever and rodent-borne diseases.	(Gubler et al., 2001; Morgado et al., 2021; Mojahed et al., 2022; Wiskel et al., 2023)
Changes in biodiversity brought on by deforestation increase the risk of malaria in the Brazilian and Peruvian Amazons (by increasing the population of *Anopheles darlingi* and transmission rates). An augmentation in the number of preferred breeding sites established by populated areas, typically followed by deforestation to clear land for agricultural practices, is another potential cause of increased malaria transmission risk in the Amazon.	(Whitmee et al., 2015)
Biodiversity loss	
Global biodiversity has fluctuated throughout geologic time as new species have been added by evolution and old ones have been eliminated by extinction. Natural processes like evolution and extinction occur when populations of organisms react to changes in their physical and biological environments. Therefore, change is an inevitable part of life. Ecosystems and biodiversity play a crucial global role in deciding the Earth System's status, adapting its material and energy flows and determining how it responds to sudden and rapid change.	(The Lancet Planetary Health, 2023) (Romanelli et al., 2015) (Almond et al., 2020)
The 2020 Worldwide Living Planet Index (LPI) indicates an average 68% drop in checked vertebrate species population between 1970 and 2016. The 94% decrease within the LPI for the tropical sub-regions of the Americas is the most significant drop surveyed in any region.	
Most of the Earth's ice-free terrestrial surface seas are changed or contaminated.	

(*Continued*)

Table 3. (*Continued*)

Environmental challenges, impacts and regions	References
Agriculture and deforestation	
The health of human populations is connected to Earth's natural systems and biodiversity. The production, distribution and nutrient content of food are all impacted by climate change. Likewise, agricultural production systems significantly affect the environment and public health.	(Canavan et al., 2017)
Climate variations threaten crop productivity in regions already considered "food insecure," i.e., Africa and South Asia. Climate change will likely increase plant disease pressures in crops, negatively affecting food safety and sustainability, as it alters pathogen evolution and host–pathogen interactions and facilitates the emergence of new pathogenic strains and the spreading of plant diseases to new areas.	(Haines et al., 2014) (Singh et al., 2023)
The worldwide population growth and *per capita* consumption changes of natural resources and energy have resulted in unprecedented land and freshwater usage rates, with agriculture accounting for roughly 70% of global freshwater utilisation. Developing zones beneath farming and forestry, comprising commercial manufacturing, have upheld utilisation and nourishment accessibility for a developing populace. However, with substantial territorial variety, these changes have contributed to expanding net GHE, damaging the natural ecosystems and declining biodiversity.	(Masson-Delmotte et al., 2020)
Stopping global deforestation is essential for combating climate change and maintaining natural biodiversity. Healthy primary forests support billions of people's lives and livelihoods, storing and sequestering significant amounts of carbon. However, deforestation is still a major problem worldwide, and land-use change is responsible for 12%–20% of annual GHE.	(The Lancet Planetary Health, 2023)

size of reservoir species (Engelthaler et al., 1999; Muschetto et al., 2018). Floods and droughts can intensify the rodent–human interaction because food and habitat shortages can draw the rodents near households and buildings (Gubler et al., 2001; Fichet-Calvet et al., 2007) and increase the susceptibility of the reservoirs to infections (Eads et al., 2016). In this context, Leptospirosis is a rodent-borne disease closely linked to heavy rainfall and flooding. Flooding can lead to increased human contact with contaminated water, the displacement and concentration of rodents and humans in dry areas, the dispersion of leptospires in the soil and the creation of poor hygienic conditions. A previous systematic review on this subject suggests that approximately 23% of leptospirosis outbreaks worldwide between 1970 and 2012 could be attributed to exposure to water during floods and extreme weather events (Munoz-Zanzi et al., 2020).

Additionally, elevated temperatures and increased precipitation have been linked to higher incidences of certain foodborne diseases, such as Salmonellosis and Campylobacteriosis (Djennad et al., 2019; Lee et al., 2019; Kuhn et al., 2020; Morgado et al., 2021). This association is partially attributed to high temperatures facilitating the rapid replication of most foodborne pathogens, thereby heightening the risk of contamination along the food production chain. Conversely, heavy rainfall enhances the likelihood of water supplies and agricultural products becoming contaminated by facilitating the transport and dispersion of animal and human faeces containing the pathogens (Semenza et al., 2012).

