ORIGINAL RESEARCH

Dynamics of a Global Zoonotic Research Network Over 33 Years (1980–2012)

Liaquat Hossain, PhD; Faezeh Karimi, PhD; Rolf T. Wigand, PhD

ABSTRACT

Objective: The increasing rate of outbreaks in humans of zoonotic diseases requires detailed examination of the education, research, and practice of animal health and its connection to human health. This study investigated the collaboration network of different fields engaged in conducting zoonotic research from a transdisciplinary perspective.

Methods: Examination of the dynamics of this network for a 33-year period from 1980 to 2012 is presented through the development of a large scientometric database from Scopus. In our analyses we compared several properties of these networks, including density, clustering coefficient, giant component, and centrality measures over time. We also elicited patterns in different fields of study collaborating with various other fields for zoonotic research.

Results: We discovered that the strongest collaborations across disciplines are formed among the fields of medicine; biochemistry, genetics, and molecular biology; immunology and microbiology; veterinary; agricultural and biological sciences; and social sciences. Furthermore, the affiliation network is growing overall in terms of collaborative research among different fields of study such that more than two-thirds of all possible collaboration links among disciplines have already been formed.

Conclusions: Our findings indicate that zoonotic research scientists in different fields (human or animal health, social science, earth and environmental sciences, engineering) have been actively collaborating with each other over the past 11 years. (*Disaster Med Public Health Preparedness*. 2015;9:496-503)

Key Words: animal diseases, capacity building, civil defense, communication, education, public health professional

At global and local levels, we are observing an increasing range and rate of disease outbreaks that show evidence of infections jumping from animals to humans. Consequently, understanding the education, research, and practice of animal health and its connection to human health is pivotal to safeguarding human health. Zoonoses are diseases transmissible between vertebrate animals and humans,[1] which comprise 75% of emerging infectious diseases.[2] Therefore, successful management of zoonotic disease risk and outbreaks requires an understanding of the complex interaction network of humans, animals, and their living environments.[3] Previous bibliometric studies on relevant topics either investigated specific infectious diseases, such as acquired immune deficiency syndrome (AIDS),[4,5] tuberculosis,[6] and malaria,[7] or examined infectious diseases in general.[8-11] The latter studies examined the research productivity and contribution of different countries and regions of the world in infectious diseases and showed a gradual increase in research on infectious diseases in the United States, the European Union, and other regions in the world. Our investigation focuses on the contribution and collaboration of different fields of study in exploring the intersection between animal and human health by examining research networks.

We investigated the dynamics of the zoonotic research network over 33 years by constructing and using a large scientometric database. The study first explains the process of developing a scientometric database for exploring research collaboration on this topic. The database is based on extracted publication information in the span of 1980 to 2012 from Elsevier's Scopus database, which is a bibliographic database containing abstracts and citations for academic journal articles. It covers nearly 22,000 titles from more than 5000 publishers, of which 20,000 are peer-reviewed journals in the scientific, technical, medical, and social sciences (including arts and humanities). The publication trend over this period of time as well as top journals in terms of number of publications are then discussed. The study proceeds with exploring the developed data set by extracting a bibliometric network (ie, affiliation network). Several social network measures, such as network density and centrality, are used to analyze this network. Moreover, the network is also mapped over different time intervals.

MATERIALS AND METHODS

Elsevier's Scopus (www.scopus.com), as one of the main sources of bibliometric data covering the greatest number of journals,[12-14] was used to build the database for this study. The search for publications was carried out with 240 search queries using combinations of key words, including coordination, collaboration, cooperation, communication, preparedness, surveillance, emergency response, crisis management, containment, recovery, zoonotic, zoonosis, animal human, disease outbreak, illness outbreak, epidemic, pandemic and social network, occurring in the articles' titles, abstracts, and key words. This initial set of key words was selected after consulting with 2 experts in the field. The focus of the key words was on 3 concepts—coordination, zoonotic diseases, and disease outbreaks at the various stages of disease prevention, detection, effective response, and elimination. The publication's information (eg, author[s], document title, year, author key words, source title, citation count, source and document type, affiliations, publisher, language) were extracted using the Scopus export option. The publications used in the subsequent analysis were restricted to those written in English as specified in their language field. In the second stage, in order to account for any important key word that was not included in the first stage, another set of key words were identified. As part of this process, the original author key words (ie the key words authors assigned to their documents) in the extracted publications from the first stage were analyzed for their frequency. In addition, the author key words, which could be a single word (eg, epidemiology) or could be multiple words (eg, West Nile virus), were split apart to produce a list of single words. The list of single-word key words was produced to provide a better understating of various key words describing the extracted publications. The frequency analysis of the key words included identifying the most frequent author and single-word key words. Table 1 shows the top 10 frequent author and single-word key words.

