A Systematic Visualization Review of Green Environment and Public Health for 2003-2019 Based on The Co-Citation Bibliometric Analysis Theory

Yan Liu
Sichuan Agricultural University

Mansoor Ahmed Koondhar
Northwest A&F University: Northwest Agriculture and Forestry University

Cheng Ya (fightgod008@163.com)
Sichuan Agricultural University

Zaid Ashiq Khan
Northwest A&F University: Northwest Agriculture and Forestry University

Research Article

Keywords: Green environment, Public health, Bibliometric, Co-citation, Authors, Institutions

Posted Date: December 28th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-1119441/v1

Abstract

Currently, the world is facing challenges of environmental pollution and public health owing to increasing urbanization. Therefore, many researchers from developed and developing countries are considering environmental pollution and public health to be the most important topics for sustainable development alongside a healthy and green environment. Although in the literature many researchers have investigated a pictorial view of green environment by defining the urban green space and blue space effects on public health, the green environments and public health research trend remains unclear. Thus, this study aimed to contribute to the literature by visualizing the bibliometric for green environments and public health, and to identify the missing research pathway. Data for this study was collected from the Web of Science from 2003-2019 in order to facilitate a visualization and bibliometric analysis carried out by CiteSpace. The visualization results reveal the most influential studies, institutions, authors, countries, keywords, and category cloud in the green environments and public health research field. Furthermore, this study suggests that researchers need to pay attention to how the genome changes due to climate change, as well as environmental pollution and its effect on human health. Mental health and research related to green environment and social health is also missing. In addition, there is also a missing link regarding green environment, underground water and public health. Additionally, this study could help authors and publishers make decisions concerning research on green environments and public health and planning for future perspectives to contribute to both academic development and applied methodology.

1. Introduction

The world is facing challenges regarding increasing public health and environmental issues owing to rising urbanization. The total urban population recorded in 2018 was 55%, while the estimation of the United Nations was approximately 68% by 2050 (U.N 2018). Urbanization is the key to development in any country but also endorses the negative effects on human wellbeing (Alcock, White et al. 2014). To overcome the adverse effect of urbanization, urban green environment is introduced. Green environment and public health studies comprise qualitatively and quantitatively diminished connections with natural environments (Van Dillen, de Vries et al. 2012). In the past few decades, such a topic became the focus of researchers due to the exposure of the population to the natural environment and its causality related to positive health outcomes in an emerging field in environmental epidemiology.

Urban green environment development such as parks, rivers, lakes, and forests are commonly considered as health-promoting characteristics in the residential environment and help to mitigate environmental challenges. Green environments in urban societies are helping reduce mental sickness, depression, and fatigue (Berman, Jonides et al. 2008, Faber Taylor and Kuo 2009, Berman, Kross et al. 2012). This in turn reduces the crime rate, develops neighborhood social structure, and reduces violence and antagonism, in addition to developing self-reported health (Kuo and Sullivan 2001, Maas, Van Dillen et al. 2009, Maas, Verheij et al. 2009, Branas, Cheney et al. 2011). Numerous studies have concluded that regular contact with a green environment either visually or physically can help to reduce blood pressure (Pretty, Peacock et al. 2005, Van den Berg, Hartig et al. 2007) and also helps in the healing process after surgical

mediation (Ulrich 1984). Similar patterns were found for a wide range of health benefits including mortality (Maas, Verheij et al. 2009).

Among all the health benefits, mental health benefit is of particular attention in the literature, highlighting stress responses as a major connection among the health effects and neighborhood conditions. In recent studies, the green environment was directly linked to biomarkers of attention and stress (diurnal disparity of salivary cortisol) (Thompson, Roe et al. 2012, Roe, Thompson et al. 2013) and brain waves as restrained by electroencephalography (EEG) devices, signifying the link among stress reduction and fatigue with exposure to green environments (Roe, Aspinall et al. 2013, Aspinall, Mavros et al. 2015). The Attention Restoration Theory (ART) suggests that green environments can decrease mental fatigue and help to reinstate an individual's ability to focus their attention. To maintain this focus, humans require mental effort, resulting in mental stress. In order to overcome this stress, humans need the chance to relax their focused attention. The way to overcome mental stress is to engage the brain in different kinds of attention like fascination attention; this can happen spontaneously without the same mental efforts used for focused attention. Indeed, researchers claim that the green environment has the ability to fascinate the attention and help to reduce mental stress, particularly in fast-paced, urban environments. (Kaplan 1995).

According to Mass et al (2006) and De et al (2003), health and green spaces have a stronger relationship within lower-status socioeconomic groups. They stated that the elderly and other individuals staying home during the day supports the hypothesis that the extent of exposure to green space on health is directly or indirectly related to their exposure to the local environment. They suggest that it could be a cost-effective strategy to recover health with an increase in access to green environmental spaces. On the other hand, these lower-status socioeconomic groups have limited traveling ability to other places, making them dependent on the local environment in the neighborhood for their healthy exposures (Kuo, Bacaicoa et al. 1998, Taylor, Wiley et al. 1998, Mitchell and Popham 2008). This evidence suggests that green spaces have stronger health effects between ethnic, racial, and socioeconomic groups; green environmental spaces might be "systematically organized to diminish health disparities" besides improving health generally (Hartig 2008).

Besides health benefits, the green environment also contributes to a great extent in the improvement of the environment by decreasing emissions, energy saving, providing cooling effects, mitigating heat islands, and decreasing air temperature due to urbanization (Zhang, Gao et al. 2014). These environmental challenges are the most serious problems of the 21st century. Green spaces in urban areas like trees, gardens, lakes, and vegetable plots have a considerable effect on the microclimate and lessens urban heat island growth by reducing air temperature (Dimoudi and Nikolopoulou 2003). Vegetation in urban areas has a great impact on temperature reduction in two ways: shading and evapotranspiration. In the shading process, the solar radiations are intercepted by leaves and branches of trees and cannot reach the ground below the plant or tree. A study in Australia demonstrated that trees can reduce wall surface temperature by 9°C and air temperature by 1°C (Berry, Livesley et al. 2013). On the other hand, the evapotranspiration is the sum of plant transpiration and evaporation, indirectly effecting air temperature

by the consumption of energy required by plants for transpiration. It was confirmed by a study in Greece that evapotranspiration can reduce air temperature by 3.1^{o}C through a green environment (Georgi and Dimitriou 2010).

In addition, trees can promote a green environment and its beneficial effects. The placement of trees near apartments and residential areas can reduce energy consumption in relation to heating and cooling purposes because trees will provide shade in the summer and keep the environment cooler around itself, while providing lesser shade in winter and letting sunlight through. Furthermore, they help to reduce dust and make the environment better by reducing pollution, regulating air movement, and produce humidity (Prevezanos 2007).

Nowadays, bibliometrics is a widely used statistical method to analyze scientific publications and understand the past, present, and future trends in certain fields of research. Bibliometrics uses a citation analysis technique, as opposed to the existing review of survey papers, and constructs a citation graph, which is a network or graphical representation of the citations between documents to measure the impact of their field, the influence of a group of researchers/countries/institutes, and the intensity of a specific research study, journal, or author. Usually, such research was done on a co-citation nexus, keyword linkages, and an association between co-authors. Considering the association of co-citation, if there are two studies and a third paper published and cited the earlier papers, this is a so-called co-citation, as per Sun et al. (Sun, Zhou et al. 2020). This technique is easier and more reliable to aid aspirant researchers in understanding a certain research field with heavy literature data. The bibliometric mapping technique not only provides a pictorial description of the state of the sculpture in the world of research but also delivers direction for scientists in their emerging area of research interest on a specific topic, hypothetically signifying stimulus for future theoretical and practical approaches to enlarge a specific field of the existing literature.