The direct effects of heat on human health include heatstroke, cardiovascular, cerebrovascular, and respiratory conditions, and early mortality. Evidence suggests that temperatures above long-term averages during the summer and specific heat extremes (such as heat waves) cause an increase in mortality. One of the leading weather-related causes of death in high-income nations is heat. In addition, hot weather and heat extremes increase emergency room visits and hospital admissions, cardiorespiratory and other disease deaths, mental health problems, health care costs and several other outcomes besides mortality. Regardless of income, studies consistently demonstrate that adults over 65, those with cardiopulmonary and other chronic diseases, and very young children are especially susceptible to the effects of heat (Ebi et al., 2021).

Air pollution, a globally distributed environmental change, is the most significant environmental health risk factor, although not always related to a cause/effect of climate change (Arber et al., 2020). Air pollution causes millions of premature annual deaths and healthy years of life and is connected to many harmful health outcomes, including cancer, neurological issues, cardiovascular and respiratory disease, and birth outcomes (The Lancet Planetary Health, 2022; Southerland et al., 2022). Globally, there is a higher mortality rate today related to air pollution than HIV, malaria and tuberculosis altogether (COP22,).

In 2019, 99% of people on Earth lived in areas where the WHO's recommended air quality levels needed to be met (WHO, 2022), and circa one in six premature deaths per year were attributable to global pollution due to air and toxic pollution.

Regarding animal health, birds can develop respiratory distress, impaired reproduction and increased susceptibility to infections when exposed to air pollutants like aerosolised heavy metals, particulate matter and nitrogen oxides (Barton et al., 2023). Similarly, exposure to urban air pollution has been associated with the presence of carbon in the airway macrophages (anthracosis) in urban wildlife, companion and zoo animals (Ahasan et al., 2010; Leya et al., 2023; Torres-Blas et al., 2023). Anthracosis has been associated with an increased risk of lung cancer in dogs (Bettini et al., 2010).

Impacts of Global Change on animal health

Global change can profoundly affect the health of both wild and domestic animals. Climate change and land-use alterations can modify the geographical range, interactions and abundance of various species and their pathogens (Hoberg and Brooks, 2015; Williams et al., 2022). These new interactions between pathogens and potential hosts create opportunities for spillover and infection across different species. Models developed for viral and parasitic pathogens project an increase in spillover events in the future under climate change conditions (Morales-Castilla et al., 2021; Carlson et al., 2022). Changes in host–pathogen interactions within climate change can threaten wildlife conservation; the global decline in some amphibian species adapted to cool weather could be explained by the interaction of rapidly rising temperatures and the infection of the pathogenic fungus *Batrachochytrium dendrobatidis* (Cohen et al., 2019).

Similarly, anthropogenic modifications such as water pollution and rising water temperatures might have played a pivotal role in disseminating fibropapillomatosis in marine turtles. This neoplastic disease is potentially induced by the infection with a herpesvirus and the complex interaction of poorly understood external factors (Manes et al., 2022).

Furthermore, the anthropogenic drivers of emerging infectious diseases in wildlife can be categorised into those that induce immune suppression, such as pollution; those that facilitate spillover events, like habitat loss and urbanisation; and those that enable pathogen dispersion, such as international travel and trade (Manes et al., 2023).

The rise in temperatures driven by climate change can also affect the health and welfare of food-producing animals by increasing heat stress, elevating the risk of metabolic diseases, inducing oxidative stress and impairing immune function (Lacetera, 2019).

Surveillance and warning system

The duplication of the human population in the last 50 years has exposed more people living closely to wildlife, livestock and pets, increasing the chances for zoonotic diseases to pass between animals and people. About three quarts of all emerging virus-associated infectious diseases have a zoonotic origin. One Health-inspired environmental surveillance campaign is the preferred tool for monitoring human-adjacent environments for known yet-to-be-discovered infectious diseases. One Health-driven approaches facilitate surveillance and harbour the potential of preparing humanity for future pandemics caused by aetiological agents with environmental reservoirs (Leifels et al., 2022).

From a Planetary Health perspective, a surveillance system should collect, analyse and share health and environmental data at different scales and be able to assess complex relations and trends (Haines et al., 2018). From a One Health perspective, a joint surveillance and warning system should be developed using a transdisciplinary approach, fostering policy, institutional and operational collaboration to enhance cooperation among the institutions involved in environmental, animal and human Health (Bordier et al., 2020). Surveillance should focus on the drivers of disease rather than the disease itself, which should give signals that account for human and animal health and environmental degradation (Drewe et al., 2023).

Results of the bibliometric analysis

Using the search query referred to in the methods section, between the years 2012 and 2022, we pointed out 448 published documents in English. Furthermore, we verified any publications that may have been listed twice, but the total number of publications remained the same.

Documents by the year of publication

The scientific literature published from 2012 to 2022 demonstrates that planetary health has gained more interest, mainly since 2017, as supported by the Scopus database. As a result, there were 149 publications in 2022, as opposed to 1 in 2013 (Figure 1).