From these key words with top frequency, the terms avian influenza, West Nile virus, H5N1, control, and risk were selected for the second search; key words that were too

TABLE 1

Top 10 Most Frequent Key Words

Key Words (Author)	Frequency	Key Words (Single Word)	Frequency
Surveillance	132	Influenza (flu)	417
Epidemiology	101	Virus	261
Avian influenza	70	Disease(s)	301
Influenza	68	Surveillance	217
Pandemic	55	Avian	163
West Nile virus	50	Epidemiology	154
Zoonosis (zoonoses)	82	Health	117
H5N1	40	Pandemic	117
Control	35	Control	111
Outbreak	38	Animal	77
		Risk	74

TABLE 2

Scopus Subject Areas

	Broad Subject Clusters	Major Subject Areas
1	Health sciences	Medicine
2		Nursing
3		Veterinary
4		Dentistry
5		Health professions
6	Life sciences	Agricultural and biological sciences
7		Biochemistry, genetics, and molecular biology
8		Immunology and microbiology
9		Neuroscience
10		Pharmacology, toxicology, and pharmaceutics
11	Physical sciences	Chemical engineering
12		Chemistry
13		Computer science
14		Earth and planetary sciences
15		Energy
16		Engineering
17		Environmental science
18		Materials science
19		Mathematics
20		Physics and astronomy
21	Social sciences	Arts and humanities
22		Business, management, and accounting
23		Decision sciences
24		Economics, econometrics, and finance
25		Psychology
26		Social sciences

FIGURE 1

Subject Area Mapping.

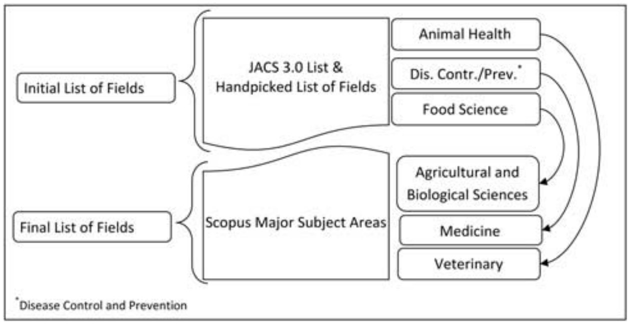

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FIGURE 2

Frequency of Publications Per Year.

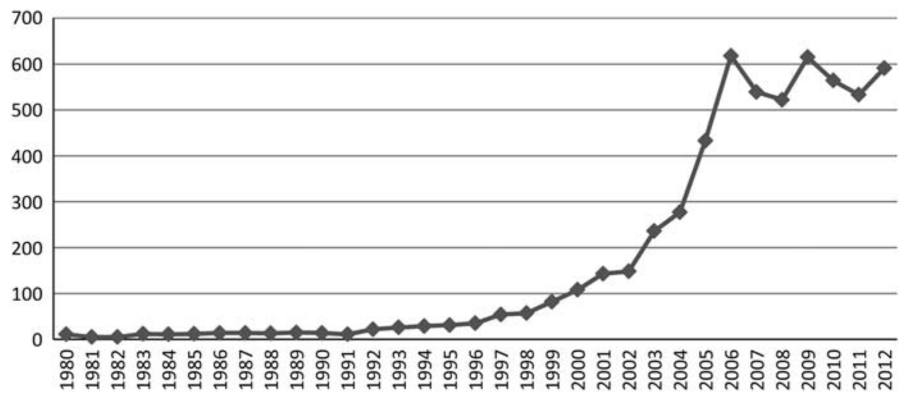

FIGURE 3

Frequency of Publications and the World Health Organization's Disease Outbreak News Per Year.

