Bibliometric Analysis of Urban Carrying Capacity: History, Current Status, Development and Future Direction

Jay Vineshbhai Tailor*, Ravin Maheshkumar Tailor

Urban Planning Section, Department of Civil Engineering, Sardar Vallabhbhai National Institute of Technology, Surat, Gujarat, INDIA.

ABSTRACT

For stable functioning of an urban area, a balance between natural resources, urban infrastructure, and population is very much required. That's where concept of carrying capacity comes into the picture to find out limitation and current overloading on natural resources and urban infrastructure. In this study to understand growth of research work on Urban Carrying Capacity (UCC) from seed to tree, a thorough bibliometric analysis has been done in R language-based software package called Biblioshiny which is an online web-based data analysis framework. Analysis has been done for the time span of 1978 to 2021, from which 327 manually filtered documents have been selected. The results show that (1) since 1978, papers on UCC are gradually increasing. This time span is divided into low production period, stable production period and rapid production period (2) UCC research covers 28 countries, out of which China, Indonesia and USA are the top three. In which China is having the most number of papers and collaboration with other countries (3) Sustainable development, ecological carrying capacity, ecological footprint, environment carrying capacity, water resources and analytical hierarchy process are the high-frequency keywords used in recent years (4) Mostly papers are focused on single factors based studies (land-based, water-based, air-based, infrastructure-based) and low numbers papers are on comprehensive analysis. Finally, study conclude that future scope on UCC includes strengthening existing definition and theory of carrying capacity, introducing new technology and model in the system like artificial intelligence, work on more comprehensive analysis than single-factor analysis and constructing a practical planning policy.

Keywords: Urban carrying capacity, Ecology, Sustainability, Thematic evaluation, Bibliometric analysis, Biblioshiny.

INTRODUCTION

Natural resources are basic needs of human survival on earth. No matter how advanced technology we have but land, water and air are the most basic need of any human being on earth.[1] According to studies done by UN on population, world has entered in new era called 'urban century' means era of urbanization.[2] And with rapid urbanization, it is reported that 70% of the world total population will live in urban area by 2050.[3] Because of this rapid urbanization, various urban disease like traffic congestion, scarcity of land, air pollution, water pollution, housing shortage etc. are increased which can be seen by fact like worldwide, there are around 1.1 billion people who has lack access to water, and around of 2.7 billion experience at least one month water scarcity in a year,[4] According WHO (World Health Organization) report (2018), 7 million people are suffering from premature deaths from air pollution and 90% of them are from low and middle income countries.[5]

India is one of the world's main rising economies, and it is undergoing an urban revolution, as evidenced by the fact that India's urban population has grown faster than the rural population since 1931.[2] India's fundamental challenge is that its urban structure is largely dominated by a few large cities, which are also evenly dispersed, making large cities key owners in the Indian economy, active industries, and economic opportunities.[2] As India continues to develop, major issues such as housing, water supply, transportation, energy, and pollution persist. According to the 2011 census in India, 38 percent of urban families lacked access to purified tap water, 28 percent lacked a source of drinking water within their premises, and 12.6 percent lacked access to a latrine and defecated in the open, with 6.0 percent utilizing community latrines.

Because of finite land resource, instead of expanding it we should find out alternative like strengthen existing sources and changing use process.[6] That's where concept of carrying capacity comes in the picture. As before taking any further step in direction of planning about these natural resources or urban infrastructure,

knowing about their capacity to supply and demand of urban area is very important. To stop overloading of pressure on nature resources and urban infrastructure measuring and monitoring of Urban Carrying Capacity (UCC) is important.[7]

Concept of carrying capacity was introduced by Thomas Malthus in 1798.[8] Using of concept of UCC in urban development is well appreciated by worldwide government and research scholar. Also, UNESCO has published publish report on resource carrying capacity stating importance of carrying capacity.[7] In China, signification of carrying capacity was mentioned in 12th Five-year plan.[9]

There are many different concepts of carrying capacity, (1). Carrying capacity can be used with basic urban infrastructure for finding out potential growth of any urban center. As there are already standards for urban infrastructure like water and sanitation but with help of UCC there are chances of more accurate results.[10] (2). UCC can be accessed from regenerative capacity of resource and consumption capacity of waste generated.[10] (3). Land carrying capacity is population which can be support with necessary economic development and environment.[10] (4). According to UNESCO, "land resource carrying capacity is intensity of human activity carried by region while maintaining acceptable standard of living".[6] (5). UCC can be also refer as limit of population growth, physical development and socio-economic activities that can be perpetually supported by urban supporting system without any degradation and irrevocable damage.[9] (6). UCC can be a range of "acceptable" values of indicators related to environmental loads, derived from different structural and functional components of urban ecosystem such as: natural state, population, resources consumption, waste/emission production and urban facilities.[11] In spite of all of this definitions, Carrying capacity is not just a scientific concept or formula of obtaining a number beyond which development should cease, but a process where the eventual limits must be considered as guidance.[8]

Current works on UCC have very different themes because of many different definitions, meaning, principles of UCC. Also it considers mainly environmental and physical factors and not taking factors like science, technology, culture in account.[9] Main components of UCC are environmental, infrastructure, public perception, institution, and economy.[9] UCC assessment can be done two ways like first is single factor analysis like land, water, air, tourism, transportation etc. and second is multi-factor analysis like comprehensive.[5] In past, there were many studies have been done single factor analysis which are included in this report like land,[1,6,12] water,[13] tourism,[14] air,[15] disaster,[16] environment,[17] etc. But main focus of study is for comprehensive carrying capacity as UCC is complex combination various resources and infrastructure and cannot be define by a single factor.