The bibliometric visualization method has previously been widely used in a number of studies to find research pathways and understand the trend of the specific research area. In the current dearth of literature, one researcher use bibliometrics to investigate the research trend for a local climate change classification scheme in order to improve the sustainability of the urban area (Xue, You et al. 2020). Rodrigues-Sabiote et al (2020) used the same strategy to estimate the conceptual research structure for environmental innovation training and sustainability. Additionally, there exists a climate change mitigation and resilience using a visualization technique investigated by Einecker et al (Einecker and Kirby 2020). Moreover, Gulluscio et al conducted a systematric review analysis to report climate change and accounting (Gulluscio, Puntillo et al. 2020). Lucarelli et al (2020) performed a visualization for environmental sustainable activities in European countries. Other studies spanning different studies areas using a bibliometric visualization analysis were completed for the development of renewable energy source analysis (Lu, Khan et al. 2020), for the nexus between innovation and development (Maier, Maier et al. 2020), for the system of land ecosystems (Xie, Zhang et al. 2020), for urban street space and public health (Meng, Wen et al. 2020), for sustainable rural as well as urban areas (Sheikhnejad and Yigitcanlar 2020), and for research on smart cities (Guo, Huang et al. 2019). Although many researchers

and scholars have carried out visualization and bibliometric review analysis for different fields, still the green environments and public health field was undiscovered. Consequently, this study tried to investigate the conceptual missing research pathway, the trend of the research, research links, active research countries, and active research institutes who are executing research related to green environments and public health. This study will contribute to the literature so researchers can understand the green environments and public health research area and provides a pathway for future research. This study was conducted based on the literature data of about 5916 documents; there is no author who claims to have done similar research.

2. Material And Methods

2.1. Data source

For this study, data was collected from Web of Science (WoS) published papers in the indexing of scientific citation index (SCI), social sciences citation index (SSCI) and science citation index expended (SCIE) database by searching for green environments and public health. By avoiding the bias and errors in analysis, the data screening were carried out by following the guidelines of Professor Chaomei Chen. The suitable designed formula was applied in order to make sure that all the papers available on WoS core collection were accurately and correctly gathered and the results cover the green environments and public health research field very well. For this study, a time span from 1950-2020 was selected and data were downloaded, while the screening data results found that before 2003 there was no research related to green environments and public health. Therefore, this study continues to visualize Scientometric analysis from 2003-2019 by fixing the slice=1.

Table 1
Data specification

Search setting on WoS	Result contents
Database	Web of Science core collection (SCI, SSCI &SCIE)
Search keywords	Green environment and public health
Data type	Literature review
Data searching timespan	1950-2020
Data visualization time span	2003-2019
Searching date	2020-09-11
Results	5915

2.2. Research method

Visualization network mapping is the analysis of the co-occurrence method, which provides to an author the missing link of a certain research area, research pathway, hotspot, process of evaluation, and trend

towards the development of a specific research field. The visualization method takes the literature (published papers) as a sample for the visualization of the time trend in a certain research area; this paper, for example, covers green environments and public health. The study used the CiteSpace software in order to visualize the research pathway, and knowledge innovation for green environments and public health developed by Professor Chen Chaomei (12). This study will analyze the visualization network map of co-citation, network of authors, mapping network of countries, mapping network of institutions research links, literature published in the journals network, and keywords. Using visualization, within green environments and public health new pathways of research and missing links in previous research can be found, allowing researchers to clearly understand the research trend development. Co-citation indicates that two research articles are cited to each other in publication, which reveals the degree of nexus between the cited publications (Zhenjiang, Lin et al. 2012). A set of co-citations reflects the set of research articles received, which are significantly and semantically correlated. Two widely used techniques were applied while collecting data from WoS: firstly, research article citation analysis (RACA), which permits the documents to identify research papers with peer citations. Each research article contains a specific node and links acquire the relationship between nodes. Secondly, the analysis of the author correlation (AAC), which connects the links between the author's nodes and institutions.

The RACA and AAC agree to cluster the mapping into periodic themes or theoretical hotspots. Generally, the cluster depends on the research work composed and connected with another cluster. Clusters are also known as the label based main keywords. CiteSpace regulates the grading of the key terms by different algorithms. The maximum algorithm level is denoted with long-likelihood ratio (LLR) as it takes the exclusivity of the cluster (Chen, Ibekwe-Sanjuan et al. 2014). Apart from LLR, this study also considers the Latent semantic index (LSI) because it seizes the frequency of the cluster term. The visualized results of both RACA and AAC are denoted with a timeline view and network mapping view. In the former, it shows the structure of nodes, location, and specification with time lag, while the timeline layout distributes the nodes and clusters with linkages to each other in a particular axis. The timeline layout gives a clear understanding of co-citation association links between each other with different time durations. In RACA, however, when the cluster is generated then the nodes are merged with each cluster, which allows one to observe the research gap with a time trend.

When analyzing the RACA and AAC, two important parametric points were fixed at the g-index for the node criteria section and over the selected time period. The G-index was selected because it defines the most cited article and quantifies significant productivity. The setting of the g-index was manually fixed at 25 and the time duration was selected for 16 years. Setting the g-index and time duration helped CiteSpace to read the literature co-citation links for 16 years and show the most highly cited co-reference work to aid researchers in comprehensively understanding the data.

2.3. Temporal structure metrics

In the case of burstness, the temporal matric is the only singular matric which signifies the citation count of literature in the short-term; citation counts help the researcher to take into consideration the research interest around the globe (Wang, Cruse et al. 2012). CiteSpace software reports the burst strength from

the starting period and duration. Similarly to the total citation count, this matric is vulnerable to self-citation.

In the network mapping, betweenness certainty shows the measure of certainty of the structure matric of the extent to which a node is connected with two or more nodes (Freeman 1977, Brandes 2001). Nodes with high certainty are connected with a big node as well as a number of nodes together, meaning that it has a highly significant influence on the green environments and public health research field (Chen, Ibekwe-Sanjuan et al. 2014). Citation count certainty, on the other hand, denotes the relevance of node structure in the mapping network.

3. Results And Discussion

3.1 References network

Table 2 shows the top ten reference citations, including the number of citations, author details, paper published in journal, and DOI for easy access to the paper, and for the top 10 cited references a mapping network is given in Figure 1. Among the top ten citation count references is a paper entitled nature and health which was published in the *Annual Review of Public Health* journal published by Terry & Hartig (2014), with a citation count of 170, the highest found in the data. The author investigated that due to increasing urbanization, resource degradation and social life changes had a significant effect on nature as well as human health. Furthermore, this study takes nature as the physical environment owing to the consideration of increasing urbanization and population demand for natural resources in order to keep a sustainable green environment to aid public health. The 2nd position was taken by Wolch et al (2014), with a citation count of 92. Wolch investigated environmental justice, public health, and urban green space and aimed to make cities green enough. This study followed the literature of Anglo-American green urban space, especially considering public parks, and compared the USA with large Chinese cities. In the USA, many cities have adopted a policy to increase the supply of green urban environments to make neighborhoods healthy, as well as implementing policies to reform land into green urban environments. Similar policies were followed by China in many big cities, while the Chinese land is state owned; regardless, the Chinese government took the initiative to make urban areas green and reduce environmental pollution to aid sustainable public health. The third is Mireia et al (Mireia, Margarita et al. 2015), with a citation count of 88. This study conducted a systematic review of 28 studies and investigated green and blue environments and their long-term mental health exploitation. The conclusion of this study reveals that there is limited evidence that green spaces positively and significantly improve the mental health of adults, but in the case of children the literature has many studies whose results found highly positive and significant improvements in their mental health due to green environments. Further, this study suggests that green urban environmental planning is compulsory to produce clever children for the future.

With a citation count of 79, Lee & Maheswaran (Lee and Maheswaran 2011) ranked fourth among the top ten citation counts. Lee & Maheswaran performed a literature review on the health benefits of green urban

environments, and their conclusion is that there is not enough strong correlation between urban space, mental health, and wellbeing. They also found that natural environmental resources such as green environments positively influence physical activity. Although many studies have concluded that green environments have a positive influence on public health, this remains hard to overcome with strong correlation. The fifth study, with 58 citation counts, was conducted by Markeyach et al (Markevych, Schoierer et al. 2017); this study explored the green environment pathway linkages, and concluded that although there is enough evidence that the green environment effect is correlated with public health, the pathway of green environment remains, including functions such as how green environments affect public health, age groups, and what health outcomes result from a green environment. This study gives a clear missing link of research needing to be done.