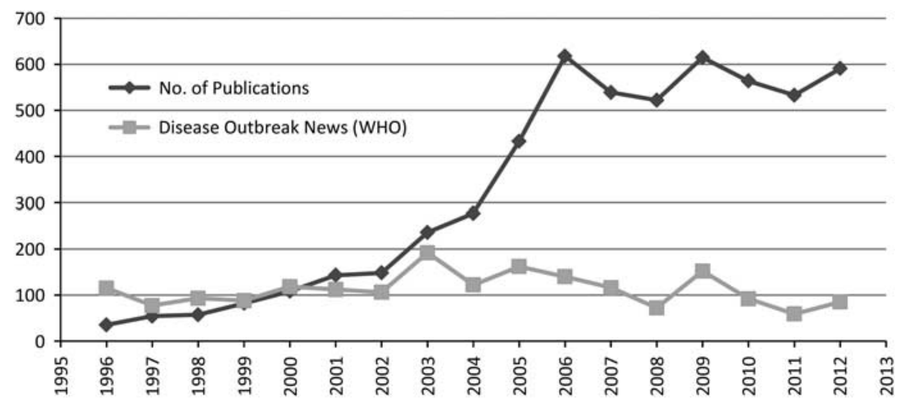

TABLE 3

Top 10 Journals With the Largest Number of Publications

	Journal Name	No. of Publications
1	Emerging Infectious Diseases	187
2	Veterinary Record	123
2	Euro Surveillance: Bulletin Européen sur les Maladies Transmissibles = European Communicable Disease Bulletin	123
3	PLoS ONE	119
4	Avian Diseases	118
5	Vaccine	109
6	OIE Revue Scientifique et Technique	92
7	Nature	91
8	Science	89
9	Journal of Infectious Diseases	81
10	Epidemiology and Infection	70

generic or that had been used in the previous stage (eg, virus) were not included. These selected key words were used in combination with the words coordination, collaboration, cooperation, communication, preparedness, surveillance, emergency response, crisis management, containment, recovery, outbreak, epidemic, pandemic, and social network for the second round of publication search (216 search queries). The combination was to ensure that the second set of key words was in line with the rationale behind the first set of key words and tapped into various stages of a zoonosis outbreak. The extracted publication data from this round were added to the previous results. The search span in both stages consisted of the period from 1980 to 2012. The search for the publications was conducted in July 2013. The two search rounds resulted in 5800 publications after filtering the publications with the same title.

The affiliation network was built based on the field of study (academic discipline) that is reported in the affiliation records

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of the publications. We used a 3-step strategy to identify the fields of study associated with each publication. In the first step, a list of fields of study was used to search each affiliation record in the database. In this study, the joint academic coding system (JACS) version 3.0 served as the initial list of fields of study. JACS 3.0 (owned and maintained by the Universities and Colleges Admissions Service [UCAS] and the Higher Education Statistics Agency [HESA]) is used for subject coding of provision across higher education in the United Kingdom.[15] With 1570 specific fields of study, JACS 3.0 provides a comprehensive list of fields of study to search for at least one matching field within each affiliation record in the database of this study.

After this step, many affiliation records did not have a matching phrase with the 1570 fields because even a simple variation would cause the search function to dismiss that variation as a correct match with a string in the JACS 3.0, and many variations of a field exist in the affiliation records of the database. Therefore, in the second step, each of the records with no matching phrase in the JACS 3.0 was examined individually, and a relevant phrase indicating their field of study was extracted. This resulted in an additional 488 phrases pertaining to a field of study. In some cases where the affiliation record did not contain useful information to extract a field of study, the records were not included in the affiliation network analysis.

