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Analysis of convergence between a unified One Health policy framework and imbalanced research portfolio

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Abstract
The One Health (OH) approach is collaborative, multisectoral, and transdisciplinary, acknowledging the interdependence among animal, human and environmental health. It has garnered attention within the scientific community, particularly in response to the rising prevalence and global spread of emerging and re-emerging infectious diseases. Common OH issues include zoonotic diseases, antimicrobial resistance (AMR), food and water safety, and the human-animal bond. Among various OH topics, AMR represents a well-described, long-term, complex issue, with a substantial global death toll and large economic costs. Whereas interdisciplinary and transdisciplinary teamwork seems appropriate to address such complex challenges, effects on knowledge production are poorly known. In this study, we investigate how the scientific community mobilizes "One Health." A comparative bibliometric analysis of OH and AMR research enabled us to assess the level of transdisciplinary research, identify emerging themes, through a co-occurrence network analysis of keywords, and disciplines mobilized, through a co-citation network analysis of scientific journals, in research, as well as level of international collaboration through analysis of co-authorship among countries. We detected a lack of consideration for non-communicable diseases (e.g., obesity, diabetes, cardiovascular diseases) and the well-being of human and animal populations in analysis of themes. Furthermore, although many disciplines are involved in OH and AMR research, little attention was given to social sciences, environmental health, economics, and politics. There was a strong influence of major global economic powers, including the United States and China, in scientific research on OH and AMR, as well as substantial collaboration among European countries. The present results indicated that guidelines are needed to address the mentioned concerns, and specific funds are required for underrepresented countries.

1 Introduction

The One Health (OH) approach consists of a collaborative, multisectoral, and transdisciplinary approach, acknowledging the interdependence among animal, human and environmental health [1]**.** Furthermore, the Covid-19 pandemic, triggered by a virus potentially of animal origin, has renewed interest in OH approaches [2]**.**

In March 2022, the World Health Organization (WHO), the World Organization for Animal Health (OIE), the Food and Agriculture Organization of the United Nations (FAO), and the United Nations Environment Programme (UNEP) signed an agreement to establish a quadripartite OH alliance aimed at enhancing collaboration, communication, capacity, and coordination

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across all sectors responsible for health issues at the interface of humans, animals, and the environment [3]. The Quadripartite Alliance relies on political dialogue to raise awareness among various stakeholders and advocate for inclusion of OH approaches in regional, national, and international health policy and scientific programs [3]. A high-level One Health expert panel (OHHLEP) was established in May 2021 with the objective of providing relevant scientific assessment for formulation of OH health policies [4]**.** These health policies will strengthen strategic guidance and coordination of OH approaches at the community, subnational, national, regional, and global levels, plus provide political visibility to these approaches. The OHHLEP has developed a clear definition [4] of the OH approach: "One Health is an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals, and ecosystems. It recognizes the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and interdependent." This definition demonstrates the need for shared and effective governance, communication, collaboration, and coordination across sectors for implementation of equitable and holistic solutions to address health and environmental challenges. Communities of researchers worldwide have recognized the need for interdisciplinary collaboration to prevent and control diseases, including experts in medicine, life sciences, humanities, social sciences, and engineering [5]. Effects of transdisciplinary research on both the health sector and society as a whole are obvious, garnering increased attention from policymakers, funding organizations, and researchers across various disciplines [6–8].

The work of the Quadripartite Alliance has also led to establishment of a Joint Action Plan [9] for 2022 to 2026. This plan outlines activities to align systems and resources to better prevent, anticipate, detect, and treat health threats collectively, with the ultimate goal of improving the health of humans, animals, plants, and the environment, while contributing to sustainable development. It focuses on supporting and building capacities in six areas: health systems; emerging or re-emerging zoonotic epidemics and endemic zoonoses; neglected tropical vector-borne diseases; food safety; antimicrobial resistance; and the environment.

Among the various topics in OH, antimicrobial resistance (AMR) poses a complex challenge to public health and development. Selection of resistant bacteria results primarily from use and misuse of antimicrobials in humans, animals, and plants. Resistant pathogens can spread from person to person, from humans to animals and vice versa, as well as through animal-derived foods and the environment [10]. A global action plan on AMR, developed by WHO in 2015, provides a framework for addressing AMR with various objectives, e.g., improving awareness and understanding of AMR through effective communication, education, and training [11].

Although there is a relatively stabilized policy vision of OH approach, one could question how this vision is reflected in research. The OH approach to research promotes integrated research, surveillance, control programs, and policy frameworks [12]. For example, in AMR research, several action plans have called for multi-disciplinary, interdisciplinary transdisciplinary research [13], although interventions to mitigate AMR—and underlying research—may not need to be cross-sectorial. For example, antibiotic drug development concerns mostly the human sector [14–16]. In veterinary medicine, one of the most important issue associated with the use of biocides consists of the selection of resistant bacteria in commensal floras, which can potentially infect humans. This is especially problematic in the livestock sector, where antibiotics are frequently used for prophylaxis and metaphylaxis, creating high selective pressure in densely populated farming environments. The spread of resistant bacteria is facilitated through the food chain and environmental contamination. Regulatory gaps and inadequate surveillance further exacerbate the problem, along with a lack of training and awareness among farmers about proper antibiotic use and resistance management. [17, 18].By studying scientific output produced over the recent years, our objective is to evaluate levels of interdisciplinarity and transdisciplinary research conducted in the OH space, potential imbalances between sectors and disciplines, and science leadership in the OH domain across the globe. To do so, a bibliometric analysis was conducted to summarize large amounts of bibliometric data, and assess the state of intellectual structure and emerging trends around a research topic [19, 20]. We comparatively assessed scientific production in OH approaches, AMR, and studies incorporating both OH and AMR. We analyzed research clusters and networks, plus overlaps among OH, AMR and OH-AMR research.

2 Methods

2.1 Search strategy

A bibliometric analysis was conducted to determine the main themes, disciplines involved in research, influence of countries, and level of international collaboration on OH, AMR, and on OH and AMR. Themes correspond to the central subjects or ideas studied in the research, providing insights into research trends and major concerns in a particular

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field of study. Disciplines refer to academic fields or specialties in which research is conducted. The bibliometric analysis was conducted in 3 stages (data extraction, performance analysis, and network analysis) and applied to OH, AMR, and both. Bibliometric analysis primarily focuses on information related to the document carrier, which is to say, the bibliographic information of the documents, and not the specific content within the full text [21].