This paper includes bibliometric analysis of urban carrying capacity topic for deepen study of history and current scenario of topic which also list of most interested authors, countries, journals, research area in which most work is done, year-wise analysis etc. Also includes proper literature review of research done till now by different authors, different indicators, methods and aims for their studies etc. and try to understand research gap, scope for Indian cities, objectives of research etc.

METHODOLOGY FOR BIBLIOMETRIC REVIEW

There are many different types of method for analysis of literatures like systematic literature review, content analysis, meta-analysis, bibliometric analysis etc. In bibliometrics analysis, statistical analysis of published articles is carried out and also done quantification of citations of articles to understand impact of that article. Bibliometric analysis is primary need for good quality of literature. It uses both mathematical and statistical techniques and also it is highly effective and widely used method for deep literature review and academic publication.[5] In simple words, Bibliometric analysis is numeric analysis of literatures on particular topic leaving other all aspects from which we can get information like leading authors, country, journal, research area etc. on that particular research topic.

Data Source and Research Platform

SCOPUS uniquely combines a comprehensive, expertly curated abstract and citation database with enriched data and linked scholarly literature across a wide variety of disciplines that's why SCOPUS was used as database for getting more variability of results. Search used for literature find out was ("carrying capacity" OR carrying capacities) AND ("urban" OR "city" OR "cities") which have included many different search paths and initially 2356 results are founded. Then after applying English language filter 1939 papers are remains and then after excluding irrelevant subject areas like health, medicine, neuroscience, business and management, chemistry, astronomy etc. total 1454 results are remains. After wise from remaining results which also included partially related areas like decision making, multidisciplinary, bio science, art and humanity etc. are manually filtrated and final list of 340 results were made. Then this data was converted in different raw data forms to input in bibliometric analysis software.

The bibliometric analysis was done using R language-based software package called Biblioshiny which is online web-based data analysis framework. This platform with data raw data obtained from Scopus or web of science can be used for many bibliometric processes like statistical analysis, data preprocessing, co-occurrence matrix construction, co-citation analysis, coupling analysis, co-word analysis and cluster analysis.

ANALYSIS

Preliminary Analysis

According raw data collated from Scopus there are total 340 documents from time span of 1978 to 2021. In these 340

documents can be categorized into 213 articles, 120 conference paper, 5 review papers, 1 retracted paper and 1 book chapter.

There are 152 different sources like journal, book etc. having 16.29 Average citations per documents, 2.284 Average citations per year per document, 10,363 references. These 340 documents have total 798 authors out of which 24 are authors of single-authored documents and 774 are authors of multi-authored documents from which estimate there 2.35 authors per document and 3.56 co-authors per documents making collaboration index value 2.46.

Annual Distribution of Documents

Every research topic has gone through some specific phases which are evolution, development, rapid growth, stable and degradation. Annual production shows life journey of research topic from its beginning and also helps in understanding of topic importance or say problem identification with time period.

As we can see in Figure 1 that evolution of carrying capacity has been started in late nineties then period. We can divide this whole development time from 1978 to 2021 in three parts which are low production period, stable period and rapid production period. As we can see in below graph that up to 2008, it can be consider as low production which explains that world and researchers have not recognize seriousness related to urban carrying capacity issue. After that it's gradually increase at stable rate up to 2016 with yearly average of 13 articles then as world and researchers started more focusing on limited availability of resources and increasing demand, need of understanding carrying capacity increase and we can see starting of rapid production period.

Average Article Citation per Year

Figure 2 shows average yearly citation documents have got from its publication year which also shows quality of work done in that particular years. As we can see from above annual production graph that up to 2008 there is very low production of papers which is also reflect in below yearly citation graph.

Graph shows few peak points in 1991,1992,1996,1998 and 2005 which represent good quality of work in low production period and this big line in 1992 is only from one paper by William E. Rees which is also globally most cited document.

And after 2008, we can see gradually increase with slight fluctuation which shows increase in quality of work with time. Most of the paper in these times are on different model and methods for the more accurate result of carrying capacity for example using AHP, TOPSIS, GIS, remote sensing, MATLAB, artificial intelligence, system dynamics etc.