Documents by source

Figure 2 shows the most frequently published articles. Lancet Planetary Health had the majority (n = 74), followed by the Lancet (n = 23), International Journal of Environmental Research and Public Health (n = 21) and Frontiers in Public Health (n = 15).

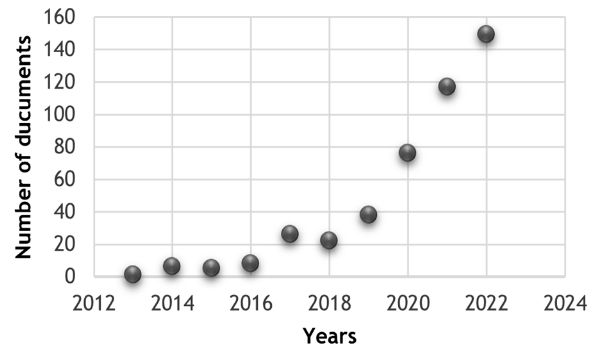

Figure 1 Documents by the year of publication.

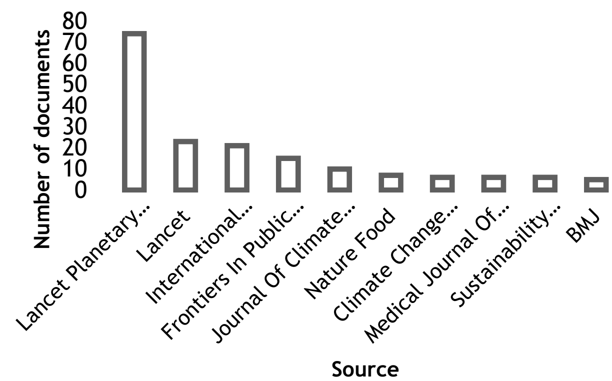

Figure 2. Documents by source, over 2012–2022.

The other four following journals' publications ranged between 5 and 10 documents. Interestingly, Lancet Planetary Health and Frontiers in Public Health indicate a later publishing history on this subject than other journals. Most papers from the top four sources were released between 2020 and 2022.

Documents by affiliation

The London School of Hygiene and Tropical Medicine (n = 27) topped the list of institutions actively participating in publishing documents on the subject, followed by the University of Washington (n = 19), the Australian National University (n = 16), the Harvard T.H. Chan School of Public Health (n = 15) and University of Melbourne (n = 14) (Table 4).

Documents by country

The United States was in the top spot with the most publications (n = 162), followed by the United Kingdom (n = 112), Australia (n = 72), Canada (n = 51) and Germany (n = 46) (Table 5).

Documents by type

The "Articles" category, with 178 publications (40%), accounted for the most significant percentage of the literature on our topic of interest, followed by "Notes" with 91 publications (20%), "Reviews" with 81 publications (18%), "Editorial" with 34 publications (8%) and "Book Chapter" with 28 publications (6%), round out the top five categories under document type analysis.

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Table 4. Documents by affiliation

Rank	Affiliation	Documents
1st	London School of Hygiene & Tropical Medicine	27
2nd	University of Washington	19
3rd	The Australian National University	16
4th	Harvard T.H. Chan School of Public Health	15
5th	University of Melbourne	14
6th	Harvard University	13
7th	University of Toronto	12
8th	The University of Sydney	12
9th	Stanford University	11
10th	The University of British Columbia	10

Table 5. Documents by country

Rank	Country	Documents
1st	United States	162
2nd	United Kingdom	112
3rd	Australia	72
4th	Canada	51
5th	Germany	46
6th	Sweden	23
7th	France	20
8th	Switzerland	20
9th	Spain	19
10th	China	17

Co-authorship analysis

We used "Countries" as the unit of analysis for the co-authorship analysis. While choosing the threshold, we set the requirements for a minimum number of documents and citations for a country to be 5, correspondingly. As a result, only 28 of the 89 countries met the requirement. The United States topped the list with the most documents (n = 160) and 5583 citations. The United Kingdom came second (n = 112) with 4183 citations. Australia, Canada and Germany ranked third, fourth and fifth, respectively. Australia counted 72 publications and 1564 citations, followed by Canada with 51 publications and 2722 citations, *versus* Germany, which counted 46 and 1240 citations.