TABLE 4

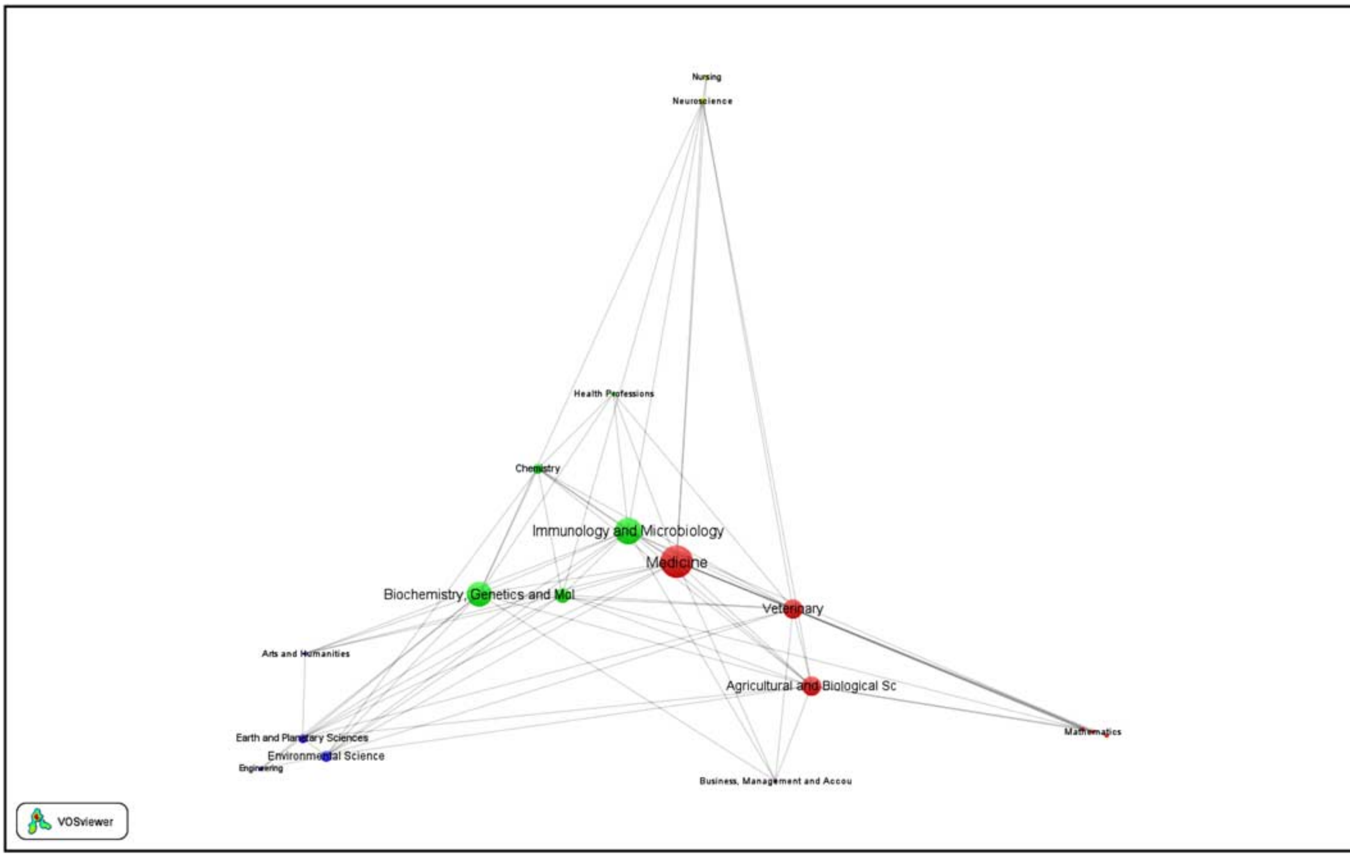
Measures of Affiliation Network in Different Periods

Measures	1991–2001	2002–2012	1980–2012[a]
Density	47.1%	68.3%	63.4%
Clustering coefficients	80.6%	86.0%	85.8%
Number of components	1	1	1
Giant component size	18	25	25
Centrality measures			
Degree	52.9%	29.9%	31.0%
Closeness	52.3%	30.8%	35.6%
Betweenness	23.5%	7.1%	6.7%

[a]Data for entire study period.

FIGURE 4

Affiliation Network (1991–2001).



The font and circle size of the nodes depend on their collaboration weight.