Data were extracted from the Web of Science (WOS) bibliographic database, with queries created to select documents related to each study topic. For query creation, multiple keywords related to each topic were selected and searched for in title, abstract, and keywords of each document available in WOS. For OH approaches, the keywords "One Health," "environment," "human," and "animal" were entered into the search engine. For AMR, keywords "antibiotic resistance," "antibacterial resistance," "antimicrobial resistance," "drug resistance," "multidrug resistance," and "AMR" were used. Finally, for both OH and AMR, the above-mentioned keywords were combined. The queries used specifically for the WOS search engine are available in the Supplementary Table S1 online. The data were extracted from 01–01-2018 to 06–09-2023. Extracted data correspond to key characteristics of the literature content, such as the title, authors, abstracts, authors' keywords, and publication years. These data enable a quick and systematic identification of the research status in published literature, as well as clarifying the context within published scientific research [21]. All types of documents (scientific publications, meeting, abstracts, editorial material) and all types of languages indexed in WOS database without any restrictions were included in the analysis. All obtained documents were extracted in plaintext format.

3 Data analysis

3.1 Performance analysis

Performance analysis of extracted data was performed with the *bibliometrix* package in the RStudio software (Version 4.2.2 2022–10-31) [22]. This descriptive part includes identification of the total number of publications, number of publications per year, number of journals, top journals, number of countries and their scientific production, and number of author keywords for each topic [19]**.** The function and packages used are available as Supplementary Information**.**

Maps of scientific production by countries for each study topic were done with QGIS (Version 3.28.2) [23]. The large number of publications associated with AMR exceeded *bibliometrix* biblioshiny tool capacity, so a representative random sample of 1,000 documents per year (6,000 in total) was used. Each document was considered for all countries of co-authors (i.e., one publication was considered as many times as the numbers of co-authors). Therefore, the map of scientific production by countries measures number of authors' appearances by country affiliations [22]. Data on scientific production by country are available in Supplementary Information (.xlsx file).

3.2 Network analysis

Network analysis was performed with *VOSviewer* [24]. The software explores various linkages, including co-authorship, co-occurrence, citation, bibliographic coupling, and co-citation, and represents them as networks [25]. Three key analyses were performed (keywords co-occurrence, co-citations, and country co-authorship).

The author keywords co-occurrence analysis is based on the principle that words that frequently appear together have a thematic relationship [19]. This analysis identifies emerging themes or concepts in academic literature for each study topic, i.e., OH, AMR, and OH-AMR. For each cluster defined by the network of authors keywords co-occurrence, current themes in scientific research are identified [26]. For our analysis, 100 keywords were displayed with a minimum occurrence of 5 for each co-occurrence network for each study topic.

The co-citation analysis assumes that two journals are connected when they appear in the reference list of another publication and that publications frequently co-cited together are thematically similar [19]. For our analysis, we decided to represent the 50 most co-cited journals on each network for each topic, with a minimum number of citations of 20 journals. The groups of cited journals identified in *VOSviewer* corresponded to research specialties and enabled identification of dominant disciplines in a research topic [27]. Journal scopes were used to identify disciplines involved within clusters for each study topic [28]. Scopes were identified on the journal websites and indicate research disciplines that can or should be presented in research papers published in that journal**.**

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Co-authorship analysis assesses scientific interaction and relationships between countries. This analysis was conducted on countries to determine collaborations in research related to each topic [26]. Joint publications result from collaborations between organizations and representatives from countries participating in a research domain [29, 30]. In our study, for each study topic, we represented the 30 most collaborative countries on networks.

4 Results

From 2018 to 2022, the number of documents increased from 351 to 1,225; from 19,663 to 29,223; and from 78 to 455 documents, for OH, for AMR, and for OH-AMR respectively (see Supplementary Table S2 online). Numbers of authors, journals, countries, and references per topic highlighted differences between OH and AMR (Table 1).

4.1 Research themes

Co-occurrence of author keywords analysis on OH identified six clusters (Fig. 1). The term "One Health" was at the center of the network and had the largest node, indicating it appeared most frequently. The keyword "One Health" had an occurrence of 2,104 (Table 2). The red cluster was represented by the keyword "antimicrobial resistance" with an occurrence of 718 and co-occurring with keywords "genomes," "*E. coli,*" "antibiotic," or "salmonellosis." The green cluster was represented by the keyword "zoonoses" with an occurrence of 628 and co-occurring with keywords "Covid-19," "infectious diseases," "epidemiology," "surveillance," and "transmission." The blue cluster was represented by the keyword "One Health" and co-occurring with keywords "public health," "environment," "climate change," biodiversity," and "global health."

Co-occurrence of author keywords analysis of AMR identified five clusters (Fig. 2). The central term in the network is "antimicrobial resistance" with an occurrence of 39,150 (Table 2). The red cluster was represented by the keyword "cancer" with an occurrence of 1,937 and co-occurring with "breast cancer," "chemoresistance," and "apoptosis". The green cluster was represented by bacteria related to antibiotic resistance, such as "*E. coli*," "*Salmonella*," and "*Klebsiella*." The dark blue cluster was represented by infectious diseases like "tuberculosis", "HIV," and "malaria". Yellow was focused on "infectious diseases," co-occurring with keywords "Covid-19," "epidemiology," "surveillance," and "One Health."

The co-occurrence of author keywords analysis of OH associated with AMR identified 10 clusters (Fig. 3). These clusters are all very close to each other and shared strong connections. Within this network, the majority of topics covered have been discussed previously, such as "One Health," "antimicrobial resistance," "zoonoses," and "*E. coli*." The yellow cluster highlighted the importance of OH and AMR in health management, with keywords "health policy," "governance," and "global health." The green cluster illustrated the risk of contamination of the food chain with keywords "transmission," "food animals," "bacteria," "antibiotic," and "meat."

4.2 Research disciplines

Co-citation networks analysis of journals for the topic OH identified four clusters (Fig. 4). The red cluster contained journals with scopes in microbiology, biochemistry, genetics, pharmacology and food safety. Other disciplines involved in this cluster were environmental impacts, air quality, ecosystems services, hydrology, wildlife, and climate change. The green cluster had journals involving research on pathogenesis, clinical features, drug administration and treatments, epidemiology, vector biology, parasitology, prevention, and vaccination. The blue cluster contained journals with a multidisciplinary scope.