Four clusters were visible using the VOSviewer (Figure 3): *the red cluster* – nine items (United States, United Kingdom, Brazil, Canada, Chile, Colombia, Kenya, Malaysia and South Africa); *the green cluster* – 9 items (Austria, China, Finland, Germany, India, Japan, Philippines, Sweden and Switzerland); *the blue cluster* – 9 items (Belgium, Denmark, France, Indonesia, Ireland, Italy, the Netherlands, Norway and Spain); and *the yellow cluster* including only one item – Australia. Countries that belonged to the same cluster had significant interests in the same scientific field. As shown in subsection 4.4, the United States and the United Kingdom had the highest percentage of published documents relevant to our topic. The same can be affirmed if referring to the large node visualised on the map produced by VOSviewer. Furthermore, a strong collaboration between these two countries is indicated by the close distance between the two nodes that represent them.

Co-occurrence analysis

We applied the "Author keywords" as our analysis units in the co-occurrence analysis and set 5 as the minimum number of keyword occurrences. As a result, out of 890 keywords, 43 met the threshold when the criteria above were used. The top five keywords used by researchers in publications about planetary health's relation to human health and climate change were: "climate change", "planetary health", "sustainability", "public health" and "environmental health" (Figure 4).

Seven clusters were detected in the VOSviewer visualisation (Figure 4): *the red cluster* representing nine items (e.g., air pollution, climate change, COVID-19, human health, medical education, planetary health, pollution, sustainable healthcare and urbanisation); *the green cluster* representing nine items (e.g., biodiversity, ecology, environmental health, food systems, health equity, health promotion, mental health, microbiome and social justice); *the blue cluster* representing seven items (e.g., adaptation, Anthropocene, ethics, global warming, health, mitigation and well-being); *the yellow cluster* representing seven items (e.g., carbon footprint, environment, food security, greenhouse gas emission, nutrition, planetary boundaries and sustainability); *the purple cluster* representing seven items (e.g., global health, governance, One Health, policy, social determinants of health, sustainable development and sustainable development goals); *the cyan cluster* representing three items (e.g., public health, infectious diseases and system thinking); and *the orange cluster* representing only one item – higher education.

Citation analysis

We applied the "Sources" counting method to citation analysis, establishing five as the bare minimum for the number of a source's documents and its citations. It resulted that out of 214 sources, 11 met the threshold. Table 6 shows that the top ten cited sources are led by The Lancet (n = 1759), followed by The Lancet Planetary Health (n = 1231), the International Journal of Environmental Research and Public Health (n = 505), Journal of Climate Change and Health (n = 264) and Nature Food (n = 260).

Bibliographic coupling

We applied "Documents" as the unit of analysis for the bibliographic coupling and set 5 as the minimum number of citations for a document. Out of 448 documents, 226 met the threshold. As a result, we obtained eleven clusters from the map (Figure 5). With a total of 1440 citations, the article with the most citations was "Safeguarding human health in the Anthropocene epoch: report of The Rockefeller Foundation-Lancet Commission on planetary health" (Whitmee et al., 2015). This article is included in the orange cluster, mainly focused on planetary health publications, that is "Limits to growth, planetary boundaries, and planetary health" (Butler, 2017), "Planetary Epidemiology: Towards First Principles" (Butler, 2018)," "Planetary health: a new science for exceptional actions" (Horton and Lo, 2015), "Human and planetary health: towards a common language" (Demaio and Rockström, 2015), "Governance for planetary health and

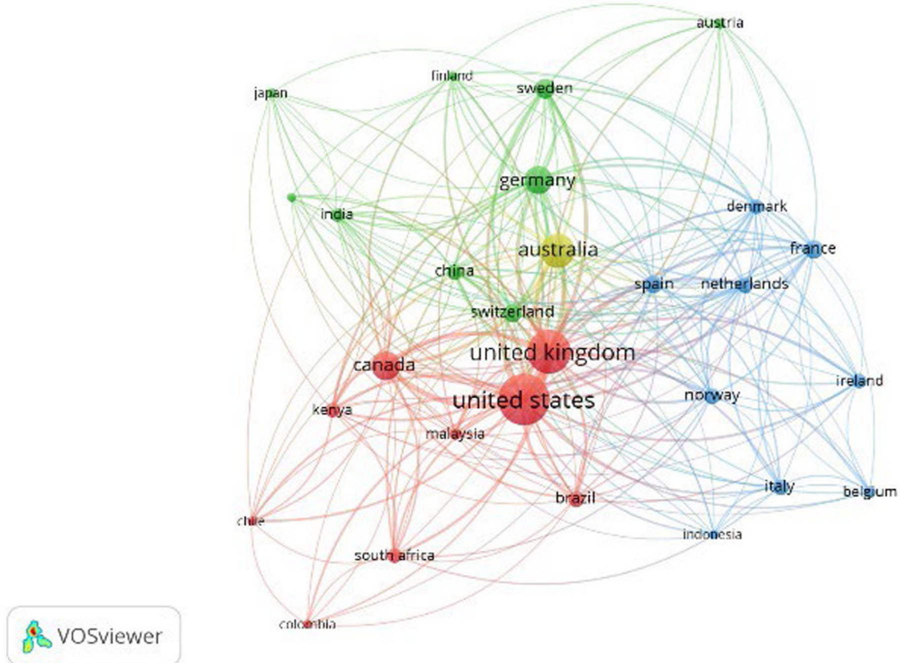

Figure 3. Co-authorship analysis.