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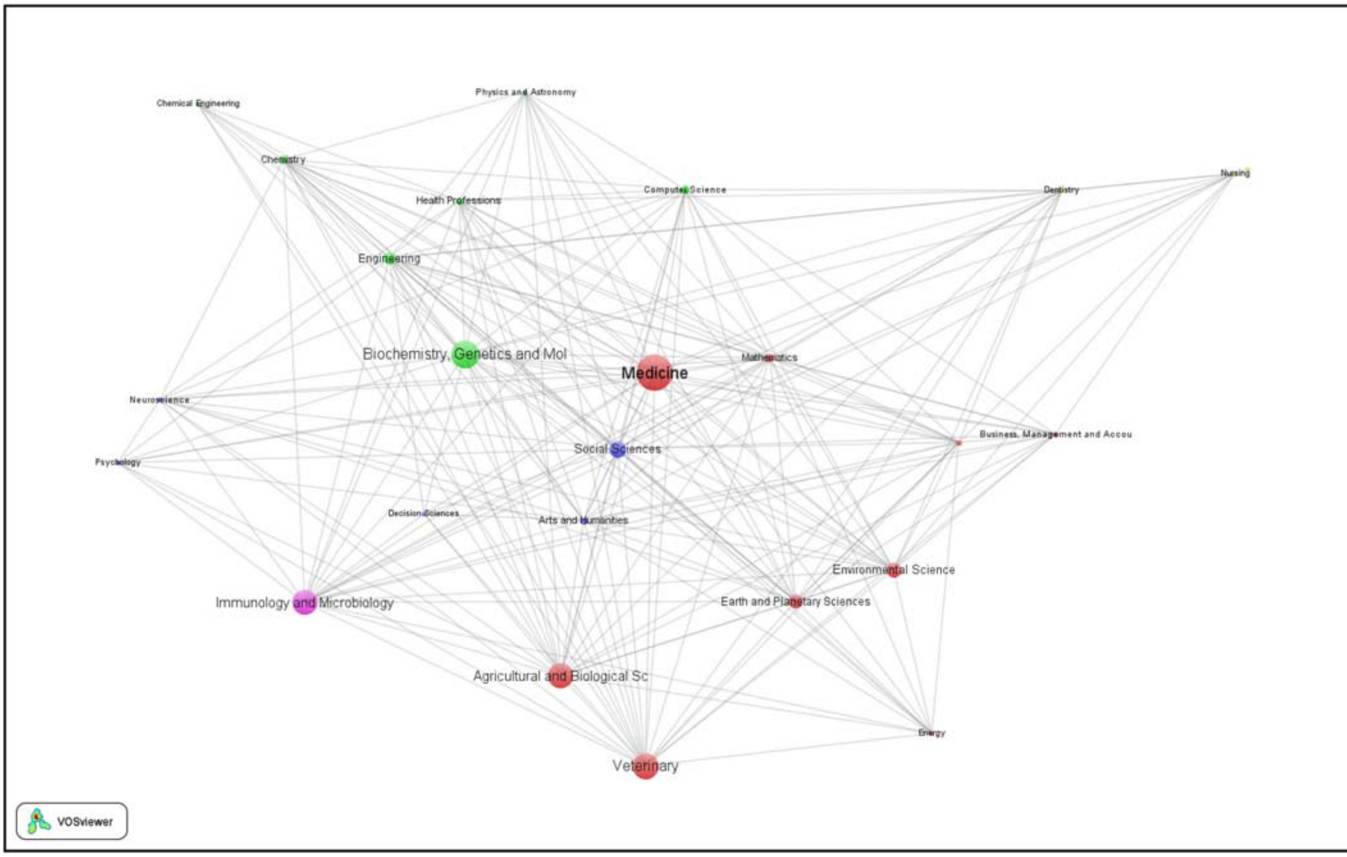
FIGURE 5

Affiliation Network (2002–2012).



The font and circle size of the nodes depend on their collaboration weight.