The co-citation network of journals related to AMR identified four clusters (Fig. 5). The red cluster contained a group of journals in which the major disciplines were oncology, human biology, immunology, molecular biology, metabolism, and therapy development strategies, (Table 3). The blue cluster contained journals in biomaterials, chemistry nanoscience, biological and health sciences, medical engineering, and earth and environmental sciences. Research themes in the green cluster were antimicrobial stewardship, genetics and epidemiology of antimicrobial resistance,

Table 1 Descriptive statistics of the database

	Documents	Journals	Institutions	Countries	References	Authors' keywords
OH	4,429	1,035	6,928	167	205,173	8,949
AMR	134,183	7,884	65,535	210	2,775,339	141,414
OH and AMR	1,389	370	2,649	128	64,047	2,891

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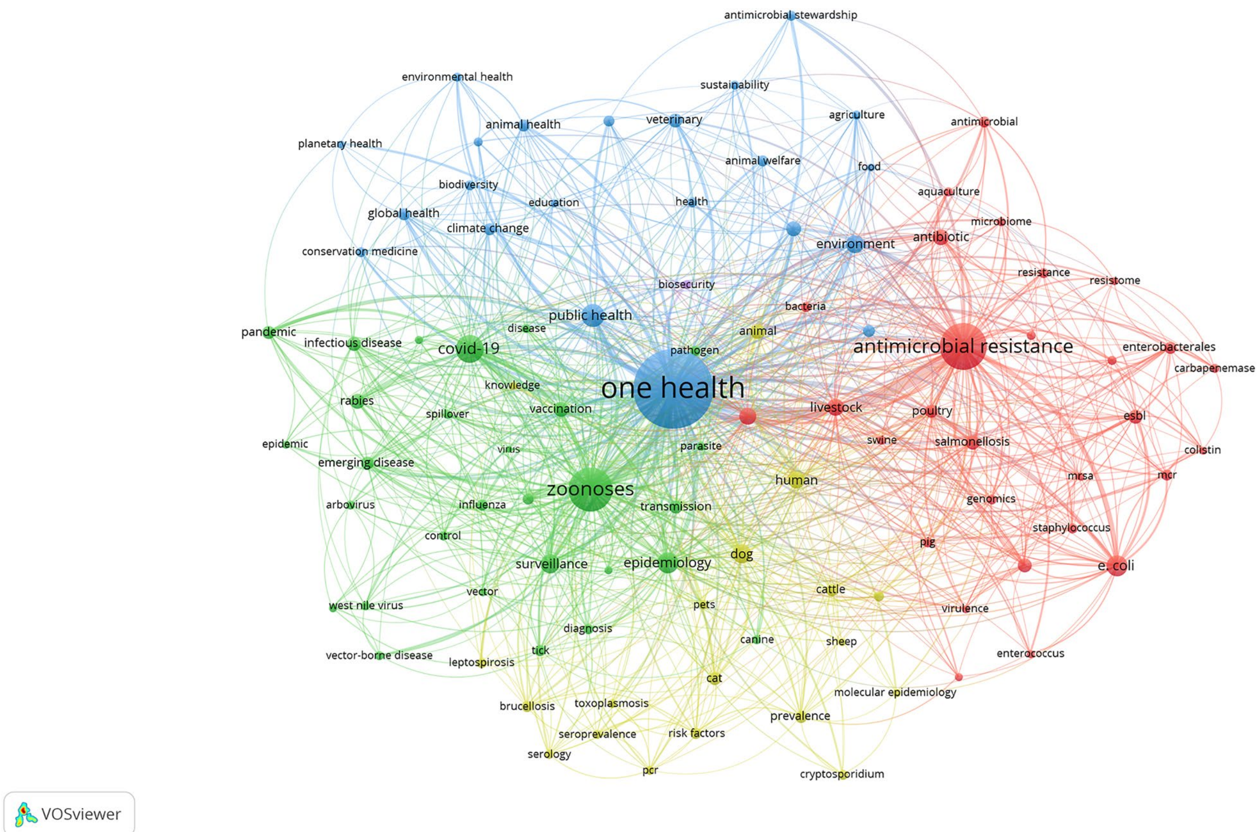

Fig. 1 Keywords co-occurrence network of OH topic. Within a given networks, the size of a node represents the number of occurrences of the associated word. The distance between nodes illustrates the strength of the relationship between two words. The closer two keywords are, the higher the co-occurrence between them. Red cluster: 29 keywords; Green cluster: 29 keywords; Dark blue cluster: 22 keywords; Yellow cluster: 19 keywords; Purple cluster: 1 keyword

clinical trials, genome sequencing, immunology, microbiology, and pharmacology. Only three journals (yellow cluster) involved disciplines related to environmental sciences and technologies, water and air quality, adverse effects of climate change on health and the environment, and ecosystem services.

The co-citation network analysis of OH approaches associated with AMR (Fig. 6) demonstrated significant interactions across disciplines, as illustrated by the proximity of the three identified clusters. The red cluster contained journals where main themes were complex environmental phenomena, natural and engineered systems, environmental pollution contaminants and the biological, ecological and human health effects, and microbial processes in the environment. This cluster also contained journals where main disciplines were genomics, phylogeny, sequencing, bioinformatics, molecular biology, and microbiology. The green cluster disciplines were related to antimicrobial stewardship, mechanism of resistance, chemistry, epidemiology and surveillance of AMR, experimental therapeutics, pharmacology, parasitology, immunology and emerging infectious diseases. Finally, the blue cluster contained journals publishing on foodborne pathogens, food safety, food illness, bacteriology, mycology, virology, environmental microbiology, food microbiology, and microbial ecology.

4.3 International influence and collaboration

A detailed analysis of country maps of scientific production and country co-authorship networks for each topic are in Supplementary Material (see Supplementary Fig. 1 and Fig. 2 online). The United States had the greatest influence in scientific production on OH with 3,134 documents. For AMR, China dominated research production with 4,875 documents and for the OH-AMR topic, the United States and the UK produced the most (657 and 494 documents, respectively).

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Table 2 Top 10 of most frequent authors keywords on OH, AMR, OH and AMR topics

Subject	Keywords	Occurrence
OH	One Health	2,104
OH	Antimicrobial resistance	718
OH	Zoonoses	628
OH	Covid-19	261
OH	Public Health	177
OH	Epidemiology	154
OH	E. coli	142
OH	Dog	126
OH	Surveillance	124
OH	Environment	109
AMR	Antimicrobial resistance	39,150
AMR	Antibiotic	4,513
AMR	E. coli	3,530
AMR	Resistance	3,246
AMR	Biofilm	2,972
AMR	Virulence	2,651
AMR	Tuberculosis	2,330
AMR	Pseudomonas	2,324
AMR	Staphylococcus aureus	1,986
AMR	Cancer	1,937
OH and AMR	Antimicrobial resistance	804
OH and AMR	One Health	670
OH and AMR	Escherichia Coli	136
OH and AMR	Antibiotic	96
OH and AMR	Extended-spectrum beta-lactamase	82
OH and AMR	Zoonoses	71
OH and AMR	Whole genome sequencing	63
OH and AMR	Salmonella	50
OH and AMR	Environment	49
OH and AMR	Surveillance	47

For each topic, there was strong collaboration among European countries, including Italy, France, Portugal, and Spain. Other countries, including Australia, Brazil, and Canada, also had important research production in these three topics.