Time wise Evolution of topic

Figure 3 shows time-wise evolution of research direction on carrying capacity. As we can see in graph that evolution has started with terms like land-use and agriculture. Because in that period of 1978 to 2005, limitation land was one of the big concerns so most of research work was attracted towards it and also 1978 to 2005 was also low productive period in research of carrying capacity. Then after during 2006 to 2010, it was diverted toward ecology and mathematical models and also some other factors like water resource, optimization, information science and environmental which give velocity and new direction to research. After that in 2011 to 2015, research has more evolve with addition of more research in previous areas and new area like economic and region planning in research and also work towards comprehensive evaluation has started. And in latest period of 2016 to 2021, it is more attracted towards economics and sustainable development.

Research Publication Connectivity

Figure 4 shows connectivity between top 20 Source, Author and keyword respectively which explains that in which top authors research is publishing and also what keywords maximum times used.

For the topic of carrying capacity, this graph explains that Journal of cleaner production, ecological indicator, Sustainability (Switzerland) are one of top sources having more than 7 outflow from each which means they have more 7 papers published in their production from top authors like Wang Y., Lei K. Shen I. and Wang J. using keywords like carrying capacity, water resources, ecological carrying capacity and sustainable development which have been used more than 7 times.

Top Researchers

The research paper involved 798 authors in total, among which 610 authors have 1 paper, 140 authors have 2–3 papers, 40 authors have 4–7 papers, 5 authors have 8-9 papers and 3 authors have 13-15 papers. In below Figure 5, the size of the circle in the Figure represents the number of documents, and the shade of the color represents the number of citations. The top four authors are Wang Y., Wang J., Zhang Y. and Li J., with 15 articles, 15 articles, 13 articles, and 9 articles, respectively. In the field of Carrying capacity, Wang Y. and Wang J are comes first for producing a greater number of documents. Wang Y.'s total production period is from 2011 to 2021 with 8 production nodes in different years and highest 4 article in one year when Wang J.'s total production period is from 2014 to 2021 with 5 production node and highest 7 article in one year.

Table 1 shows that Wang J.'s *h*-index, *g*-index, and mean citation per document values are 10, 12, and 18, respectively. In year 2020, Wang J.'s has published total 7 articles which have mean citation of 54.67. In field of carrying capacity, Wang J.'s has write variety of papers staring with water carrying capacity in 2014 then regional carrying capacity, resource capacity using remote sensing then comprehensive carrying capacity with inclusion of environment,
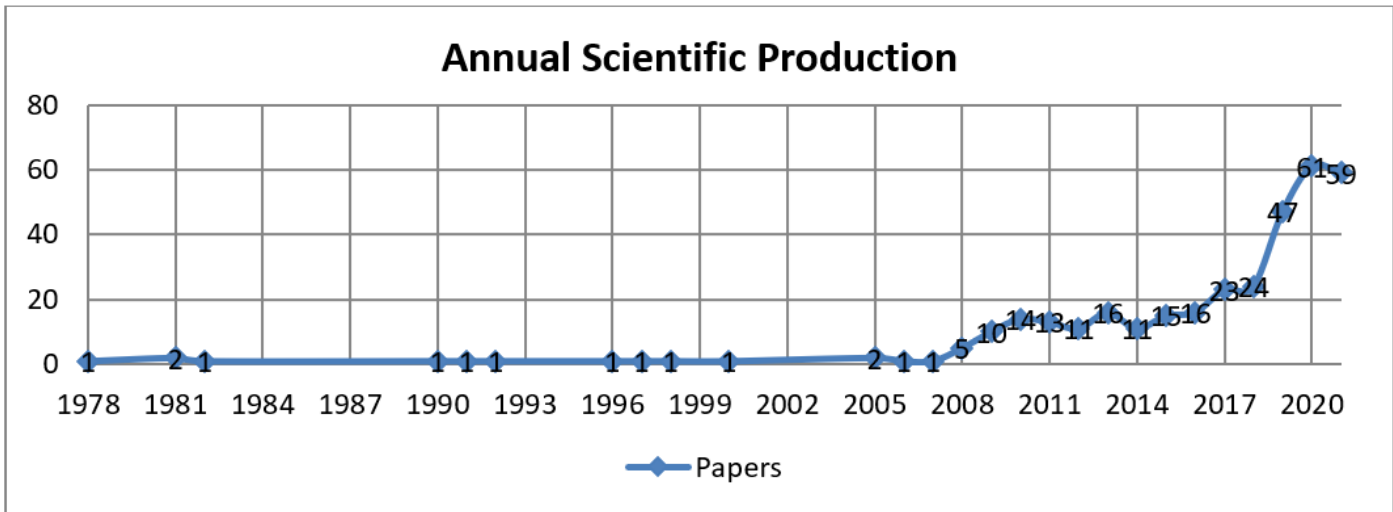
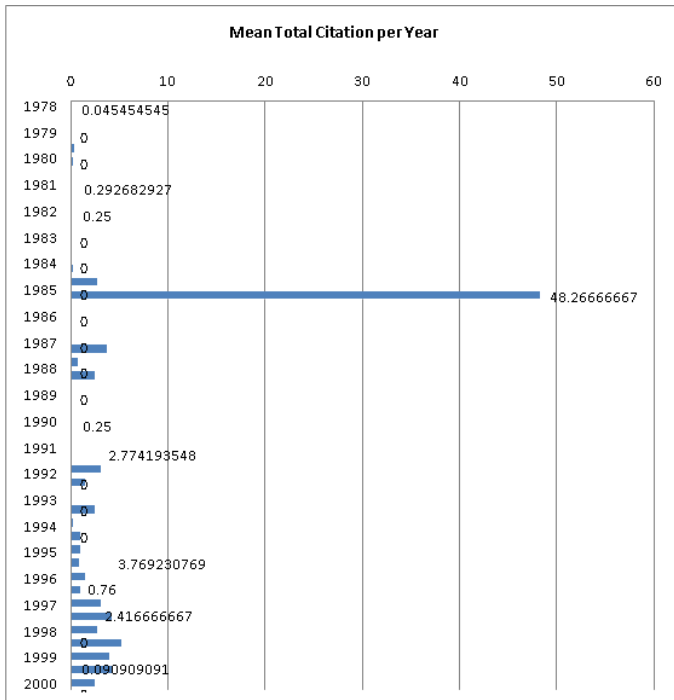**Figure 1:** Annual Scientific Production.