In the last step, in order to have a consistent list of fields of study with a manageable size for network analysis, all the fields (whether from the JACS 3.0 or the handpicked list of fields) were mapped into the Scopus classification of major subject areas. Scopus classifies the fields of study of its journals into four broad subject clusters: health sciences, life sciences, physical sciences, social sciences. These four clusters are further divided into 26 major subject areas. This classification is presented in Table 2. Our mapping process focused on the Scopus 26 major subject areas (fields of study) in 2013 (See Figure 1).

In performing our analysis, we used the following measures: (1) network density, that is, the number of links in a network expressed as a proportion of the maximum possible number of links;[16] (2) network centralization, in which the centrality of a node counted the number of other nodes that are directly connected to it,[17] the closeness centrality was calculated by summing the graph-theoretic distances of that node to all other nodes in the network,[17,18] and the betweenness centrality of a node was defined as the frequency with which it settles in the shortest path connecting any other pair of nodes in the network;[17] (3) the giant component was the large and complex network seen to have a connected component that included a substantial portion of the nodes in those networks;[19] and (4) the clustering coefficient of a node (eg, node A) referred to the probability that 2 randomly selected adjacent nodes of A are adjacent to each other.[19] UCINET 6 software[20] (Analytic Technologies, Lexington, KY) was used to calculate network measures and VOSviewer 1.5.4 software[21,22] (Leiden University's Centre for Science and Technology Studies, Leiden, Netherlands) was used for mapping the affiliation network and displaying its structure.

RESULTS AND DISCUSSION

As shown in Figure 2, the trend of publications on zoonotic research has been increasing since 1980. Before 1991, the number of extracted publications was constantly low, but an increasing trend starts after that. This increase in the number of publications continued gradually and accelerated after 2002. This observation provides 3 time intervals in which to examine detailed changes in the collaboration networks: 1980–1990,

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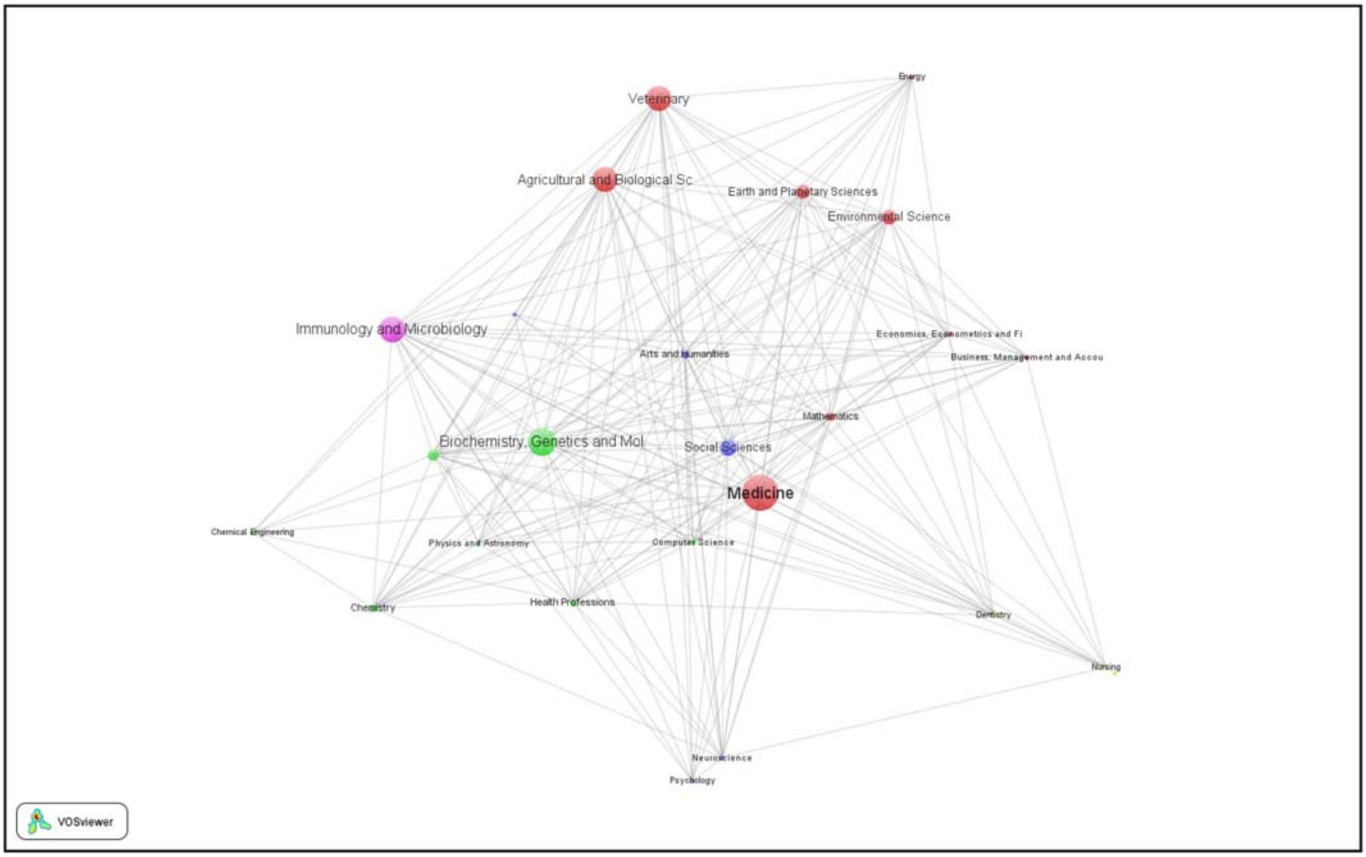
FIGURE 6