The sixth study was by Triguero-Mas et al (Triguero-Mas, Dadvand et al. 2015), with a citation count of 58. This study analyzed the nexus mechanism between outdoor green environment, and physical and mental health. The conclusion of this study reveals that the outdoor green environment is significantly correlated with gender specification, socioeconomic conditions, and mental health. The seventh study counts 57 citations and is by De Veries et al (De Vries, Van Dillen et al. 2013). De Veries analyzed the three mechanisms of stress reduction, improving mental health, and facilitating the social cohesion to improve physical involvement by collecting the data of 1641 respondents with an emailed questionnaire. The results of this study reveal that there is a strong mediation between stress and social cohesion with outdoor green environments, but full physical condition does not show mediation with outdoor green environments. Furthermore, in this study respondents often participated in outdoor green environmental activities; this was not found to be significant. Beyer et al (2014) ranked eighth among the top 10 citation counts. Bayer et al explored the mental health environmental green space by using the survey data from the USA. The results of this study reveal that environmental green spaces are highly significantly correlated with depression, stress, and anxiety. Additionally, this study suggested improving green environments in the USA would improve the mental health of the population. The ninth study, by Gascon et al (Gascon, Triguero-Mas et al. 2016), recorded a citation count of 54. Gascon et al completed a literature review based study in order to explore and understand the correlation between green environments and mortality. The conclusion of this study reveals that people who are living in lush green environments are much less influenced by cardiovascular disease; their mortality rate is also lower compared to people who live in non-green environments. This further suggests that studies related to green and blue environments with socioeconomic conditions need to be further investigated. Alcock et al (Alcock, White et al. 2013), ranked tenth, with 52 citations recorded; by using British panel survey data with 5320 observations, this study investigated the effect on mental health by moving in less green environments and lush green urban areas. The results found that moving in green urban areas is highly positive and significantly correlated with improving mental health, as well as reducing stress.

Table 2
Citation counts of the top 10 references

Citation	Author	Journal	DOI
170	Terry & Hartig (2014)	Annual Review of Public Health	https://doi.org/10.1146/annurev-publhealth-032013-182443
92	Wolch, Byrne & Newell (2014)	Landscape and Urban Planning	https://doi.org/10.1016/j.landurbplan.2014.01.017
88	Mireia et al., (2015)	International journal of environmental research and public health	https://doi.org/10.3390/ijerph120404354
79	Lee & Maheswaran (2011)	Journal of Public health	https://doi.org/10.1093/pubmed/fdq068
58	Merkevy et al (2017)	Environmental research	https://doi.org/10.1016/j.envres.2017.06.028
58	Triguero-Mas et al (2015)	Environment International	https://doi.org/10.1016/j.envint.2015.01.012
57	De Veries et al (2013)	Social Science and Medicine	https://doi.org/10.1016/j.socscimed.2013.06.030
56	Beyer et al (2014)	International journal of environmental research and public health	https://doi.org/10.3390/ijerph110303453
54	Gascon et al (2016)	Environment International	https://doi.org/10.1016/j.envint.2015.10.013
52	Alock et al (2013)	Environmental science and technology	https://doi.org/10.1021/es403688w

Furthermore, from the co-citation mapping the top 20 burst references were detected with strong burstness, as well as a sudden increase in citation counts; this indicates the peer review interest in the research field of green environments and public health. Figure 2 shows the results of the top 20 strong bursts references.

3.2. Journals research mapping network

The journal visualization mapping network is another feature to visualize the green environments and public health field. For this analysis, the based on the node the setting of CiteSpace was fixed to cite journals, for the journal visualization network mapping the 5916 documents record were analyzed. The

merged network nodes resulted by CiteSpace were 1078 and the links density form one node to another node found 9767, then top 10 highly cited journal were visualized.

Table3: Visualization of the top 10 journals

Frequency	Full title	Abbreviation	Publisher	IF-2019-2018	Bursts	Certainty
2072	Environmental science and Technology	Environ Sci Technology	ACS Publications	6.198	62.26	0.99
1783	Science of the total environment	Sci total environ	Elsevier	6.55	47.19	0.81
1717	Chemosphere	Chemosphere	Elsevier	5.78	36.66	0.77
1517	Environmental Pollution	Environ Pollu	Elsevier	6.79	36.34	0.76
1320	Water Research	Water Res	Elsevier	9.13	34.94	0.76
1157	Journal of Hazardous Materials	J Hazard Mater	Elsevier	9.03	34.40	0.75
1132	Science	Science	American Association Advancement Science	41.84	33.19	0.74
984	Environment International	Environ Inter	Elsevier	7.57	31.77	0.73
894	Plos one	Plos one	Public Library Science	2.74	27.32	0.73
879	Environmental toxicology and Chemistry	Environ Toxico Chem	Wiley	3.15	25.87	0.71

The results of Table 3 and Figure 3 represent the visualization network of highly cited journals and their frequency. The highly cited journals are sorted with large nodes and according to place the auto node size was fixed. Among the top 10 journals, the top ranked journal was *Environmental Science and Technology* (ES&T), with citation counts of 2072 for the publication of green environments and public health. ES&T is a multidisciplinary journal who published the paper environmental related audience work, as well as providing authors, researchers, and policy makers with information upon which to make their decisions. ES&T has been a foundational focus for thought-leading, policy-changing contributions and will continue

to serve as the home for significant, broadly relevant, and generalizable research that serves to inform decision-making.

The second ranked journal is the *Science of the Total Environment* (STOTEN), with a citation count of 1738. STOTEN is also an international multidisciplinary journal publishing research related to hypothesis driven, novel work and has a high impact on the environment, particularly in regards to the lithosphere, astrosphere, hydrosphere, biosphere, and atmosphere fields. With a citation count of 1717, the *Chemosphere* journal ranked third among the top 10 journals. *Chemosphere* was originally designed for communication related papers and literature reviews. It also publishes high impact research related to the environment and engineering. The fourth journal is *Environmental Pollution*, with a citation count of 1517. *Environmental Pollution* publishes high quality research and review papers in the discipline of environmental pollution and employs a peer review publication process. The fifth journal recognized is *Water Research*, with a citation count of 1320. *Water Research* publishes papers related to science and technology, including anthropogenic, water quality, and water recycling research. The *Journal of Hazardous Material* (JHAZMAT), with a citation count of 1157, ranked sixth. JHAZMAT publishes papers related to public health impacted by environmental effects, environmental science, environmental engineering, risk mitigation, and hazardous material. The seventh journal is *Science*, a multidisciplinary and highly significant research publication journal related to the environment and other disciplines. The *Environmental International* journal covers health impact assessments, environmental epidemiology, and environmental health risk assessments. The *Environmental International* journal is ranked eighth, with a citation count of 987. The ninth journal is *PLOS One*, with a citation count of 894. *PLOS One* is also a multidisciplinary journal which publishes high impact research related to medicine, social sciences, all science related research, and engineering. *Environmental Toxicology and Chemistry* is ranked tenth and publishes papers related to theoretical work, original experiments, and significantly advanced research related to environmental toxicology.

3.3. Country and institutes visualization mapping network

Country visualization is also an important feature to aid in understanding which countries are actively carrying out research related to green environments and public health. The Citespace selection of node type was fixed to country and the top 10 countries were selected from the merged nodes 568, as shown in Figure 4.

In the case of country mapping visualization, the USA, Republic of China, England, India, Spain, Australia, Germany, Canada, and Italy were selected as the top countries doing research on green environments and public health. China ranks first, followed by the USA. The USA has a history of being a developed country, therefore in earlier years focused on green environments and public health. China is still running towards the pathway of development, but is rapidly developing. This speed of development, however, brings about environmental pollution in China. Therefore, latterly China also considers green environments and public health for the sustainable development of the nation. By the literature's visualization, England and India are also quite concerned with green environments and public health, England is also a developed country but India belongs to the list of developing countries. Due to high population pressure and industry, India is

also actively researching green environments and public health. Australia, Canada, Germany, and Spain are also developed countries with less population; therefore, their contribution in green environment research has been less compared to the USA, China, and India.