5 Discussion

Our study aimed to first assess existence of a gap between the policy vision of OH approaches as defined by international organizations and what has been recently published. One Health research advocates for transdisciplinary and multidisciplinary approaches, promoting coordination and collaboration among various sectors of scientific research, a variety of stakeholders, and policymakers [31].

Bibliometric analysis provides new avenues for assessment of knowledge production and enables a better understanding of a studied phenomenon by integrating statistical and quantitative aspects [19]. Articles related to research on OH, AMR, as well as research on both OH and AMR, were extracted from Web of Science. In this study, documents were not selected using a specific methodology, e.g., PRISMA method. Our study did not aim to be exhaustive; rather, we sought a broad perspective on data available for the three topics analyzed. Therefore, we used only the WOS database, as it contains numerous well-recognized academic references across various scientific domains and provides a comprehensive view of scientific production on a given subject [32].

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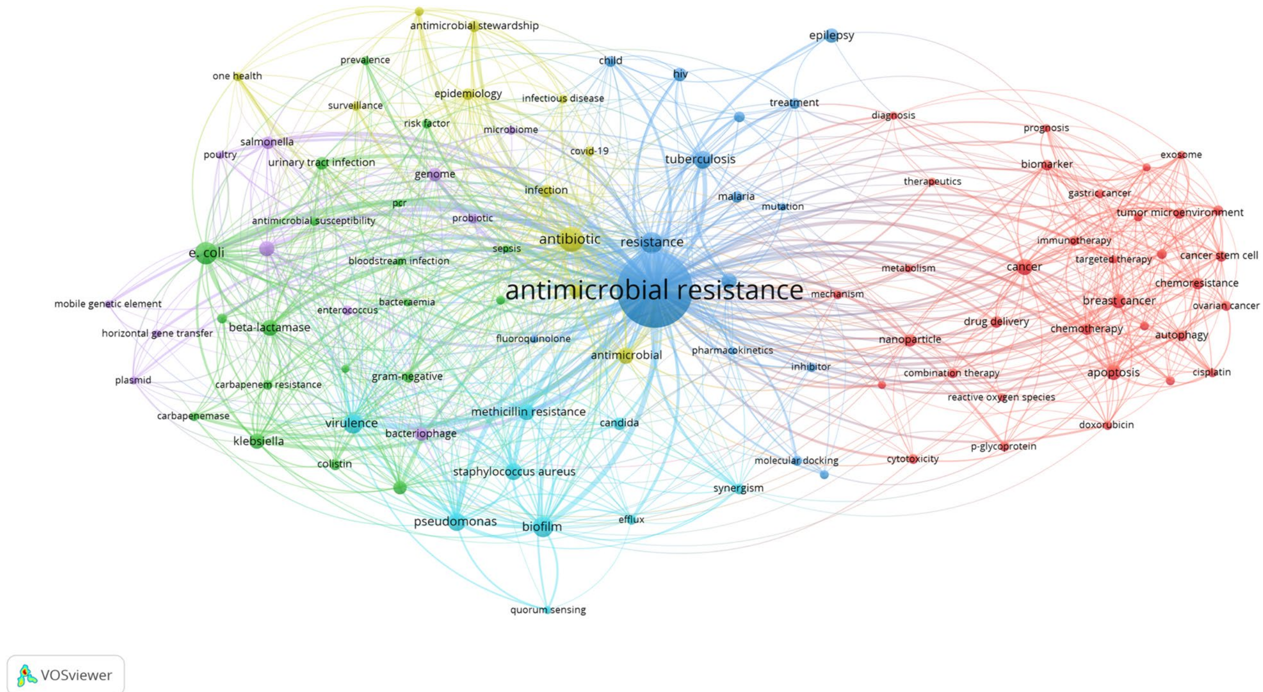

Fig. 2 Keywords co-occurrence network of AMR topic. Within a given networks, the size of a node represents the number of occurrences of the associated word. The distance between nodes illustrates the strength of the relationship between two words. The closer two keywords are, the higher the co-occurrence between them. Red cluster: 34 keywords; Green cluster: 19 keywords; Dark blue cluster: 16 keywords; Yellow cluster: 11 keywords; Purple cluster: 11 keywords; Blue cluster: 9 keywords

We investigated the conceptual structure of research on various topics through analysis of keyword co-occurrence networks, which identified the main and emerging themes surrounding each research topic [33]. We examined research themes related to OH, with a focus on AMR for several reasons. First, it constitutes a looming threat to public health, recognized as a major global health challenge [34]. Second, the issue is not an emerging one; this implies that there has been a sufficient body of literature to enable meaningful bibliometric analysis. Third, many national and international action plans have called for multi-disciplinary, interdisciplinary and transdisciplinary research in AMR [13]. We demonstrated that research themes related to OH topic were centered around zoonotic diseases. Understandably, the Covid-19 pandemic triggered numerous research in recent years, where the importance of intersectoral collaboration is paramount, especially for surveillance, risk management, and health security [35], and Covid-19 was one of the most important keywords associated with OH. The theme "public health" was also identified and illustrated key challenges of One Health approaches aimed at reducing the burden of infectious diseases on planet [36].

Interestingly, although AMR was a major theme of OH research, OH was not a main theme of AMR research. Rather, AMR research dominant themes were antibiotic, *E. coli*, resistance, and biofilm. Fostering a One Health approach could contribute to combat AMR, especially by strengthening knowledge and the evidence base through epidemiological surveillance systems, or by reducing the incidence of infections through effective health measures, hygiene, and prevention, and promoting collaborations focused on human and animal health, as well as environmental balance [37].

When examining the research themes on OH and AMR together, many topics previously addressed were present, such as zoonoses, *E. coli*, public health, surveillance, environment, and antibiotics. This highlighted the importance of considering OH approaches to address AMR, particularly to enhance trust, transparency, communication, and collaboration among healthcare professionals. It would foster exchange of experiences within collaborative programs for AMR management at the interface of human, animal, and environmental health [38].