Figure 2: Mean total Citation per Year.

social and economic factors in year 2020 in which year he has maximum papers.

Authors collaboration network

Figure 6 shows collaboration networks of different authors which have been created based on co-authorship of papers and number of papers. The size of nodes shows numbers of contributed papers and thickness of link shows numbers of common papers between authors. Collaboration network created with Louvain cluster algorithm with minimum 2 numbers of edges. As we can see there are total 11 networks which have been classified with different color and network including authors named Wang J., Shen I etc. is biggest among them. Resident country authors are

very influencing factor creation of collaboration network. For example, in this network of Wang J. and Shen L., mostly all authors belong to China. The overall density of entire collaboration network is very low because few scholars have a certain degree of cooperation, but most scholars lack cooperation that's why research cooperation network diagram looks relatively scattered.

Country's Scientific Production

Contribution from different countries shows importance and worldwide acceptance of research area. There is total 20 countries or regions have made contribution in field of carrying capacity between 1978 and 2021 which have been shown in Figure 8. Among these China, Indonesia, USA, Iran and Italy comes in top five respectively but as we can see China alone have more than 200 articles when other countries or regions have less than 15 articles and, in this list, India comes on 7th position with only 3 articles.

As worldwide, India is on 2nd position in total population after China with less land resource compare to China, India also should more focused on find carrying capacity of own for the more sustainable and planned development. China has understood importance knowing different capacity of country like resource carrying capacity, land carrying capacity, water carrying capacity etc. while other developed countries with good number of resources have not seen carrying capacity as big problem but developing countries should focused on this area. Major reasons for less amount of article could be negligence from the developed countries and in developing or in transition countries, non-availability proper technology and shortage of funds.