Affiliation Network (1980–2012).



The font and circle size of the nodes depend on their collaboration weight.

TABLE 5

Top Collaborating Fields of Study

	Field of Study	No. of Collaborations	No. of Collaborating Fields
1	Medicine	6546	23
2	Biochemistry, genetics, and molecular biology	4007	23
3	Immunology and microbiology	3327	22
4	Veterinary	3310	22
5	Agricultural and biological sciences	3160	22
6	Social sciences	1463	22
7	Environmental science	1148	20
8	Earth and planetary sciences	986	20
9	Engineering	708	22
10	Chemistry	421	17

1991–2001, and 2002–2012. The dynamic analysis in this study focused on the last 2 time intervals as the number of publications in the first period was limited.

Another interesting point of time shown in Figure 2 is 2006. Up to this year the number of publications was increasing but this upward trend halted here though there were occasional rises. To have a better understanding of the possible underlying reasons for such a trend in the zoonotic research output, the frequency of zoonotic research publications and the WHO's disease outbreak news per year[23] since 1996 are depicted in Figure 3. Three highest points of disease outbreak news occurred in 2003 (due to the severe acute respiratory syndrome [SARS] pandemic), 2005 (due to the avian influenza pandemic), and 2009 (due to the influenza A [H1N1] pandemic). After 2002, with the SARS and avian influenza pandemics, the publications on zoonotic research grew rapidly, started to decline after 2006, but again increased in 2009 with the spread of the H1N1 pandemic, and decreased again with the reduction in the disease outbreak incidents. This pattern may indicate that the scientific output on zoonotic research has reached a saturation level since 2006, and only occurrences of global disease outbreaks trigger increases in the number of related publications.

Table 3 shows the top 10 journals publishing on this topic over the 33 years examined in this study. *Emerging Infectious Diseases*,

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TABLE 6

Strongest Collaborations Among the Fields of Study

	Field of Study	Collaborating Field of Study	No. of Collaborations
1	Medicine	Biochemistry, genetics, and molecular biology	1261
2	Medicine	Immunology and microbiology	1188
3	Medicine	Veterinary	1140
4	Medicine	Agricultural and biological sciences	984
5	Biochemistry, genetics, and molecular biology	Immunology and microbiology	835
6	Veterinary	Agricultural and biological sciences	737
7	Medicine	Social sciences	484
8	Biochemistry, genetics, and molecular biology	Veterinary	434
9	Biochemistry, genetics, and molecular biology	Agricultural and biological sciences	418
10	Veterinary	Immunology and microbiology	367