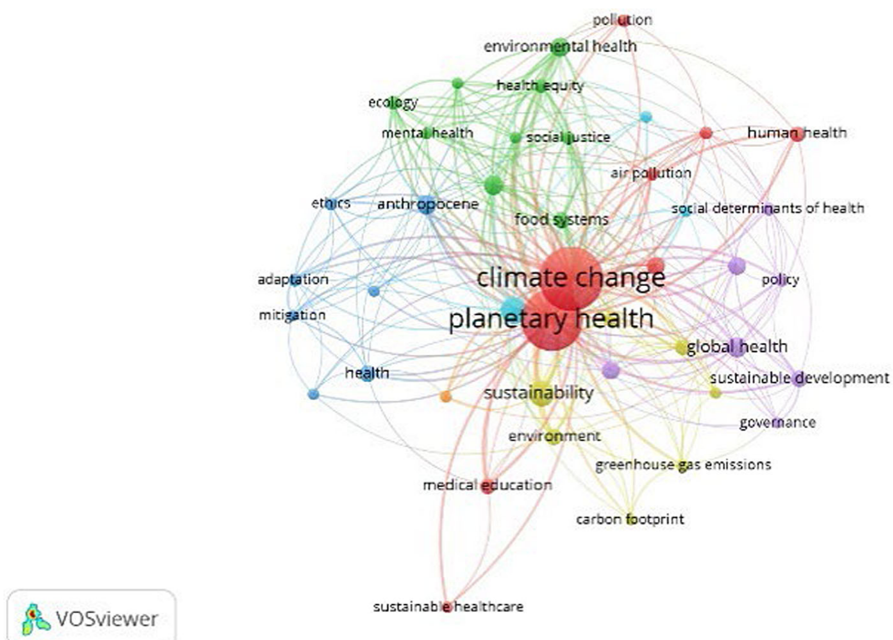

Figure 4. Visualisation of co-occurrence analysis by authors' keywords, using VOSviewer.

sustainable development" (Clark, 2015) and "Connecting planetary health, climate change, and migration" (Schütte et al., 2018).

The second most cited article was "Climate Change and Global Food Systems: Potential Impacts on Food Security and Undernutrition" (Myers et al., 2017a), with 491 citations. This publication, along with five others, was a part of the tan cluster, principally directed to environmental issues on a global level, that is "Global environmental and non-communicable diseases risks" (Frumkin and Haines, 2019) and "Implementation of policies to protect planetary health" (Pattanayak and Haines, 2017).

The article "Pollution and health: a progress update" (Fuller et al., 2022), with 408 citations, was included under the cyan cluster. Such a cluster consists of other publications whose key focus was planetary health integrated with sustainable health care/education, that is "Education for the Anthropocene: Planetary health, sustainable health care, and the health workforce" (Barna et al., 2020), "Opportunities and challenges within urban health and sustainable development" (Fisher et al., 2017), "Envisioning planetary health in every medical curriculum: An international medical student organisation's perspective" (Omrani et al., 2020),

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Table 6. Citation analysis by the source of publication

Rank	Source	Citations
1st	The Lancet	1759
2nd	The Lancet Planetary Health	1231
3rd	International Journal of Environmental Research and Public Health	505
4th	Journal of Climate Change and Health	264
5th	Nature Food	260
6th	Medical Teacher	234
7th	Frontiers in Public Health	161
8th	Sustainability (Switzerland)	73
9th	Medical Journal of Australia	54
10th	Health of people, Health of Planet and our responsibility: climate change, air pollution and health	30

"Planetary health and primary care: what's the emergency?" (Kemple, 2019).

Discussion of the bibliometric analysis

The scientific literature on Planetary Health in the Scopus database increased from 1 in 2013 to 149 in 2022. Indeed, since the early 2000s, health-related concepts like "Planetary Health" or even "One Health" have become popular in the fields of science, politics and medicine (Zschachlitz et al., 2023).

The four top journals by the number of publications are Lancet Planetary Health (n = 74), followed by the Lancet (n = 23), International Journal of Environmental Research and Public Health (n = 21) and Frontiers in Public Health (n = 15). Many of them are from the 2020 to 22 period. The greater number of publications in the Lancet Planetary Health journal can be possibly explained by its focus on all critical aspects of society and its relationship with the environment, including drivers of change, impacts on people and communities, and practical strategies and interventions for a better planet (About The Lancet Planetary Health, n.d.)