The visualization networking map presented in Figure 5 is for the most influential institutes focusing on green environmental and public health. The most active institute is from China, the Chinese Academy of Sciences (CAS). This is the national academy for natural sciences and natural resources, and the headquarters of CAS is located in Beijing, the capital city of China. Since 2016, the CAS ranked as the number one academy around the world in the nature index. It is also the world's largest academy, where more than 60,000 researchers are working in different research directions. The University of Exeter, located in Devon, United Kingdom, is also an active institute and ranked second. The University of Exeter are doing influential research related to green environments and public health; it was established in 1955 and with time developed over four campuses. It is also a member of the European University Association, Universities UK, and the Association of Commonwealth Universities. The third institute is the Chinese Academy of Sciences (UCAS), a public university for undergraduate and graduate students working under the leadership of CAS. UCAS was established in 1978. It was the first graduate school to approve state council technology of China. UCAS ranked first in China and eighteenth in the performance ranking regarding publishing scientific research around the world. The fourth ranked institute is the City University of Hong Kong, which was founded in 1984 as the City Polytechnic of Hong Kong; the current name was revised in 1994. The University of Melbourne was established in 1853 and ranked fifth among those universities who are active in doing research related to green environments and public health. More information on active institutes is given in Figure 5. In the literature, published papers are collaborated with the international institutions which are most influential in the research field of green environments and public health (Valera-Gran, Prieto-Botella et al. 2020).

3.4. Author's visualization mapping network

Considering the map of authors co-citation, this study analyzes the top 10 highest citation count and the most active on doing research related to green environments and public health. A merged network was created with 724 nodes, which are the corresponding cited authors, with 1140 links recorded. The most frequently cited author with the largest node is Mark J Nieuwenhuijshen, followed by Giovanni Benelli, Payam Dadvand, Xavier Basagana, Chellasmay Panneerselvam, and Jayapal Subramaniam in their respective positions. The highest bursts were Giovanni Benelli, Devalumar Dinesh, Udayan Suresh, and Kadarkarai Muragan and highest burst were steamed with the certainty, which indicates the structure of the relevance in the networking of visualization. The top authors with the highest certainty were Payam Dadvand, Mark J Nieuwenhuijsen, Xavier Basagana, and Marta Cirach.

3.5. Visualization of keywords and categories

The research focus was investigated by examining the keywords to find the pathway of research in a certain period of time, which indicates the discipline of large scale publications, the attentiveness of research concepts, and appearance of a great number of researchers who are doing research in parallel

(Leung, Sun et al. 2017). From previous literature, one scholar argues that scientific development is an alteration of traditional science and modern science (Kuhn and Hacking 2012). This means that scientific research is changing over time and income insurability among old and contemporary approaches, because vocabulary changes accordingly. Therefore, we can observe that the existence of a revolution occurred by the changes in vocabulary. The statistics of the figure of keywords that occurred in the previous literature imitates the significance of keywords in this period to a specific research area (Wang, Guo et al. 2019). Thus, keyword co-citations can show a missing link of research in a certain specific research area. The co-word approach first proposed by Callon et al. (1983) is widely used in the research field of information science. The concept of co-citation ideas in bibliometrics is driven by the co-word examination. Therefore, it is scientifically proven that in two scientific terms an “inscription of keywords” exists in a published research work in the same time, indicating that there is a significant nexus between these two papers with similar keywords, if the words appear more times, each time brings them closer together (Zhang and Xu 2008). The bibliometric analysis is the sum of all co-citations, co-words, and co-term analysis.

For the co-word or keywords, an occurrence analysis was retrieved from the merged nodes of 709 associated links, with 6479 for green environments and public health. In Figure 7 are the top co-occurring keywords. From Figure 5, we can see that there are different groups which connect to each other and describe how environment affects health. Group one describes the environmental pollution, drinking water, contamination of heavy metal, toxicity, and group two describes the effect on physical health, mental condition, mortality, etc. Although the keywords are different from each other, the main objective of each study presented defined how green environments affects public health, physiology, and mental stress.

The most influential node is presented with the thickness, and the colour changes over time.

For a clear understanding, there is a cloud of each keyword occurrence, as well as identification of a missing research pathway. This study analyzes the frequency of keywords by category because it is more efficient to understand and find the missing pathfinder research for green environments and public health. Figure 8 is summarized in four groups: (1) environmental science and ecology, (2) public, environmental and occupational health, (3) marine and freshwater biology, and (4) biotechnology and applied microbiology. These four groups appeared twice with high thickness and colour stratified nodes.

Environmental science and ecology

Here, environmental sciences reflect all environmental aspects of research which directly and indirectly connect to the health keywords such as water contamination, environmental pollution, carbon emission, and air quality. When environmental pollution increases, it directly affects human physical activities and mental health (Barbara 2014). From Figures 7 and 8, it is clear that not only is there a large proportion of keywords going to the environment but also going from various categories with a high frequency cloud. It is also worth noting that big data and visualization analysis identifies the correlation between green environments and public health. It is confirmed that ecosystem and environment pathways of research

trends are connected such as in ecosystem cultural activities, which can also provide significant aesthetic environmental and recreational opportunities to improve physical activities. These, in turn, are directly connected with physiological and sociological health conditions (Zhang, Yu et al. 2020). In the literature, there is enough strong evidence that physical environmental activities could reduce the risk of cardiovascular disease (Thompson, Roe et al. 2012, Van den Berg, Wendel-Vos et al. 2015)

Considering the dearth of literature, it has already considered physical and mental health in relation to urban green spaces and concluded that the physical social contact with green environments can overcome many physical benefits (Rios, Aiken et al. 2012, Fone, White et al. 2014). But according to co-occurrence keywords, there is still a missing pathway of research concerning physical and social activities. The findings of this research are to support a study published by Hertig et al (2014) concluding that the environmental social coherence pays little attention. As compared to physical health, social health received relatively lower attention concluded by Keniger et al (Keniger, Gaston et al. 2013). The correlation of health and social cohesion with green environment might declare a highly significant mediation because it is directly connected with human loneliness, feelings, and stress (Maas, Van Dillen et al. 2009). However, the correlation of social cohesion and green environment is not widely investigated, therefore researchers need to fill this research gap.

Public, environmental, and occupational health

Public, environment, and occupational health is a very important discipline in medical and biological research. Research related to public, environment, and occupational health put a shed on the current health situation, including coronary disease caused by changes in environment and health related policies, as well as the standard of public health. Sweileh et al (2014) performed a bibliometric analysis on research activities in Arab countries regarding public, environmental, and public health and concluded that public health research is not only rising in European countries but in Arab countries it is the popular for doing research related to environmental effect on public health as well as occupational health found relatively lower. Figures 7 and 8 show the dominancy of the keywords declaring the theme of public, environmental, and public health, with very high frequency thick nodes and colours over time. The available literature was mainly focused on how and to what extent green environment is associated with public health, mental health, and wellbeing (McMahan and Estes 2015, Gascon, Triguero-Mas et al. 2016). While the main objective was to connect the relationship between public health, occupational health, and green environment (Markevych, Schoierer et al. 2017), the missing links regarding the planning of public health correlated with the green environment needing to consider how it can be best promoted and provide more benefits to public health. Policy makers must reveal the urban planning policies considering the green environment such as the composition of landscaping, freshwater, air quality, public health, trees canopy, parks, etc., to sustain public health (Barnes, Donahue et al. 2019).

Marine and freshwater biology

The cloud of marine and freshwater biology is an interesting and important research area related to microorganisms available in the water, whether surface water or underground water which can be directly

contaminated due to climate changes and environmental pollution; this directly affects public health (Kamble 2014). Green environment, freshwater, and public health related research need to be done in the near future because it also has a frequency of nodes both in keywords and category. The ocean has a direct effect on public health (Fleming, Broad et al. 2006). Due to climate change and environmental pollution, microbes and contaminated seafood are consumed by humans and so directly affect human health. Therefore, it is urgent to consider green environments to reduce pollution for marine species, as well as maintain seafood safety to aid the increasing population. Furthermore, marine and freshwater organisms can cause death, injury, or long-term health problems, so is worthy of consideration in future research.