Some important issues appeared to be missing from OH research. The first was non-communicable diseases e.g., diabetes, obesity, and cardiovascular diseases. These topics are indeed critical, and a more comprehensive One Health approach could benefit from their inclusion. Non-communicable diseases (NCDs) are the leading cause of death globally [39], impeding human development and imposing substantial economic burdens, especially on marginalized groups. Non-communicable diseases also increase susceptibility to infectious diseases, emphasizing the need for integrated

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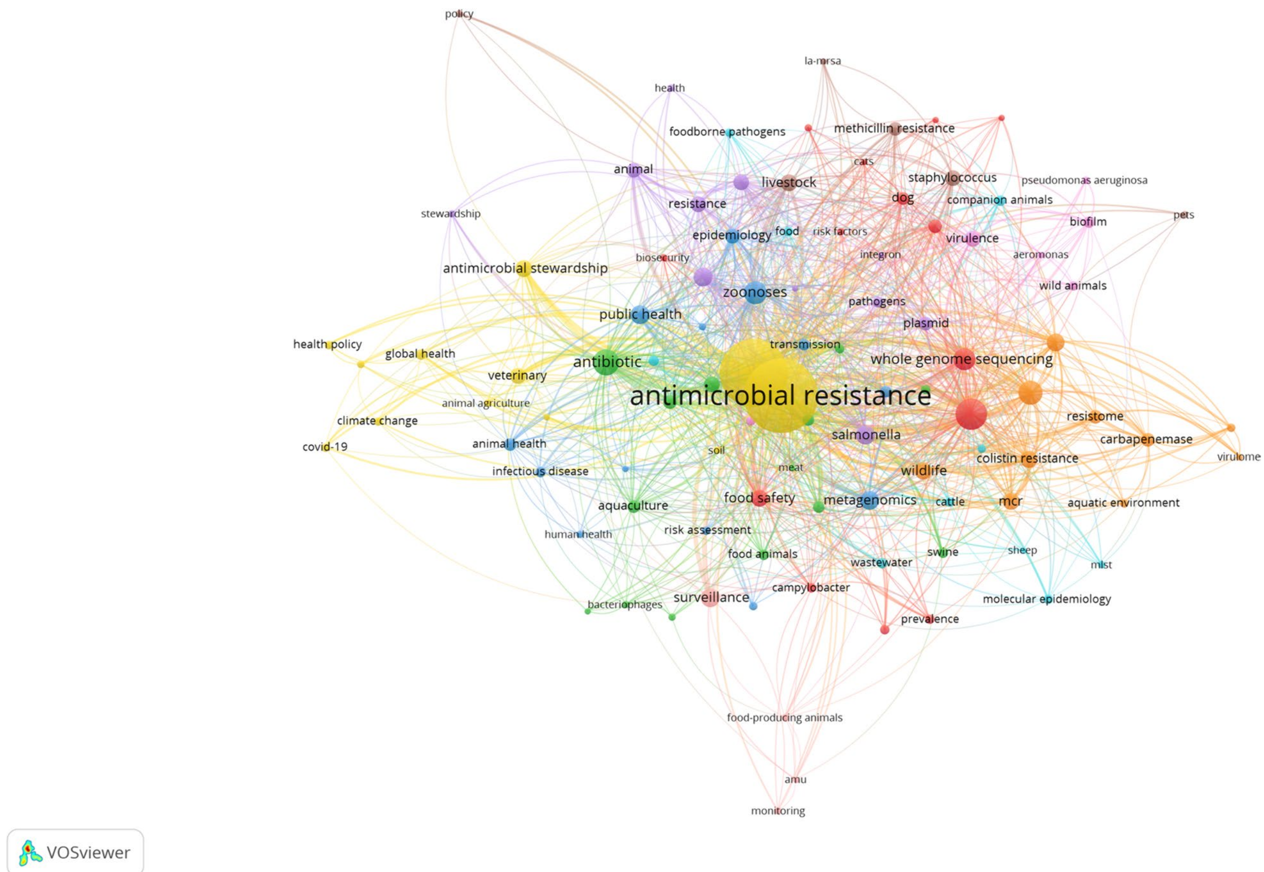

Fig. 3 Keywords co-occurrence network of both OH and AMR topics. Within a given networks, the size of a node represents the number of occurrences of the associated word. The distance between nodes illustrates the strength of the relationship between two words. The closer two keywords are, the higher the co-occurrence between them. Red cluster: 14 keywords; Green cluster: 14 keywords; Dark blue cluster: 13 keywords; Yellow cluster: 12 keywords; Purple cluster: 11 keywords; Blue cluster: 10 keywords; Orange cluster: 10 keywords; Brown cluster: 6 keywords; Pink cluster: 6 keywords; Light pink cluster: 4 keywords

intervention strategies [40]. Key risk factors for NCDs include diet, physical activity, and environmental pollutants [39]. Livestock practices driven by population growth and rising incomes lead to higher consumption of animal products and increased risks of NCDs such as diabetes, cancer, and cardiovascular diseases [41]**.** Socio-economic and environmental factors further exacerbate meat consumption and NCD prevalence, particularly in wealthier countries [41]. Addressing these challenges requires adopting integrated approaches like One Health, which includes political commitments to poverty reduction and changes in dietary habits, while acknowledging socio-economic disparities.The second issue is the well-being of human and animal populations, crucial for sustainable and holistic health approaches. Well-being, closely linked to health, includes physical, mental, emotional, social, financial, professional, intellectual, and spiritual aspects [42]. Research shows a connection between well-being and diseases, particularly non-communicable ones. Well-being can protect health by enhancing life satisfaction and emotional vitality, influenced by education, income, and employment [42]. Conversely, poor well-being can exacerbate diseases and their progression. Integrating well-being into One Health ensures a comprehensive perspective on health, addressing both symptoms and underlying issues.Although environmental studies were present in the OH corpus, they appeared far less frequently than studies focusing on human infectious diseases. This may be due to greater funding support for human health challenges, rather than agriculture, food systems, and environmental health. Yet, there is ample evidence of linkages among food systems, environmental health and human health [43]. This may reflect that research operates with an anthropocentric perspective, where natural systems are perceived as resources to exploit independently of their impact on overall health [43]. However, environmental health is crucial for the development and well-being of populations. This human-centered perspective can lead to a focus on human and animal health research, where benefits are directly observable, at the expense of environmental studies seen as less urgent or less immediately relevant to human concerns. Nevertheless, the long-term effects of