The leading research institutions publishing documents are The London School of Hygiene and Tropical Medicine (n = 27), followed by the University of Washington (n = 19), the Australian National University (n = 16), the Harvard T.H. Chan School of Public Health (n = 15) and University of Melbourne (n = 14).

Regarding the top publishing countries, the United States leads the list (n = 162), followed by the United Kingdom (n = 112), Australia (n = 72), Canada (n = 51) and Germany (n = 46). The above results are in line with those reported by Miao et al. (2022), cited by Mwatondo et al. (2023) – a bibliometric analysis of One Health highlights the prominent role of the USA-based authors' publications followed by the UK and Europe. Similarly, a systematic review conducted from 2005 to 2019 found that the United States, United Kingdom, Australia and Canada were among the countries associated with publications on planetary health (Rossa-Roccor et al., 2020).

By the type of publications, "Articles" lead the list (40%), followed by "Notes" (20%), "Reviews" (18%), "Editorial" (8%) and "Book Chapter" (6%). We thought the low percentage of chapters could be attributable to a low representativity in the Scopus database; however, they are well-represented and accessible (Scopus a, n.d).

The co-authorship by countries shows similarities with the top publishing countries. The USA tops the list (n = 160), followed by the UK (n = 112), Australia (n = 72), Canada (n = 51) and Germany (n = 46). The number of citations follows the same order, except Canada received more than Australia. Regarding One Health research, Mwatondo et al. (2023) identified the bibliometric analysis from Miao et al. (2022), who ranked the United States highest regarding the strength of their international, cross-institutional collaboration.

Apropos the co-occurrence analysis based on the author's keywords, the top five are "climate change", "planetary health", "sustainability", "public health" and "environmental health". The VOSviewer visualisation finds seven clusters, in decreasing order by the number of items: *red* (e.g., air pollution, climate change, COVID-19, human health, medical education, planetary health, pollution, sustainable healthcare and urbanisation); *green* (e.g., biodiversity, ecology, environmental health, food systems, health equity, health promotion, mental health, microbiome and social justice); *blue* (e.g., adaptation, Anthropocene, ethics, global warming, health, mitigation and well-being); *yellow* (e.g., carbon footprint, environment, food security, greenhouse gas emission, nutrition, planetary boundaries and sustainability); *purple* (e.g., global health, governance, One Health, policy, social determinants of health, sustainable development and sustainable development goals); *cyan* (e.g., public health, infectious diseases and system thinking) and *orange* (e.g., higher education).

Addressing the Research Directions question

From a health perspective, surveillance should focus on the drivers of disease rather than the disease itself. The drivers should give signals that account for human and animal health and environmental degradation. Some examples are land-use change, international travel and commerce, climate and weather and urbanisation (Drewe et al., 2023). In this regard, the global climate crisis influences the transmission rates of several vector-borne diseases, mainly in tropical low- and middle-income countries. Besides, in recent years, changes in the timing and magnitude of temperature and rainfall have also accelerated the spread of infectious diseases in northern countries (Leal Filho et al., 2022).

Notably, two-thirds of all new and emerging infectious diseases are zoonoses (Fong, 2017). In contrast, sixty per cent of infectious diseases arise from animal-to-human transmission with global prevalence (Cross et al., 2019). Zoonotic diseases have become a global crisis beginning around 2010–15, evidenced by the sharp augmentation of publications peaking in 2020, likely due to the COVID-19 outbreak and the increased interest in animal-to-human disease transmission (Leal Filho et al., 2022).

Effectively preventing and controlling zoonotic diseases requires a One Health approach involving collaboration across sectors responsible for human health, animal health (domestic and wildlife), the environment and other partners (Ghai et al., 2022).

Therefore, warning and response systems for infectious diseases and natural hazards, to account for their drivers (Fernandez de Cordoba, 2023), should focus on climate- and weather-based observational early warning systems and compound index integrating weather, ecological, human mobility, and animal-to-human, and mainly human-to human transmission rates.