Biotechnology and applied microbiology

Biotechnology and applied microbiology is a very wide field in the world of scientific research and it has a great effect on world development in medical sciences. In this case, researchers focus on cells, gene, genetic, genome, environmental biotechnology, and enzymes. This study reveals that research needs to be done concerning how genomes change due to environmental pollution and its effect on public health, mental stress, and physical activities. Biotechnology and applied microbiology to increase green environments careful the genome modified species. These are also sometimes harmful for human health causing allergies by physical contact with genome modified plants, because genome modified plants during pollination cause pollinate pollution and affecting human health (Key, Ma et al. 2008). Thus, it is necessary for green environments to pay attention to plant species, how it reacts in different seasons, and not only to select the plant species for green environments but also to improve human physical as well as mental health. Female plants also need to be selected because of the large amount of pollinate released by male plants (Cariñanos, Casares-Porcel et al. 2014). In addition, genome modified plants produce new pathogens due to environmental changes, which are harmful for human and animal health (Fontes, Pires et al. 2002).

3.6. Limitations

Although this study has given a pictorial visualization x-ray of the green environmental and public health research areas, this study also has a number of limitations. First, this study visualized based on the selected data of WoS, meaning that in this study only those articles were included which are published in the *International Scientific Index* (ISI). In addition, in the case of methodology, this study did not distinguish between separate green environments, green urban spaces, blue urban spaces, mental health, and public physical activities.

4. Conclusion And Future Research

Green environments and public health are popular in both developed and developing countries. The increasing population pressure and increasing urbanization are not only the main causes of reducing natural resources but are also increasing environmental pollution, bringing about climate change which directly affects human health. Therefore, this study aimed to investigate the missing research gap and

new pathways for future research by visualizing the cited references, journal mapping network, authors' visualization, active intuitions, and countries. For this study, literature data from 2003-2019 were collected from the WoS. This study collected the data from approximately 5916 documents which were published in the ISI, science citation index, social science citation index, and other high indexes available on WoS. The visualization for this study was done by using Citespace 5.7.R2. The clear understanding of the pictorial figure of the green environments and public health has divided conclusion into four parts.

1. From the dearth of literature, this study retrieved two of the most active and influential co-citation reference studies which have greatly contributed to the research area of green environments and public health, urban space, and mental health. The top research article contributed by Terry's research team in 2014 from the Institute for Housing and Urban Research at Uppsala University, Sweden. Another study conducted by Wolch and their research team in 2014 was from University of California, Berkeley, USA. Apart from these two studies, other studies also had a profound contribution.
2. The topic of green environment and public health have been published in top 10 journals, ES&T, published by ACS publications, STOTEN, *Chemosphere*, *Environmental Pollution*, *Water Research*, JHAZMAT, and *Environmental International* are published by Elsevier, *Science* is published by the American Association for the Advancement of Science, *PLOS One* published by the Public Library of Science, and *Environmental Toxicology and Chemistry* is published by Wiley. Although the top journal is ES&T, the contribution of *Science* is much more significant because of the high impact factor as well as published novel work.
3. In the case of country and instate visualization, there are many European countries such as Germany, Australia, Canada, and Spain, from Asia China and India are considered to be the active countries regards doing research related to green environment, green urban space, and public health. But the USA and China are the top two countries with the high frequency of node and thickness of node. From the colours of node, it is clear that the USA has earlier considered the importance of green environments and public health and it has a long history of development, but China has a very short history of considering the importance of green environments and public health, and is a developing countries but the speed of its development is very fast in global terms. The Chinese Academy of Sciences is the top institute doing research related to green environments and public health and is located in Beijing, China.
4. Considering the co-occurring keywords and category of research are merged in are in four clouds, environmental science and ecology, public, environmental & occupational health, marine and freshwater biology, and biotechnology & applied microbiology, selection go clouds were done basis on the density frequency of nodes. These clouds are most important clouds for green environments and public because it covers the research related to social science issues, science and biological issues.

Although this study is overcome with clear pictorial figures, it is also overcome with the missing pathway of research needing to be done in the future for a sustainable green environment and to keep the public

healthy. Therefore, this study recommends that researchers need to pay attention regarding how the genome changes due to climate change, as well as environmental pollution and its effect on human health, including mental health. In addition, there is also a missing link to connect green environments, freshwater, and public health. In future research of green environments and public health, each topic cluster needs to be visualized and more analysis needs to be done such as overlay map, earth networking map, and concept tree.

Declarations

Ethical Approval and Consent to Participate

Not applicable.

Consent for Publication

Not applicable

Competing Interest

The authors declare that they have no competing interests.

Funding Acknowledgement Statement:

Not applicable

Authors Contribution

All authors have made significant contributions to this study. Y.L., contributed to conception, data collection, analysis, and wrote original draft. Methodology and data analysis were performed by M.A.K. Visualization, review and editing were done by Z.A.K., contributed to revise the manuscript, and this study was supervised by Y.C.

Conflict of Interest

All authors declare that there is no conflict of interest.

Data availability

This study used the secondary data. Therefore all the data information with detail is available in methodology section.