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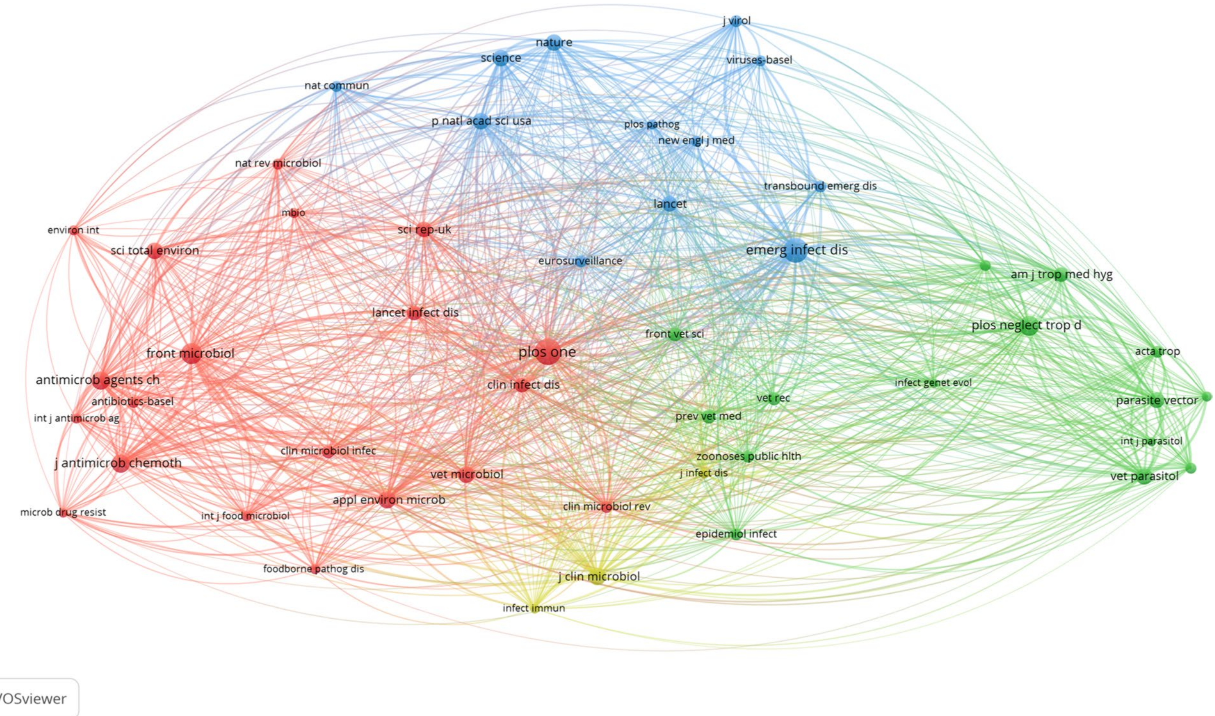

Fig. 4 Co-citation network of scientific journals of OH topic. Various colors denote distinct research areas. The size of the circles reflects the frequency of co-citations. The distance separating two circles indicates the level of correlation between them. Red cluster: 20 journals; Green cluster: 15 journals; Dark blue cluster: 12 journals; Yellow cluster: 3 journals

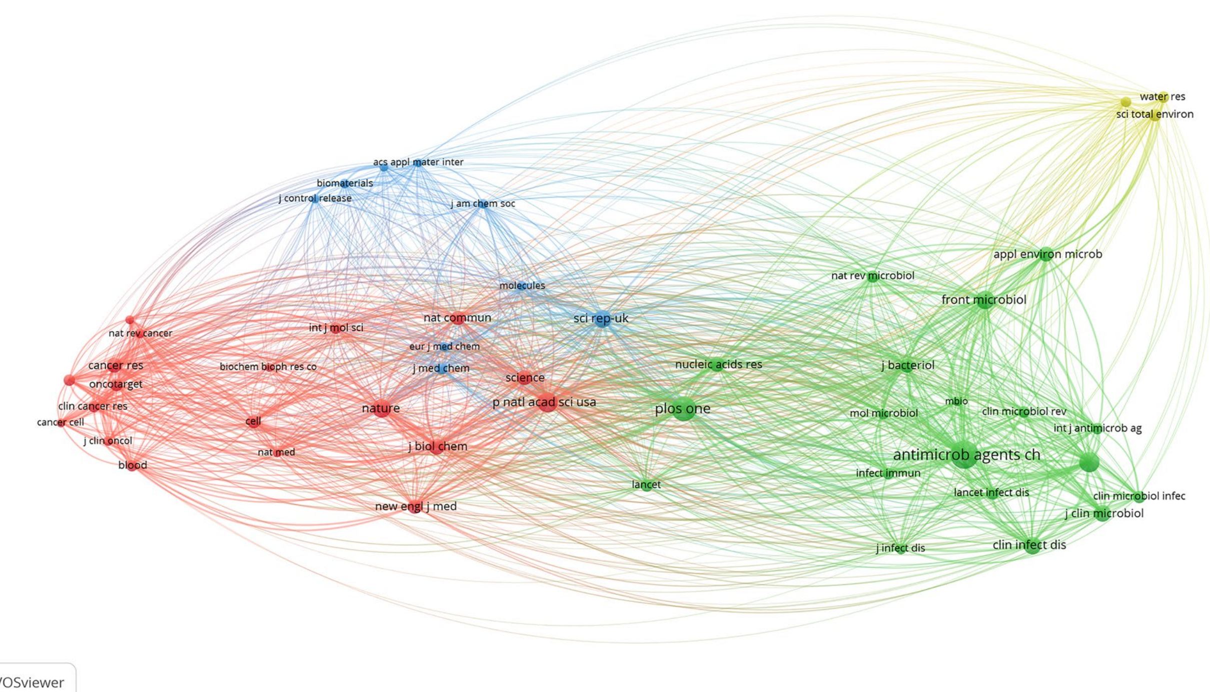

Fig. 5 Co-citation network of scientific journals of AMR topic. Various colors denote distinct research areas. The size of the circles reflects the frequency of co-citations. The distance separating two circles indicates the level of correlation between them. Red cluster: 19 journals; Green cluster: 19 journals; Dark blue cluster: 9 journals; Yellow cluster: 3 journals

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Table 3 Top 10 of most productive journals on OH, AMR, OH and AMR topics