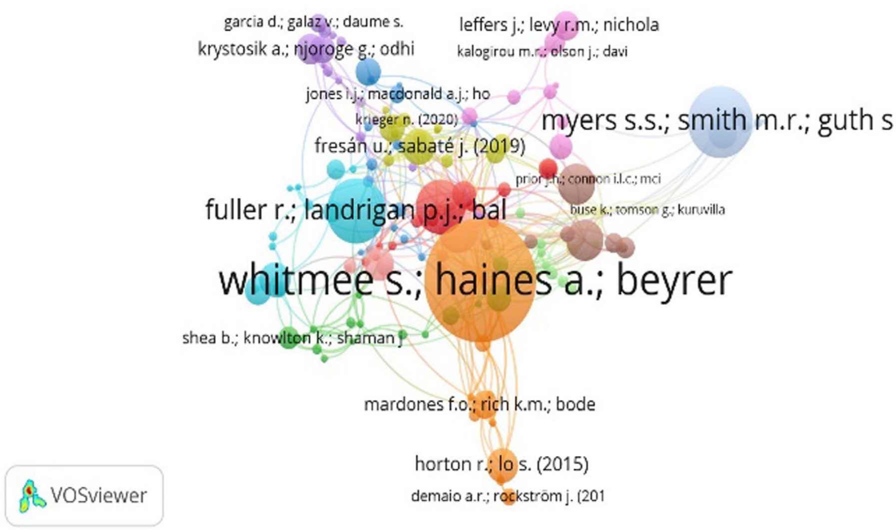

Figure 5. Visualisation of Bibliographic coupling by documents, using VOSviewer.

The complementary One Health and Planetary Health scientific approaches have solid leverage for translation into policy and practice (Ruiz de Castañeda et al., 2023). Incorporating integrative concepts of both approaches into educating human, animal and environmental health professionals is necessary. Multi-sectoral collaboration should be improved in the future by offering specialised academic degrees (Togami et al., 2018), interdisciplinary courses (Chakraborty et al., 2022), student clubs (Nguyen et al., 2022) and other means. Including these contents early at an undergraduate level and aiming at a diverse cohort of students can be a valuable strategy for building collaboration skills and fostering transdisciplinary thinking (Villanueva-Cabezas et al., 2022).

Many One Health educational efforts were initially designed in response to emerging zoonotic diseases (Stephen, 2022), and the same applies to planetary health in response to global environmental changes (Whitmee et al., 2015). Against this background, Higher Education Institutions should partner with local organisations to foster dialogue and raise awareness about the health impacts of climate change, for example the spread of vector-borne diseases, the effects of air pollution and urban heat on health, and the mental health consequences of extreme weather events (Leal Filho et al., 2023), which will allow transcending from knowledge into transdisciplinary action.

Achieving such translation demands a better understanding and integration of climate, environmental, health and social sciences interrelationships. Despite the solid advance in the required knowledge, there is also a need for enhanced communication, comprehension and partnership among public health and environmental health professionals, whether physicians, veterinarians or biologists, with public policy decision-makers to be influential.

Overall summary and conclusion

This review combined qualitative and quantitative analysis sources from an exploration of recent literature on environmental changes affecting human, animal and planetary health up to 2023, a comprehensive search with the help of AI revisiting the concepts of zoonosis and zoonotic diseases, and bibliometric analysis of planetary health from 2012 to 22 focused on the quantitative evaluation of planetary health, human and animal health and climate change.

Then, we analysed the Research Question: How can we improve and facilitate multi-sectoral collaboration in warning and response systems for infectious diseases and natural hazards to account for their drivers, interdependencies and cascading impacts? Our analysis addressed One Health and Planetary Health interactions, warning and surveillance, and capacity building in higher education institutions.

First, the literature review of the environmental changes emphasises the state of the art of heat, extreme weather events and air pollution, summarised in two comprehensive tables and comments on the surveillance system from the One Health and Planetary Health perspectives. The primary outcomes are the following.

Rising atmospheric temperatures harm the health of all plants, animals and people who live on Earth. The rise in temperature and extreme weather events impact vectors, rodents and foodborne pathogens, while numerous vector-borne diseases are experiencing an increase in incidence and geographic distribution.

Floods can elevate the incidence of mosquito-borne diseases due to the proliferation of potential breeding sites and increased humidity, contributing to higher vector survival. On the other hand, drought could increase the risk of certain mosquito-borne diseases by augmenting the number of breeding sites through the proliferation of water storage tanks and other containers near households.

Evidence is that climate change has accelerated the spread of zoonotic infections in the northern hemisphere through its effect on temperature and precipitation.

Rodents are crucial reservoir hosts for zoonotic pathogens such as Leptospira and Hantaviruses. Also, they serve as potential reservoirs for emerging infectious diseases.

Winter heavy rainfall and high temperatures can significantly impact the epidemiology of rodent-borne pathogens by altering the food resources available and, thus, the population size of reservoir species. Floods and droughts can intensify rodent–human interaction because food and habitat shortages can draw rodents near households and buildings and increase the susceptibility of the reservoirs to infections.

Air pollution is the fourth leading cause of human deaths worldwide and affects domestic and wild animals.