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Figures

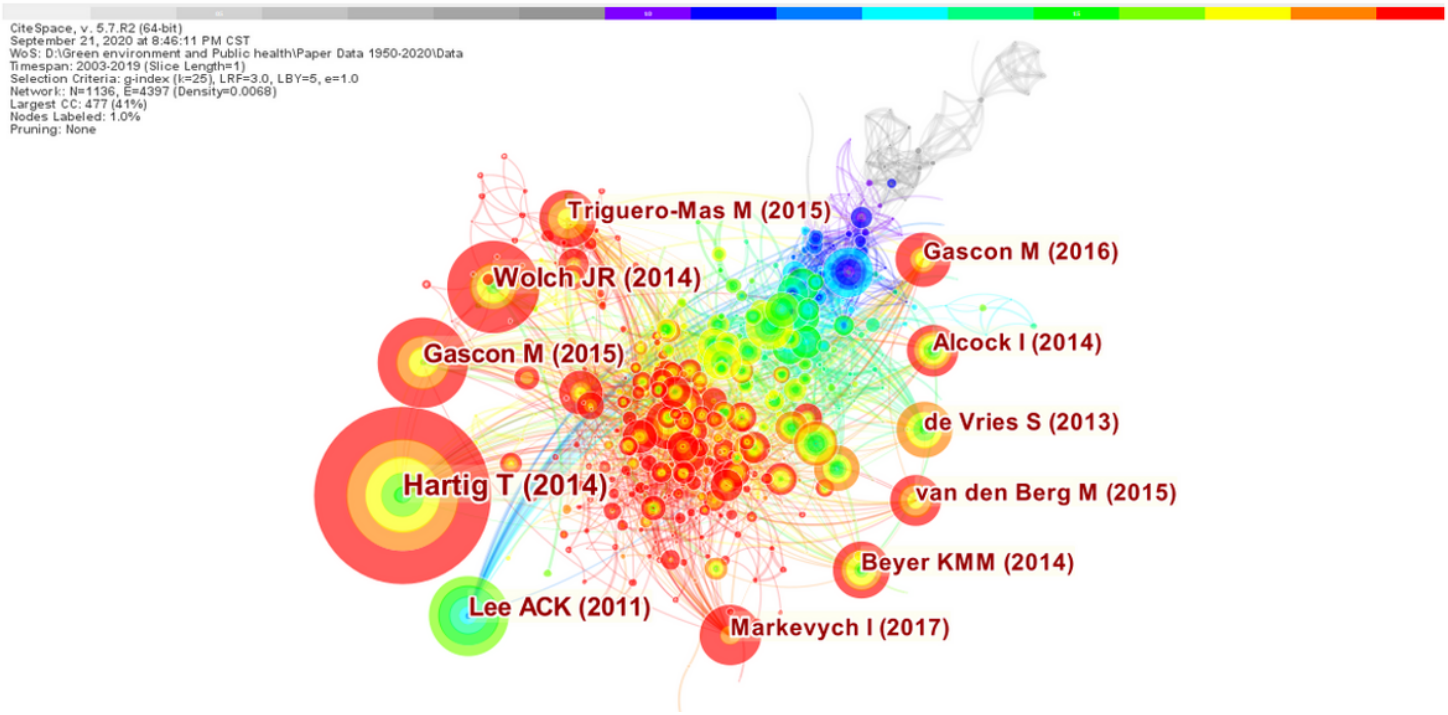

Figure 1

Visualization mapping network citation count references

Top 20 References with the Strongest Citation Bursts

References	Year	Strength	Begin	End	2003 - 2019
Hayes TB, 2002, P NATL ACAD SCI USA, V99, P5476, DOI	2002	3.36	**2003**	2019	
Hitzfeld BC, 2000, ENVIRON HEALTH PERSP, V108, P113, DOI	2000	3.29	**2004**	2019	
Chong K, 2001, ENVIRON POLLUT, V115, P107, DOI	2001	3.94	**2004**	2019	
de Vries S, 2003, ENVIRON PLANN A, V35, P1717, DOI	2003	5.22	**2006**	2019	
Hartig T, 2003, J ENVIRON PSYCHOL, V23, P109, DOI	2003	3.26	**2006**	2019	
Codd GA, 2005, TOXICOL APPL PHARM, V203, P264, DOI	2005	6.14	**2006**	2019	
Takano T, 2002, J EPIDEMIOL COMMUN H, V56, P913, DOI	2002	5.35	**2006**	2019	
Grahn Patrik, 2003, Urban Forestry & Urban Greening, V2, P001, DOI	2003	3.26	**2006**	2019	
Hoehner CM, 2005, AM J PREV MED, V28, P105, DOI	2005	3.83	**2008**	2019	
Maas J, 2006, J EPIDEMIOL COMMUN H, V60, P587, DOI	2006	14.37	**2008**	2019	
Giles-Corti B, 2005, AM J PREV MED, V28, P169, DOI	2005	3.19	**2008**	2019	
Groenewegen PP, 2006, BMC PUBLIC HEALTH, V6, P0, DOI	2006	6.57	**2008**	2019	
Hilisdon M, 2006, PUBLIC HEALTH, V120, P1127, DOI	2006	5.37	**2008**	2019	
Johnk KD, 2008, GLOBAL CHANGE BIOL, V14, P495, DOI	2008	5.21	**2009**	2019	
Crini G, 2007, SEP PURIF TECHNOL, V53, P97, DOI	2007	3.47	**2009**	2019	
Crini G, 2006, BIORESOURCE TECHNOL, V97, P1061, DOI	2006	6.75	**2009**	2019	
Mitchell R, 2008, LANCET, V372, P1655, DOI	2008	26.98	**2009**	2019	
Nielsen TS, 2007, HEALTH PLACE, V13, P839, DOI	2007	10.74	**2010**	2019	
Paerl HW, 2008, SCIENCE, V320, P57, DOI	2008	8.86	**2010**	2019	
Dodds WK, 2009, ENVIRON SCI TECHNOL, V43, P12, DOI	2009	2.98	**2010**	2019	