As Figure 8 shows, also in collaboration with other countries China came in top with frequency of 10 times with USA, 9 times with UK and 7 times with Hong Kong which shows interest and attraction of developed nations in field of carrying capacity. Thickness of links between countries shows strength of
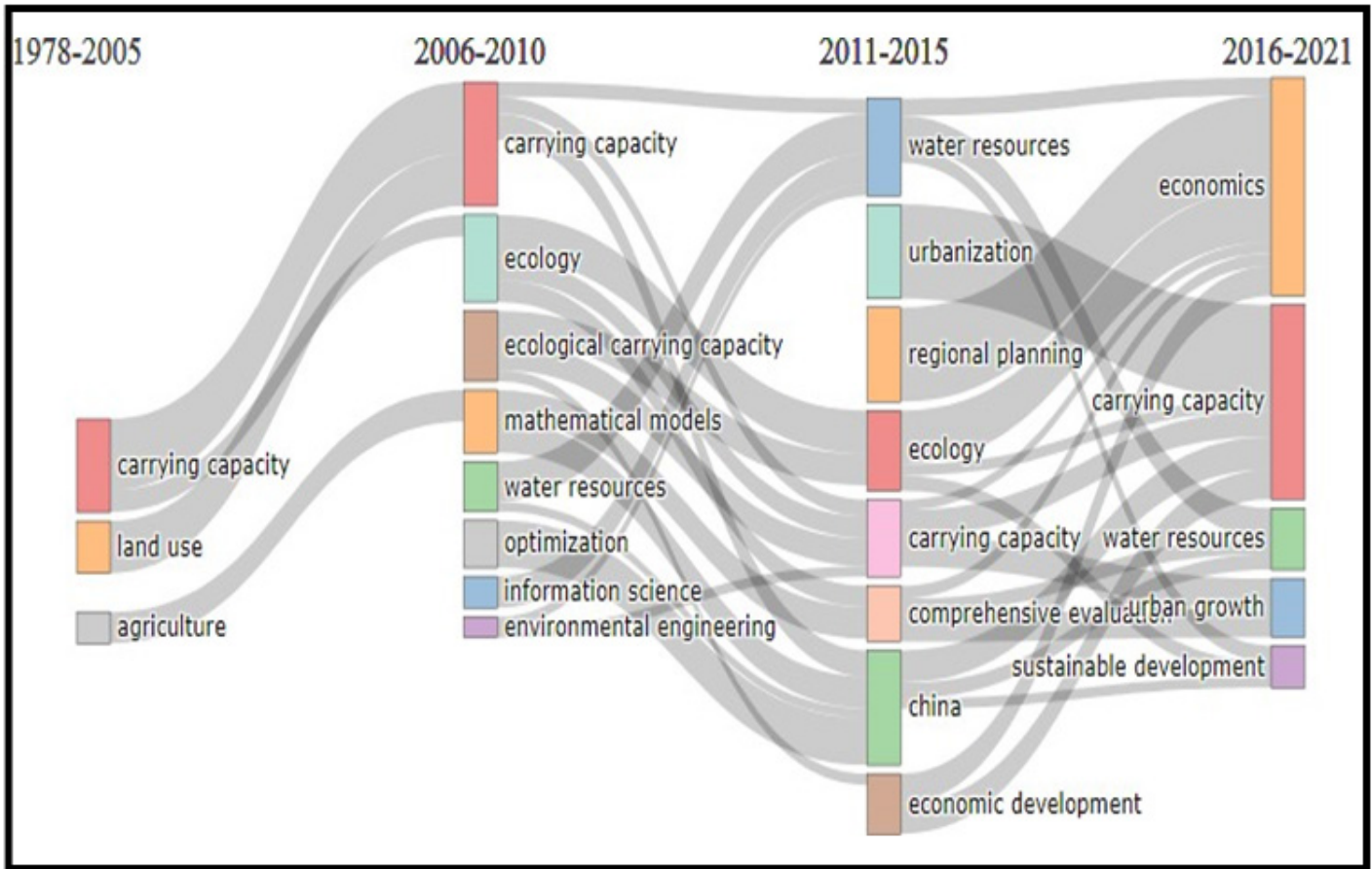
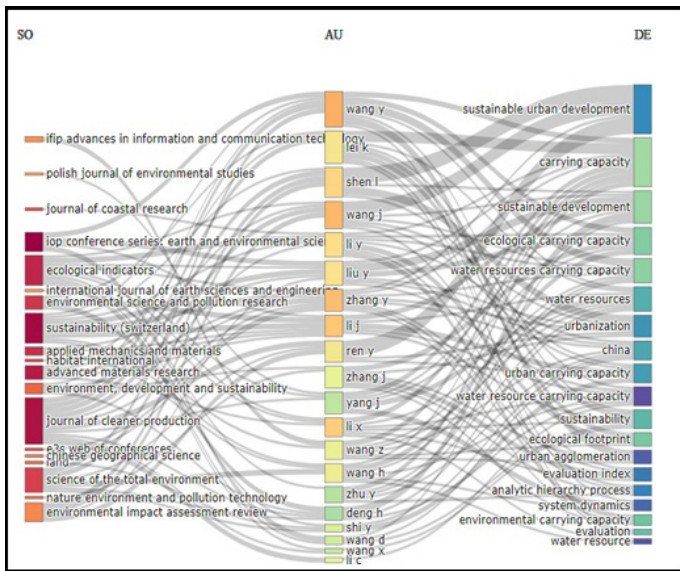**Figure 3:** Evolution of topic by time.

Figure 4: Source–Author-Keyword Connectivity map.

collaboration and size of node shows contribution of country. As we can see, there are 2 different types of clusters in map. The red one shows collaboration China with other countries but these countries are not internally collaborating and the blue one shows that USA, Poland and Netherlands are internally collaborating and also in that USA is collaborating with China alone.

Keyword Analysis

Keywords shows main characteristic and theme of the article and analysis of these keywords explains research direction and different themes in field of carrying capacity. Figure 9 shows high frequency keywords used in articles. Carrying capacity, Sustainable development, water resource carrying capacity, ecological carrying capacity, ecological footprint, environment carrying capacity, evaluation, sustainability and water resource are most used words with frequency of more than 10.