Table 2 summarises the environmental challenges to human, animal and planetary health posed by heat, extreme weather events and air pollution, showing the increase in people affected and exposed to extreme heat and other weather events.

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The adverse effects of global changes (climate change and land-use change) on animals include modifying their geographical range, interactions and abundance of species and pathogens.

Emerging infectious diseases driven by global changes threaten many endangered species, and rising temperatures affect the health and welfare of food-producing animals.

Table 3 shows that rising temperatures, altered precipitation patterns and increased occurrence of extreme events adversely impact food security. The success of the global increase in food production over the last six decades for public health was only feasible given our planet's natural resources; therefore, it is detrimental to planetary health.

In the last 50 years, the increased human population has exposed more people living close to wildlife, livestock and pets, increasing the chances for zoonotic diseases to pass between animals and people.

About three quarts of all emerging virus-associated infectious diseases have a zoonotic origin. One Health-inspired environmental surveillance campaign is the preferred tool for monitoring human-adjacent environments for known yet-to-be-discovered infectious diseases. It harbours the potential to prepare humanity for future pandemics caused by aetiological agents with environmental reservoirs.

Surveillance should concentrate on the drivers of disease, giving signals that account for human and animal health and environmental degradation.

Second, the planetary health bibliometric review findings show that it is a growing field attracting increased attention yearly, supported by the 448 documents published from 2012 to 2022, one-third of which were published in 2022.

The London School of Hygiene and Tropical Medicine leads the institutions actively publishing documents on the subject, followed by the University of Washington.

The United States is the leading country for the number of publications, followed by the United Kingdom.

Only 31% of the nations considered for the co-authorship analysis met the criteria of having at least five documents and citations. The United States and the United Kingdom had the highest percentages of published documents.

The co-occurrence analysis of "Author keywords" revealed that only less than 5% of the keywords met the criterion of five as the minimum number of keyword occurrences. The top five terms cited by researchers concerning the connections between planetary health, human health and climate change were "climate change", "planetary health", "sustainability", "public health" and "environmental health".

The Lancet was the most cited source, followed by The Lancet Planetary Health and the International Journal of Environmental Research and Public Health. When "Documents" were used as the unit of analysis in the bibliographic coupling analysis, with five defined as the minimum number of citations for a document, 50% of the documents met the threshold, creating a map of eleven clusters.

Third, regarding the Research Directions One Health question, we focused on a) improving and facilitating multi-sectoral collaboration in warning and response systems for infectious diseases and natural hazards to account for their drivers and b) integrating global environmental change, One Health and Planetary Health concepts and knowledge in the Higher Education Institutions.

The current global climate and pandemic crises highlight the need for a new paradigm integrating climate, extreme weather, ecosystems, plant, animal and human health approaches, surveillance, response and education.

The evolving and complementary concepts of One Health and Planetary Health address these interrelationships, and since 2020, global environmental changes and challenges have demanded greater unification of these concepts and approaches. However, we must acknowledge that planetary health could be a more complex way for the public health community, which hardly integrates ecology, human medicine and veterinary medicine. Therefore, as usual, education will be the key to such integration in the long term.

Multi-sectoral efforts should focus on surveillance, early warning and response systems watchful of the drivers of infectious diseases, mainly climatic and weather ones with known environmental changes or degradation leading, directly or indirectly, to adverse health effects on plants, animals and the very nature of these drivers is highly diverse. Their effects occur with different delays, only sometimes (if ever) determined. However, the sharp increase in the published literature on Planetary Health and climate change and zoonosis triggered by the COVID-19 pandemic since 2020 will help better understand the complexity of the involved causes, drivers, timing and effects.

As Ruiz de Castañeda et al. (2023) argued: "*The complementary One Health and Planetary Health scientific approaches have solid leverage for translation into policy and practice*." Also, as Stephen (2022) stated, many One Health educational efforts were initially designed in response to emerging zoonotic diseases, while the leading The Rockefeller Foundation–Lancet Commission on Planetary Health report claimed the same in response to global environmental changes. Hence, it is necessary to integrate approaches in the curricula of medicine, veterinary, environmental health and even environmental sciences from the beginning of the studies or through interdisciplinary environmental health courses or degrees, including decision-making areas. By doing this, transdisciplinary systems thinking will permeate students, allowing them to transcend knowledge, research and observation into action.

Data availability statement. The data supporting this study's findings are available from the corresponding author, [GJN], upon reasonable request.

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Author contributions. LT, GN and LV wrote the original draft of the manuscript. GN coordinated the writing team. LT, LV and GN critically reviewed the manuscript. LT conducted the bibliometric analysis. All authors contributed to the revisions.

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