Figure 2

Visualization of citation count reference burstness

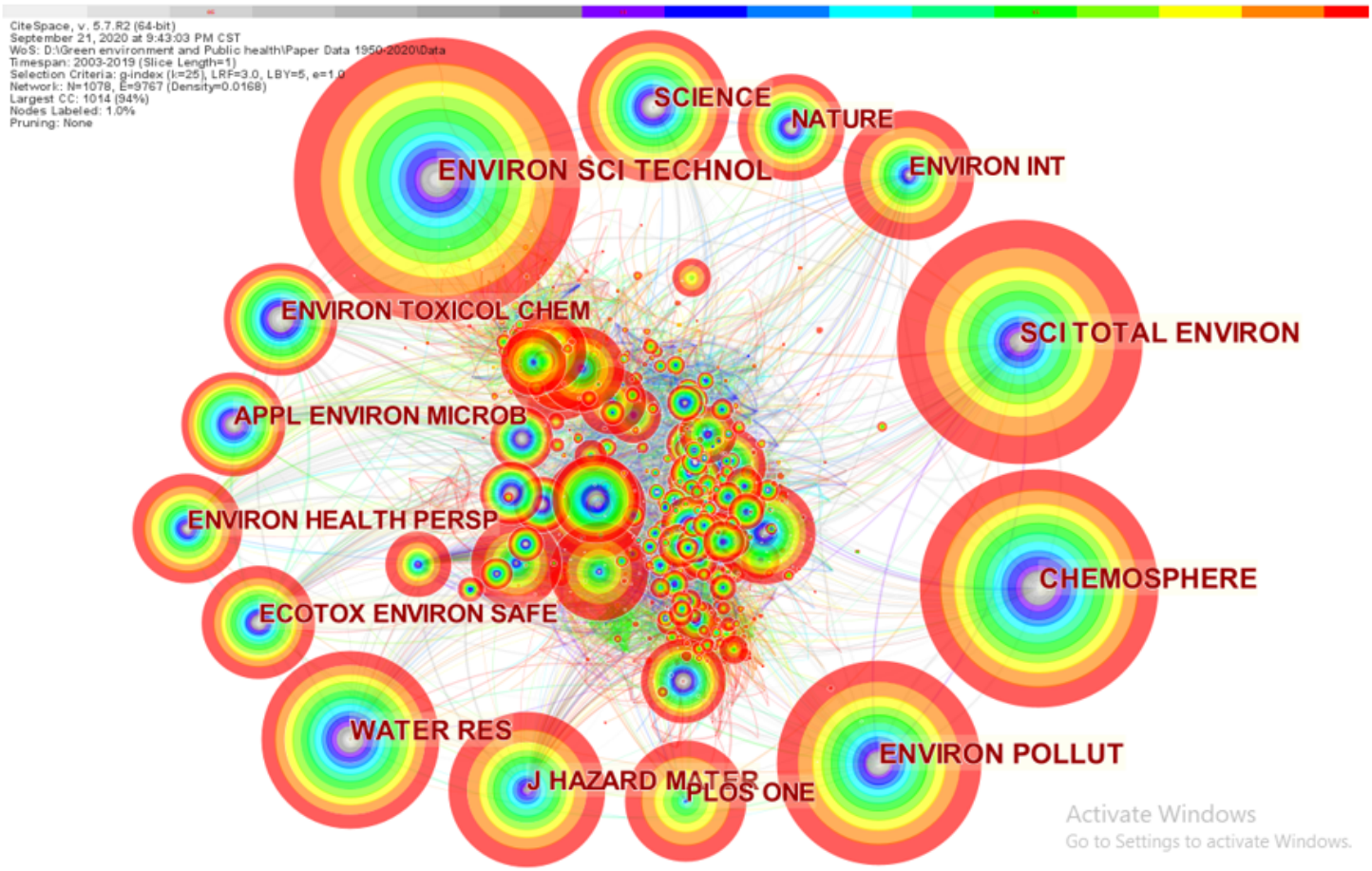

Figure 3

Visualization mapping network of the top journals

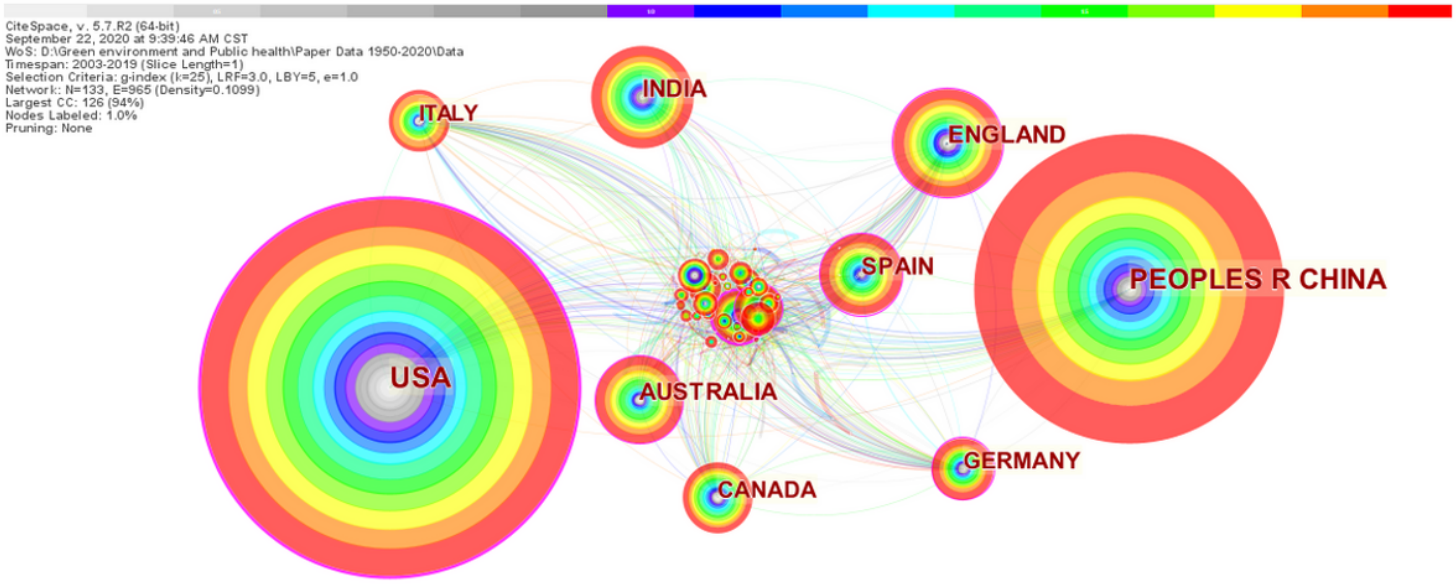

Figure 4

Visualization mapping network of active countries

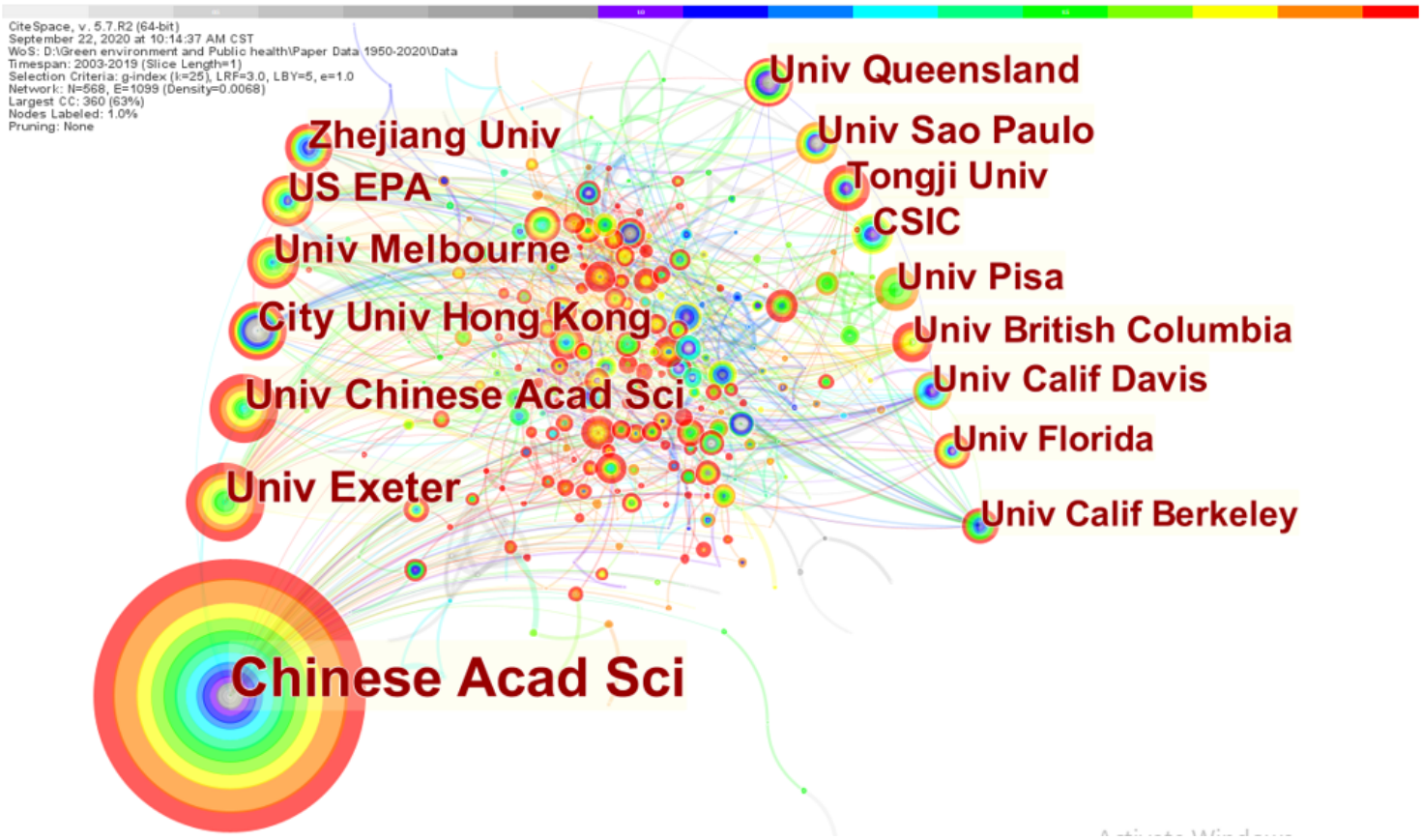

Figure 5