Subject	Journal	N. of documents	N. of citations	Search area
OH	One Health	233	1,958	Virology, bacteriology, parasitology, mycology, vectors, ecosystem, health,
OH	Antiobiotics-basel	160	1,266	Biochemistry, chemistry, genetics, microbiology, pharmacology, antibiotics
OH	Frontiers in Veterinary Science	139	1,554	Emerging infectious diseases, genomics, environmental health, wildlife conservation
OH	Animals	126	729	Zoology, ecology and conservation, animals and society, animal management and welfare science
OH	Frontiers in Microbiology	113	1,270	Interactions between microorganisms, virus and macro-organisms, mitigation of microbial communities, effects of anthropogenic activities
OH	Pathogens	111	916	Transmission and identification of pathogens, genetics and genomics, immune responses, molecular mechanism, vaccine, vectors
OH	Frontiers in public health	85	936	Epidemiology, environment, interventions in public health, prevention, climate change
OH	Microorganisms	85	763	Microbial physiology, ecology, genetics, evolution, medical, agricultural, food and environmental microbiology
OH	Plos Neglected Tropical diseases	69	610	Pathogenesis, clinical features, drug administration and treatment, epidemiology, vector biology, vaccinology and prevention, ecological and social determinants, public health and policy aspects, diagnosis
OH	Science of the total environment	69	1,535	Environmental impacts, air quality, ecosystem services, hydrology, wildlife, climate change, agriculture, nanomaterials, contaminants, quality and security
AMR	Frontiers in Microbiology	3,013	39,887	Interactions between microorganisms, virus and microorganisms, mitigation of microbial communities, effects of anthropogenic activities
AMR	Antibiotics-Basel	2,941	20,656	Biochemistry, chemistry, genetics, microbiology, pharmacology, antibiotics
AMR	International Journal of Molecular Sciences	1,763	21,474	Fundamental theorical problems and breakthrough experiment technical in biology, chemistry, and medicine, molecular studies
AMR	Scientific Reports	1,705	23,581	Natural sciences, psychology, medicine engineering, earth and environmental sciences, biological sciences, health sciences
AMR	Plos One	1,666	16,124	Natural Sciences, medical research, engineering, social sciences and humanities
AMR	Antimicrobial Agents and Chemotherapy	1,413	19,258	Antimicrobial stewardship, chemistry and biosynthesis, mechanisms of actions and physiological effects, resistance, susceptibility, epidemiology and surveillance, experimental clinical therapeutics, pharmacology, antiviral agents
AMR	Cancers	1,204	15,089	Oncology, basic, transnational, and clinical studies on all tumor types
AMR	Microorganisms	1,174	9,351	Microbial physiology, ecology, genetics, evolutionary, medical, agricultural, food and environmental microbiology
AMR	Infection and Drug Resistance	1,148	11,056	Development and use of anti-infectives, pathogenesis and etiology of infectious diseases, proteomics, genomics, mechanism of resistance, vaccine, diagnosis, clinical management, epidemiology, education and prevention, drug resistance
AMR	Molecules	1,064	13,546	Organic, medicinal, inorganic, physical, analytical, theorical, green, and supramolecular chemistry, nanoscience
OH and AMR	Antibiotics-Basel	152	1,249	Biochemistry, chemistry, genetics, microbiology, pharmacology, antibiotics
OH and AMR	Frontiers in Microbiology	82	938	Interactions between microorganisms, virus and microorganisms, mitigation of microbial communities, effects of anthropogenic activities

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Table 3 (continued)

Subject	Journal	N. of documents	N. of citations	Search area
OH and AMR	One Health	46	383	Virology, bacteriology, parasitology, mycology, vectors, ecosystem, health
OH and AMR	Animals	43	171	Zoology, ecology and conservation, animals and society, animal management and welfare science
OH and AMR	Microorganisms	43	393	Microbial physiology, ecology, genetics, evolutionary, medical, agricultural, food and environmental microbiology
OH and AMR	Science of the total environment	37	465	Environmental impacts, air quality, ecosystem services, hydrology, wildlife, climate change, agriculture, nanomaterials, contaminants, quality and security
OH and AMR	Microbiology spectrum	32	651	Applied and environmental sciences, clinical science, epidemiology, ecology, evolution, host-microbe biology, molecular biology, physiology, synthetic biology, therapeutics and prevention
OH et AMR	Pathogens	27	284	Transmission, identification, invasion of pathogens, genetics and genomics, immune responses, molecular mechanism, vaccine, vectors
OH et AMR	International journal of environment research and public health	26	455	Health promotion, diseases prevention, wellbeing, public health, biology, sociology, environment
OH et AMR	Frontiers in Veterinary Science	25	550	Emerging infectious diseases, genomics, environmental health, wildlife conservation

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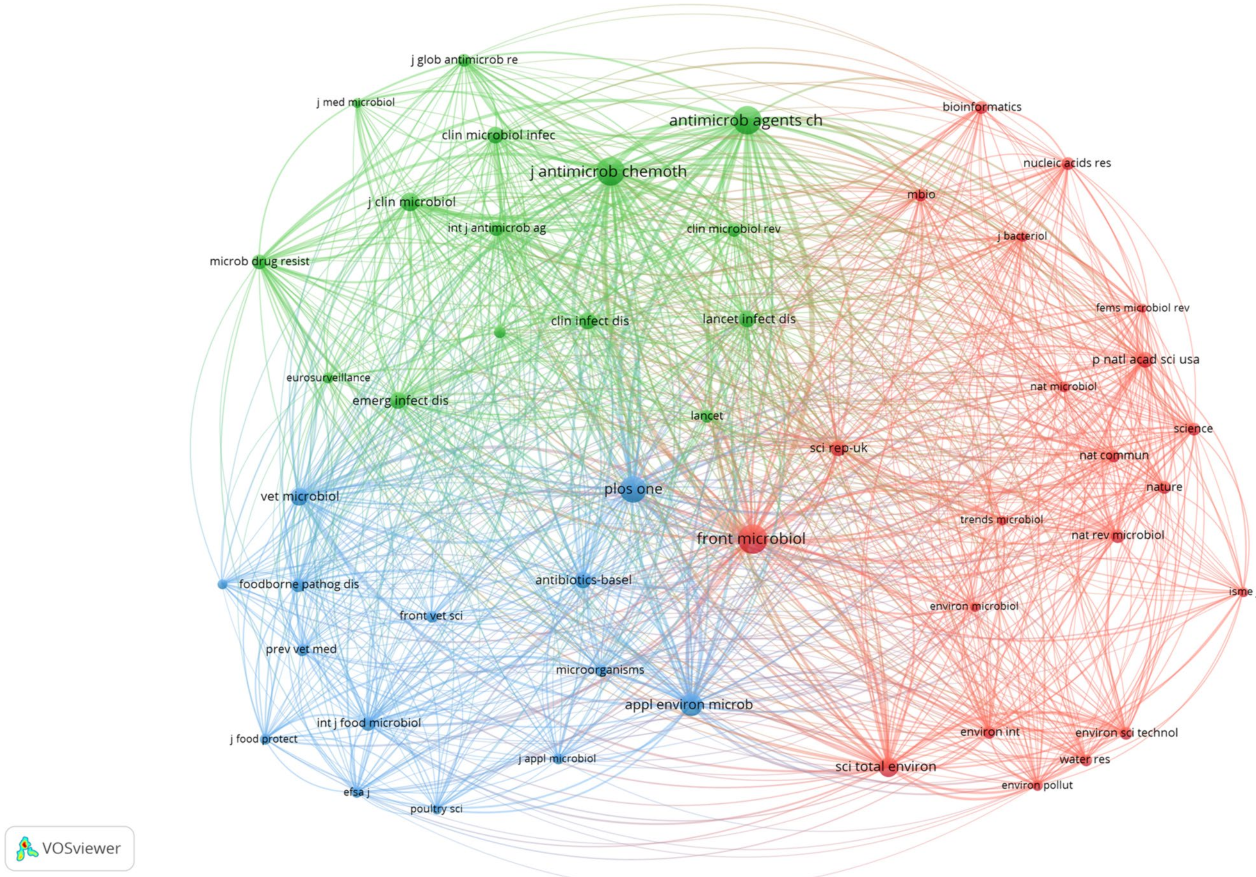