Above graph explains that study of carrying capacity has been mostly done in for water resource capacity, ecological carrying capacity, ecological footprint, environment carrying capacity with taking sustainability under consideration also many works are done for evaluation techniques, evaluation indexes using factor Weightage techniques like AHP (analytical hierarchy process). Among study of different carrying capacity, water carrying capacity is most studied area,[13,18,19,20,21] in which authors have consider human needs, ecological life, water standards using various evaluation techniques from AHP to AI (artificial intelligence).
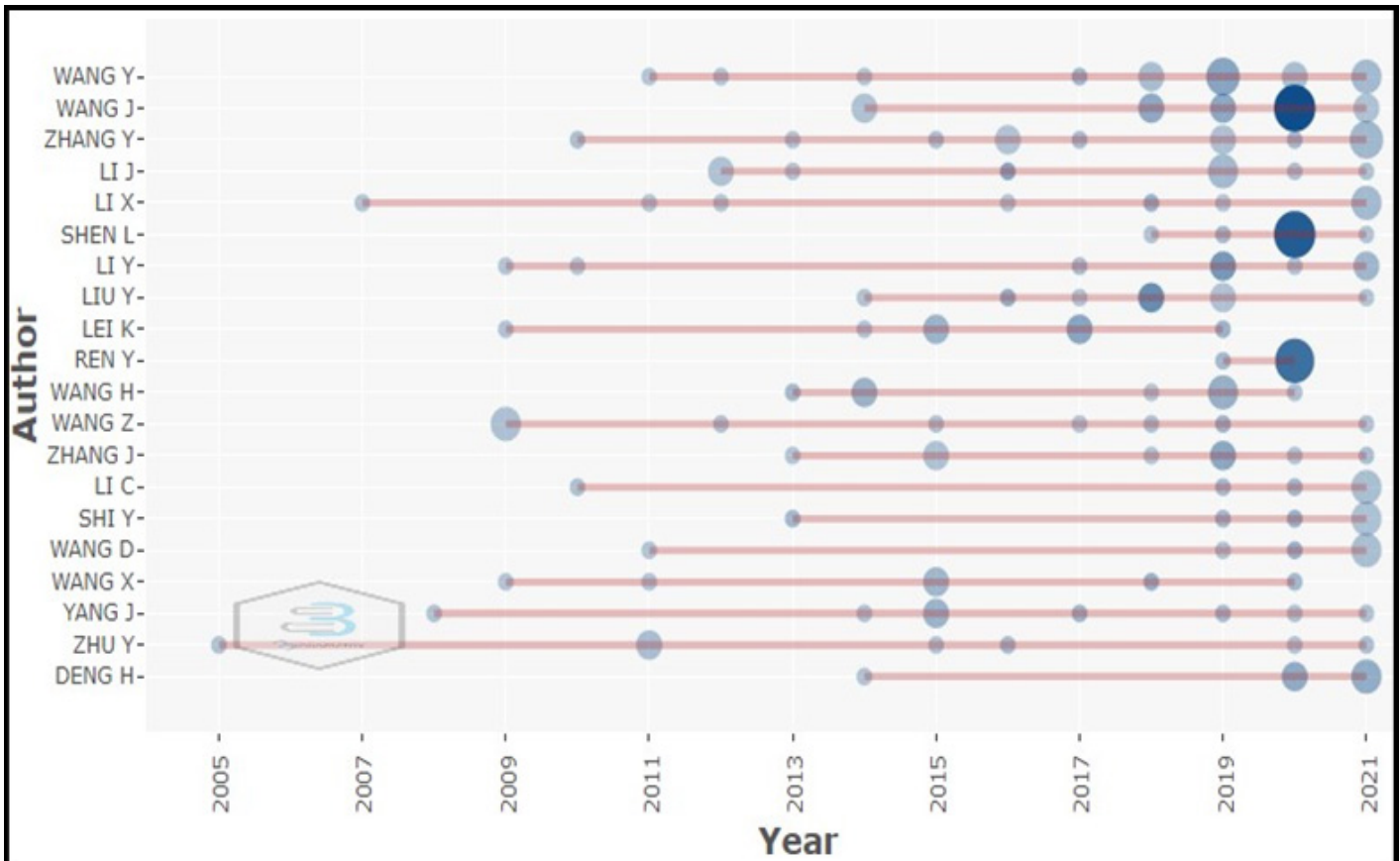
Figure 5: Author's Production over years.

Table 1: Top Author's Performances.

Author	h-index	g-index	Mean Citation per Document	Starting of Production Year
Wang J.	10	12	18	2014
Wang Y.	7	10	11	2011
Zhang Y	5	10	8	2010
Li J.	3	6	13	2012
Li X.	2	5	6	2007

DISCUSSION

Major research works have been done related to field of urban carrying capacity are from area of environmental science also in that mainly for ecological carrying capacity and water carrying capacity. As economy of urban area also play major part in its development there should be compulsory inclusion of factors like total industrial area, income from industries, GDP, employment etc.

There are many studies which have considered only single parameter like water, land, tourism, air, disaster etc. but as urban area in itself and also, its carrying capacity are very complex problems to be understood with only single parameter. So, for that researcher should more focus on comprehensive urban carrying capacity which included all different components like social, environmental, economic, transportation, infrastructure etc.

Also, we can't repeat same model for every city because every city has its own characteristics like tourism, industrial, administration, resource, service, agriculture etc. So there also need of creating different methodology and database of different types of cities.