Visualization mapping network of institutions

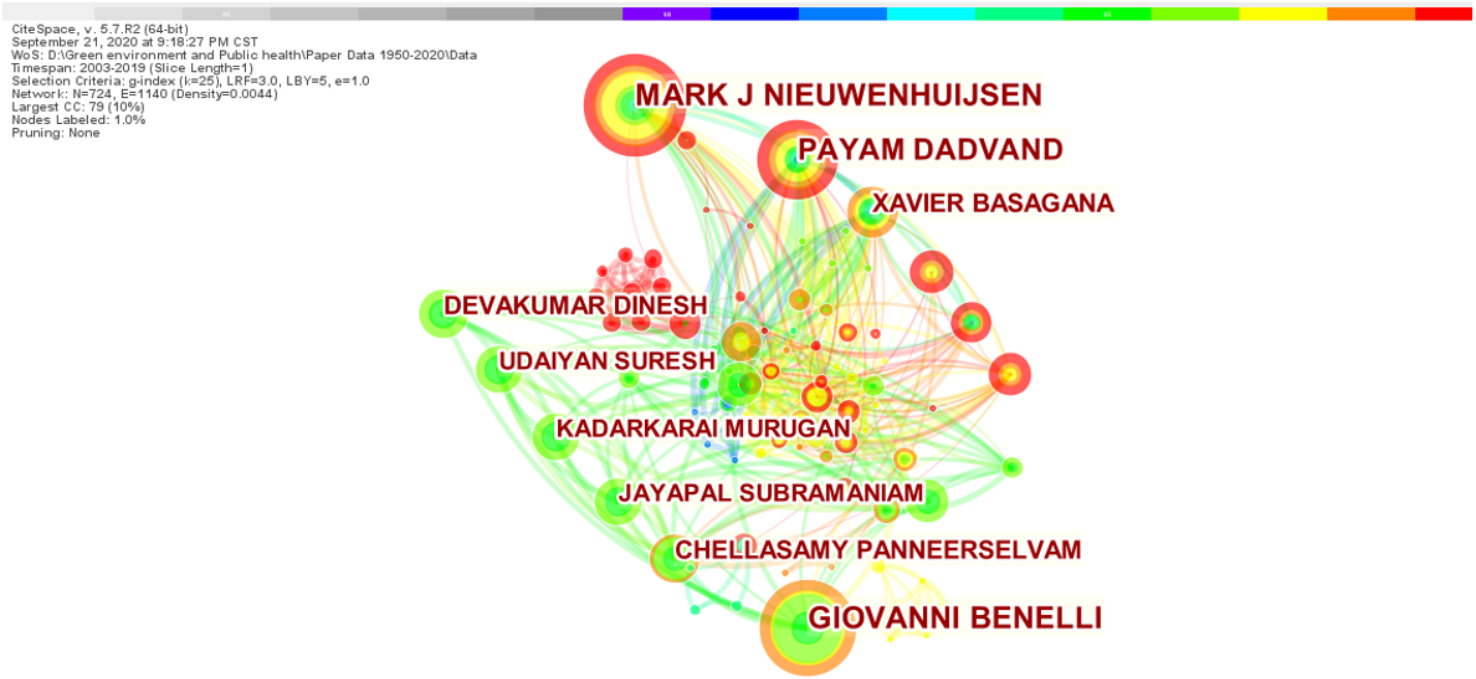

Figure 6

Visualization mapping network of authors

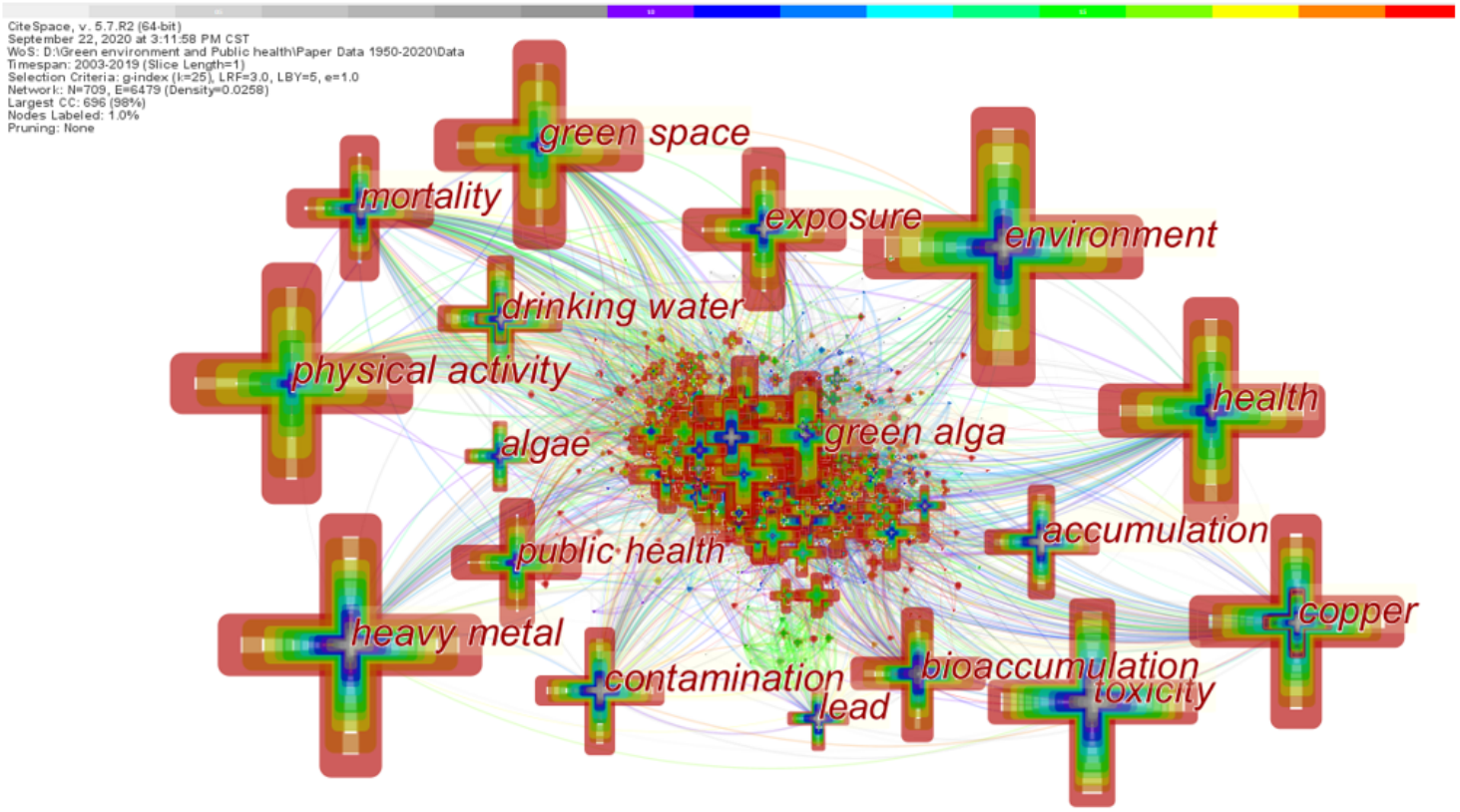

Figure 7

Visualization mapping network of keywords

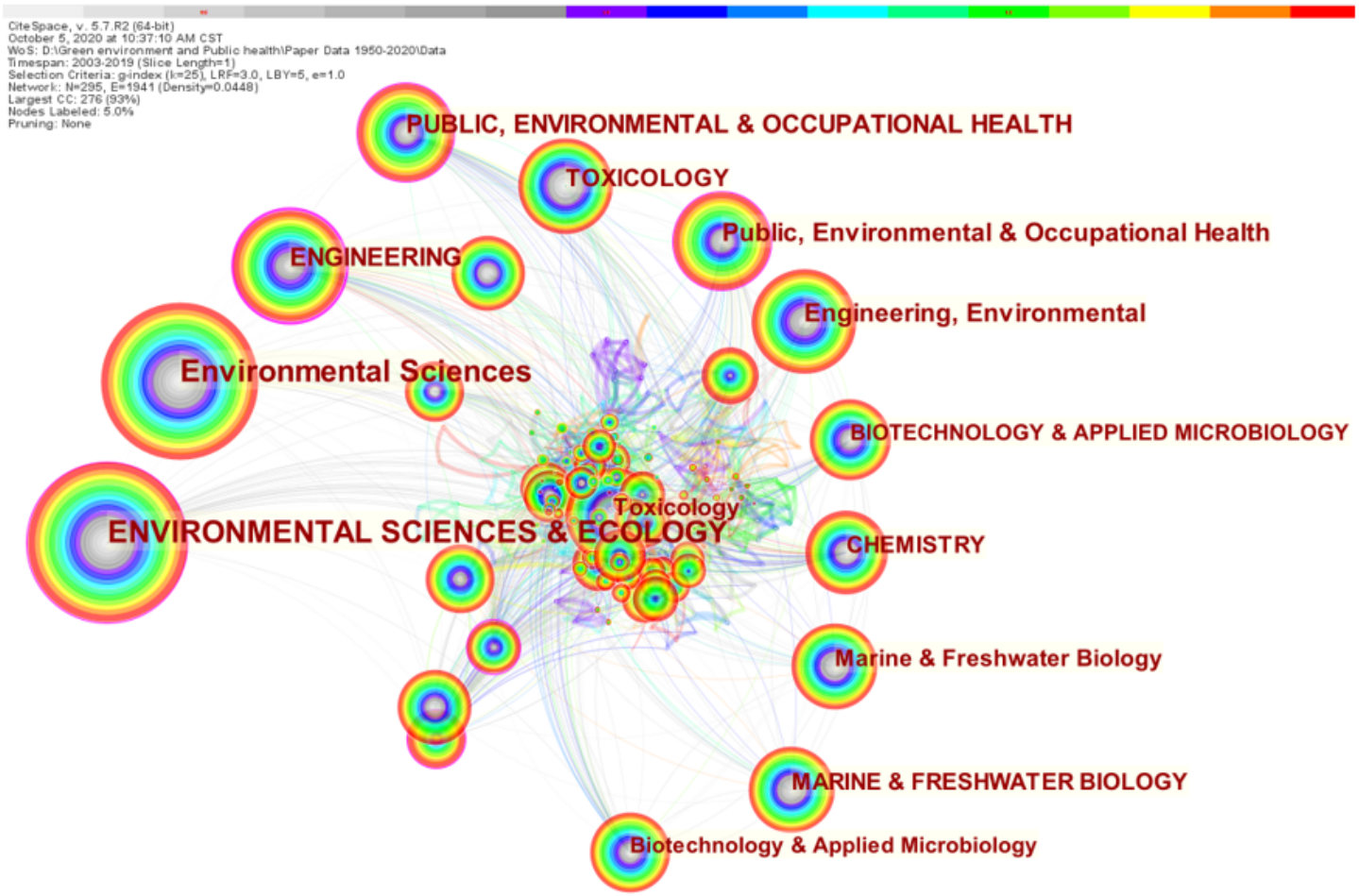

Figure 8

Visualization mapping network of categories