Fig. 6 Co-citation network of scientific journals of both OH and AMR topics. Various colors denote distinct research areas. The size of the circles reflects the frequency of co-citations. The distance separating two circles indicates the level of correlation between them. Red cluster: 21 journals; Green cluster: 15 journals; Dark blue cluster: 14 journals

environmental degradation, such as climate change, loss of biodiversity, or pollution, can have significant repercussions on human and animal health. Therefore, integrating environmental research into One Health approaches is important to understand and anticipate the complex impacts resulting from interactions between humans, animals, and ecosystems. Another potential explanation could be that research infrastructures (e.g., departments, faculties and institutes) may be hosted by organizations with core interest in human and animal health, and piloted by executives with a medical background. Further studies are needed. These points highlight the issue of "silos" in research, which hinder the exchange of knowledge and methods between disciplines, crucial for advancing One Health approaches. Isolation in research fields can result from tensions between departments and institutions, and insufficient funding for interdisciplinary training [44]. Addressing these silos requires effective collaboration management, including tools and assessments to measure the benefits of interdisciplinary work [44]. Training students in interdisciplinary approaches can also bridge this gap by emphasizing the importance of intersectoral collaboration for achieving common health objectives [45].

Investigating the intellectual structure of research on OH and AMR, an analysis of co-citation networks of journals, enabled us to identify common theoretical foundations of research and define key disciplines related to each topic [19]. The OH approach advocates for interdisciplinary and transdisciplinary scientific research. Interdisciplinary research involves close collaboration among experts from various disciplines or domains to address complex issues [46], whereas transdisciplinary research integrates perspectives, methods, and concepts from various disciplines to solve a given problem; they also involve non-academic stakeholders [46]. We identify several common disciplines across various research topics, including microbiology, immunology, virology, parasitology, epidemiology, genomics, genetics, and other related sub-disciplines. These disciplines primarily focused on human and animal health, with limited consideration for the environment. Although studies often consider environmental impacts on health, they may not evaluate how diseases impact the environment.

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Thus, there is a need to enhance the framework and implementation of OH studies in research, with particular attention to environmental health. Research in social sciences, economics, policy, but also in ecology and environmental science, represented a very small fraction of our results. However, these disciplines are crucial for prioritizing resource allocation and implementing an OH vision [37, 47]. Integrating social sciences into One Health approaches highlights the impact of human behaviors on health challenges, transforming interconnected ecological, human, and animal systems. Social science experts study motivations behind behaviors such as land clearing and agricultural intensification, which increase interactions among humans, domestic animals, and wildlife, potentially facilitating disease transmission [48]. Addressing these social issues involves community engagement on associated risks and promoting behavior changes. Social sciences play a crucial role in public engagement, communicating behavior change, and guiding decision-making [48]. They also enhance understanding of how environmental changes, human health, and animal health influence psychosocial outcomes and human–environment relationships. For instance, climate change affects temperature and water availability, influencing animal migration, health, and human attitudes toward animals, thereby impacting food security and human well-being [48]. Social sciences enable understanding of these effects and human responses to environmental changes, crucial for ecosystem health. Understanding social policies and practices to mitigate adverse health impacts is essential for effective responses [49]. A more effective governance structure for One Health is needed, involving cooperation among stakeholders in global health, guided by laws and policies, with regional, national and global coordination [1].

We investigated international collaborations to identify social structures of various topics. Not surprisingly, there was an important influence of Western countries in research on the three topics studied. These countries are the largest global economic powers, with substantial influence in international trade and policy. Most of these countries are part of organizations like the OECD, G20, or G7. One limitation is that we accounted for all coauthors affiliations in our evaluation of international collaborations, with potential to overinflate impacts of research papers with numerous coauthors. Another methodological limitation lies was VosViewer, as every paper was accounted in the same manner, regardless of number of citations or the impact factor of the journal publishing it.

In the European Union, national actions plans were implemented against AMR within the framework of the One Health initiative (2021–2022) [50]. The report of the national action plans indicated that action plans against AMR, mostly based on One Health approaches, are in place in all Member States [50]. Content of these action plans may vary among countries, reflecting progress in combating AMR. However, the environmental component is often neglected, with actions primarily focused on human and animal health. China, South Africa, and Brazil have highly productive research institutes in OH and AMR spaces, indicating the importance of these emerging countries in One Health and AMR research. We also identified collaboration among Canada, the United States, Australia, and several Asian countries such as China, India, or Japan in OH research, which are also major global geopolitical powers. Overall, nations identified in our study as key players are also actively involved in achieving the Sustainable Development Goals (SDGs). One Health initiatives strengthen ambitions of the SDGs, particularly by integrating health into development and recognizing that good health depends on other development goals, contributing to their achievement while supporting social justice, economic prosperity, and environmental protection [51, 52].

In conclusion, this study provides several foundations to guide One Health research in addressing health and environmental challenges through the analysis of scientific production in recent years on two topics: OH approaches and AMR. The results highlight a gap between the relatively stabilized political vision of OH approach and the vision in scientific research. Therefore, additional efforts are required to align with the political vision of OH approaches, and this work provides avenues to explore for achieving optimal OH approaches that can address global health challenges. Future studies should further consider research questions related to the environment, incorporating social sciences, policies, economics, and ecology. To achieve the various objectives outlined by major international organizations, it is essential to establish better governance for OH approaches, particularly for improved cooperation among various stakeholders in global health, guided by laws and policies with regional, national, and global coordination. Lastly, a more effective allocation of resources across research disciplines and among different countries is crucial to ensure optimal implementation of OH approaches worldwide, leading to a systematic and unified approach and ultimately improving the health of all.

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Author contributions L.V contributed to data management; conceptualization; methodology; data collection; interpretation and writing original draft preparation. G.L contributed to the conceptualization and methodology of the study, participated in the interpretation of the data, contributed to the manuscript writing and made revisions to the initial draft. D.R participated in interpretation and validation of the

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data, contributed to the manuscript writing, and made revisions to the original draft. All authors provided a critical review and approved the final manuscript before submission.

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Data availability The data was extracted from the Web of Science database (https://www.webofscience.com) and downloaded based on the queries available in supplementary information. Data processing and analysis were conducted using Rstudio software (Version 4.2.2, 2022–10-31) with bibliometrix package (https://www.bibliometrix.org), the script of which is available in supplementary information. Visualizations were obtained using VosViewer software (https://www.vosviewer.com/) from the data extracted in Web of Science. Maps were also created using QGIS software (version 3.28.2-Firenze) corresponding to the scientific production of countries. The data used were obtained in Rstudio software (bibliometrix package) and are available in supplementary information. The base map was obtained from the DIVAGIS website (https://www.diva-gis.org/Data). The.text files containing the bibliographic data extracted from Web of Science are available from the corresponding author on reasonable request.

Declarations

Competing interests The authors declare no competing interests.

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