By reviewing different methods used for calculating urban carrying capacity, it seems that mostly authors have focused on finding index out of data collected for UCC. As UCC in itself very complex problem which also have interrelation between some parameters, just finding index system is not enough.

There was not proper mention about saturation limits of resources or infrastructures which can become a practical solution to find out real carrying capacity of any area.
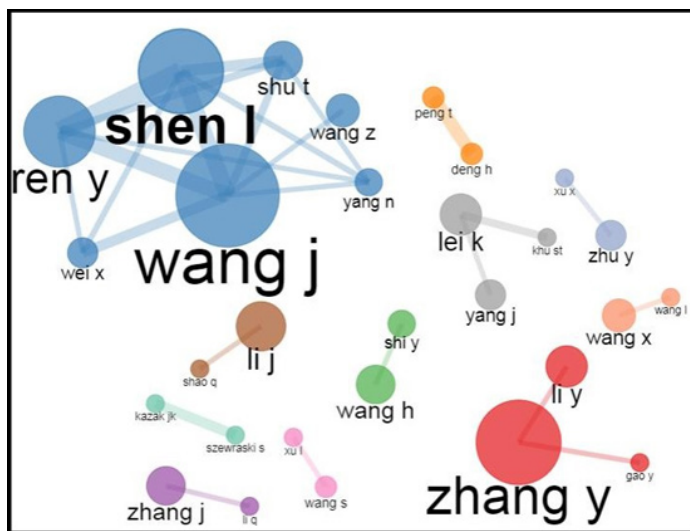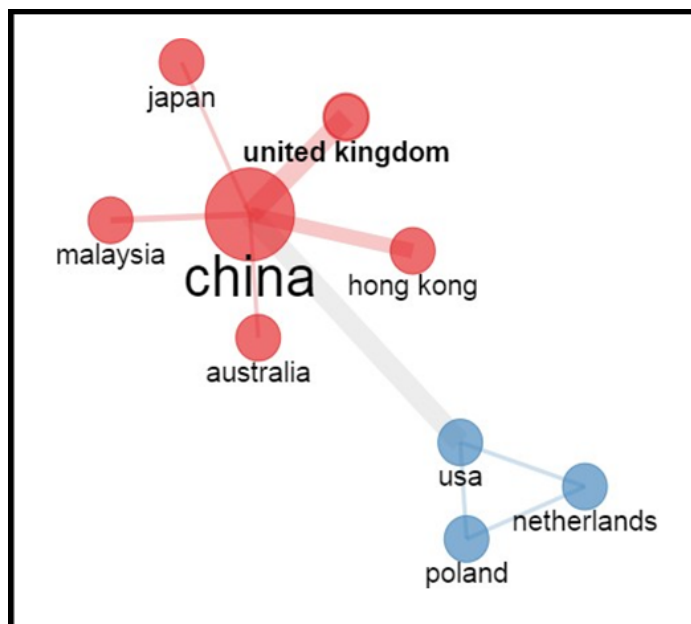
Figure 6: Authors Collaboration Map.

Figure 7: Counties Research Productions.
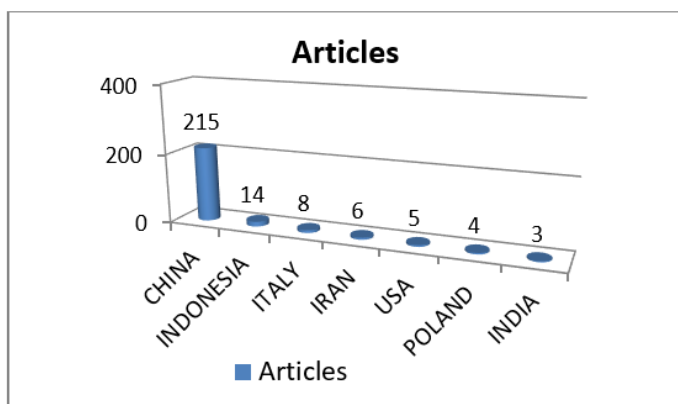

Figure 8: Countries Collaboration Map.

population wise top position China in world and availability of limited resources. Then talking about collaboration, there is very limited collaboration among the countries which affects globally popularization of research field.

Keyword based analysis of articles shows that Sustainable development, water resource carrying capacity, ecological carrying capacity, ecological footprint and environment carrying capacity are most frequently used keywords.

Overall research has been done in three directions which are calculating carrying capacity index of different individual resources like water, land, air, infrastructure, tourism etc. to compare different cities, making policy framework for sustainable development from carrying capacity and finding comprehensive carrying capacity index of city using all resources.

CONCLUSION

According to Analysis done for literatures in the area of carrying capacity from 1978 to 2021, using Scopus as database and Biblioshiny software package as tool for analysis following observation has been made:

With reference to production of articles over a time in field of carrying capacity (1978 to 2021), it can be concluded that it has gradually increase from low production period (1978 to 2008) to rapid production period (after 2016). So, there is still future potential in this field.