TABLE 7

Top Collaborating Fields of Study During 1991–2001 and 2002–2012

1991–2001				2002–2012			
	Field	No. of Total Collaborations	No. of Collaborating Fields of Study		Field	No. of Total Collaborations	No. of Collaborating Fields of Study
1	Medicine	466	16	1	Medicine	6040	23
2	Immunology and microbiology	308	13	2	Biochemistry, genetics, and molecular biology	3717	23
3	Biochemistry, genetics and molecular biology	266	13	3	Veterinary	3137	22
4	Agricultural and biological sciences	168	12	4	Agricultural and biological sciences	2986	22
5	Veterinary	168	13	5	Immunology and microbiology	2984	22
6	Social sciences	95	11	6	Social sciences	1355	22
7	Environmental science	53	9	7	Environmental science	1092	20
8	Chemistry	45	8	8	Earth and planetary sciences	942	20
9	Earth and planetary sciences	42	9	9	Engineering	705	22
10	Neuroscience	19	7	10	Mathematics	382	20

Veterinary Record, *Euro Surveillance: European Communicable Disease Bulletin*, and *PloS ONE* hold the first 3 positions with 187, 123, 123, and 119 publication records, respectively.

Table 4 shows the affiliation network properties in different periods. In the first period (1991–2001), the density of the network was high (47.1%) indicating that almost half of the possible links between different fields of study existed. The degree of centrality and closeness were also high (52.9% and 52.3%, respectively) while the betweenness was low (23.5%), which is an indication of a network centered on limited nodes (mainly "medicine" and then "immunology and microbiology" and "biochemistry, genetics, and molecular biology") (see Figure 4). In the second period as well as the overall period, the density and clustering coefficient increased. However, all the centrality measures decreased. As shown in Figure 5 and Figure 6, the network in the second and overall periods did not have a center; rather, they formed a circle. The high density and placement of fields near each other is an indication of increased collaboration among different fields rather one field with a central one.

Table 5 shows the list of top collaborating fields of study in terms of the total number of collaboration links with other fields. "Medicine" was the most collaborative field (6546 links) followed by "biochemistry, genetics, and molecular biology," "immunology and microbiology," "veterinary," and "agricultural and biological sciences." They also collaborated with 22–23 other fields out of the 26 fields. The strength of collaboration links among fields of study was determined based on the frequency of collaborations over the 33 years, which is presented in Table 6.

The "medicine" field claimed half of the top 10 strongest collaborations and encompassed "biochemistry, genetics, and molecular biology," "immunology and microbiology," "veterinary," and "agricultural and biological sciences." The fields of "biochemistry, genetics, and molecular biology" filled 3 other positions in the top 10 strongest collaborations list (excluding its link with "medicine"). Overall, the strong collaborations were observed among "medicine," "biochemistry, genetics, and molecular biology,"

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"immunology and microbiology," "veterinary," "agricultural and biological sciences," and "social sciences."

Table 7 compares the top collaborating fields over 2 time periods, 1991–2001 and 2002–2012. "Medicine" is at the top of the most collaborating fields of study during both periods. "Biochemistry, genetics, and molecular biology" and "veterinary" places in the list improved to second and third positions, respectively, in 2002–2012. The rank of "immunology and microbiology" moved from second place in the first period to fifth place in the second period. "Engineering" and "mathematics" appeared in the list in the second period, but "chemistry" and "neurosciences" dropped off the list of the top 10 most collaborating fields during 2002–2012.

CONCLUSION

This study provides longitudinal analysis of affiliation networks of zoonotic research during 1980–2012 based on a large scientific data set developed from Scopus. The overall properties of these networks as well as their dynamics over these 33 years were examined in detail. The affiliation network improved in terms of collaboration among the fields of studies over the 33 years. In the last 11 years, the top 5 collaborative fields (ie, "medicine," "biochemistry, genetics, and molecular biology," "veterinary," "agricultural and biological sciences," "immunology and microbiology") formed collaborations with 84.6% percent of other disciplines. Overall, the affiliation network grew in terms of collaborative research among different fields of study such that more than two-thirds of all possible collaboration links between disciplines have already been formed. Our results show that zoonotic research scientists in different fields (human or animal health, social science, earth and environmental science, engineering) have been actively collaborating with each other in the past 11 years.

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