According to total paper citations which show quality work, the Major growth nodes have been in 1992, 1996, 2005 and between 2015 to 2020. This explains continues increase in quality of work in recent times and also rise of interest for carrying capacity among researchers.

From perspective of country wise contribution in carrying capacity field, China is most influential country as it has produced highest number of articles compare to any country which is more than 50 % of overall articles which can explain by

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CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

ABBREVIATIONS

AHP: Analytical Hierarchy Process; **AI:** Artificial Intelligence; **GDP:** Gross Domestic Product; **GIS:** Geographic Information System; **UCC:** Urban Carrying Capacity; **UK:** United Kingdom; **UN:** United Nations; **UNESCO:** United Nations Educational;
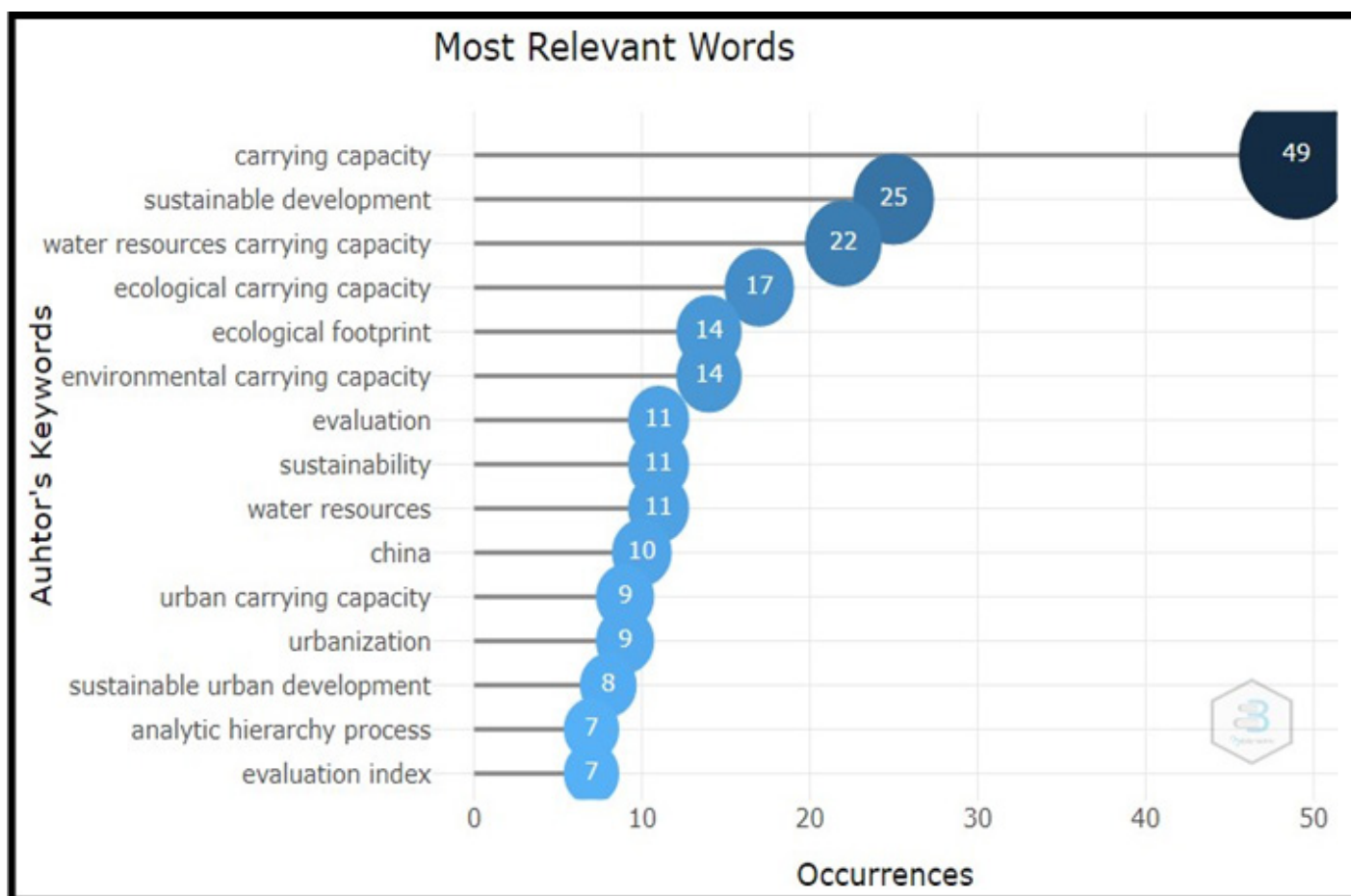
Figure 9: Most Used Keywords.

Scientific and Cultural Organization; **USA:** United States of America; **WHO:** World Health Organization.

Author's Contribution

Tailor Jay: Literature search, data collection, data analysis, writing, review and editing. Tailor Ravin: Conceptualization, guidance, editing.

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