Geospatial Big Data or Big Geospatial Data: A Bibliometric Review

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ABSTRACT

The study reviews a broad body of published literature on Geospatial big data or big geospatial data to analyse the nature of the research context, identify trends in the research area, and provide future research directions. Web of Science and Scopus databases were used to collect and convert data to information through an analysis conducted using the Bibliometrix R package and Biblioshiny. 1114 articles were retrieved after de-duplication and the analysis shows that the leading term, Geospatial big data, was first seen in the year 2012. Since then, it has captured the attention of researchers with a yearly increase in articles on the topic. The percentage decline from 2017 to 2018 was 6%, while that between 2020 and 2021 was 17%. On the other hand, the overall increase in annual scientific production between 2012 and 2021 was about 95%, which indicates a massive growth of interest in Geospatial big data. The results identify the country with the largest number of published articles, the most globally influential author, and the author with the highest average number of citations per year, while research collaborations among countries and the top leading institutions were also identified. Furthermore, the study compared author keywords plus outputs, using co-word analysis. Finally, the study identified gaps and proffered future research directions along which scholarly investigations could expand. The paper suggests that future research should focus on Geospatial big data applications to social media, urban planning, disaster management, and incorporation of artificial intelligence in addressing sustainable development challenges.

Keywords: *Geospatial data, Big data, Geospatial big data, Bibliometric analysis, Literature Review*

1. Introduction, Background and Associated Theory

The term, Geospatial data, refers to data with attached geographical components or coordinates. Such data emanate from different sources, such as Global Navigation Satellite Systems (GNSS), Global Positioning System (GPS) built into smartphones, Web 2.0 technologies and location tags, Remote sensing data, Nanosatellites, Internet of things (IoT) sensors, and Drones as major contributors to Geospatial data (Goodchild, 2007). The ever-growing emergence of technological devices and routine continuous acquisition of spatial data has resulted in the emergence of the term Geospatial big data. Big data deals with a huge volume of generated, stored, and processed data, with a high storage capacity of gigabytes,

terabytes, exabytes, and zettabytes (Villars et al., 2011) Digital streams, machine-generated or sensor data, traditional enterprise data, and social media are all examples of big data (Dijcks, 2013). Big data cannot be effectively explained without linking it to its characteristics, namely, volume, velocity, veracity, and variety (Malik et al., 2022; Naeem et al., 2022). Any data having the major characteristics of big data and with an attached spatial feature are described as Geospatial big data. Geospatial big data is useful when identifying spatial patterns and trends, modelling the real world, and making accurate predictions. Several challenges are faced when managing Geospatial big data which need to be recognised. The voluminous and varying format of Geospatial big data poses a great challenge in storing, processing, and analyzing, and in the visualization of the data. These challenges and associated theories have been addressed by several authors (Baig et al., 2019; Fan et al., 2014; Jin et al., 2015; Mishra & Sharma, 2015; Tsou, 2015; Yu, 2016)and (Coveney et al., 2016; Jin et al., 2015; Yu, 2016). In recent years, several studies have reviewed literature on big data (De Mauro et al., 2015; Ekbia et al., 2015; Elgendy & Elragal, 2014; Günther et al., 2017; Jain et al., 2016; Koh et al., 2022; Sagiroglu & Sinanc, 2013) and Geospatial big data (Koh et al., 2022; Li et al., 2016; Loukili et al., 2022). However, a specific type of review − the bibliometric review –has been conducted more on big data in general and not streamlined to Geospatial big data (Ardito et al., 2018; Di Matteo et al., 2018; Khan & Gilani, 2021; Liao et al., 2018; Mishra et al., 2018; Munim et al., 2020; Rana, 2020; Xie et al., 2020; Zhang et al., 2021). For clarity, the afore-cited studies looked at different aspects, such as trends in published work in big data analytics for business, management, land, climate, vulnerability assessments, finance, supply chain management and visualisation of medical big data research. None of the studies has conducted a bibliometric review on Geospatial big data specifically, to evaluate and identify it as scientific research and an emerging realm. It was therefore imperative in this research to investigate methods for establishing the status of Geospatial big data and to interrogate the literature to seek answers. To fully understand and evaluate the research context and distribution of Geospatial big data, a bibliometric review was required since it is a potent technique that is effective. It is employed to measure text and information, especially in big datasets (Cobo et al., 2011) to provide an overview of the current state in the field of topics, authors, countries, institutions, and areas.

2. Materials and Methods

For method context, Bibliometrics is a method of evaluating scientific research, its distribution, relationships, and variations across various preferable sources of literature. It consists of two main processes, namely, performance analysis and scientific mapping (Cobo et al., 2011; van Raan, 2005). Performance analysis evaluates groups of scientific actors, such as researchers, universities, departments, countries, etc., and the impact of their activities (Cobo, M et al 2011; van Raan, 2005). Scientific mapping displays the structural and dynamic

aspects of the scientific research process (Börner et al., 2003). Several bibliometric analyses have focused on using a single database source while neglecting others (Afuye et al., 2022; Merigó & Yang, 2017; Mishra et al., 2018; Munim et al., 2020; Van Nunen et al., 2018). However, by using a single database, the researcher was prevented from retrieving all available articles on the subject, with inaccurate and unreliable outcomes from bias. To ensure that the topic of the study was captured, a selection of keywords was needed. The study's initial keywords inclusion criteria were Geospatial big data /spatial big data / Big geospatial data /Geospatial huge data / Spatial huge data, and these were the criteria used to search the database from 1960 and ending in 2022 using several bibliometric analytical techniques. This was done on 9 December 2022, and an initial search of Scopus and the Web of Science retrieved 6951 and 5169 keywords, respectively which informed a more refined search to reflect the optimum keyword for the study, namely, "Geospatial big data" or "spatial big data" or "geospatial huge data" or "spatial huge data". These terms were used to search within the initial retrieved result. The result revealed 1096 and 301 articles on Scopus and the Web of Science respectively, and these were exported in BibTex file format. The results from the two databases (Scopus and the Web of Science) were merged and the duplicates were removed using R programming through coding. 283 duplicates were removed, leaving the remaining 1114 articles, which were used for further analysis. The analysis was conducted using the Bibliometrix R package (R studio version 4.0. 4) and Biblioshiny (Aria & Cuccurullo, 2017), which has been widely used in other studies, (Munim et al., 2020; Xie et al., 2020).

3. Results and Discussion

3.1. Annual article production

The annual production rate of an article throughout the study (1960 to 2022) was determined. The analysis of 1114 published articles showed that Geospatial big data were first seen in the year 2012. This shows that it is an emerging topic and has gradually been growing yearly owing to the rise in the volume of data used every day, as shown in Figure 1: − eight articles were published in 2012, 12 articles in 2013, 38 articles in 2014, 53 articles in 2015, 85 articles in 2016, and 132 articles in 2017. These figures point to an annual increase except for the two years, 2018 and 2021, respectively, where a decline was observed. The percentage decline between 2017 and 2018 was 6%, whereas that between 2020 to 2021 was 17%. The overall increase in the annual scientific production between 2012 and 2021 was about 95%, however, which indicates a massive growth of interest in Geospatial big data. The results are presented in Figure 1 below, which shows an annual growth rate of 35.18%.

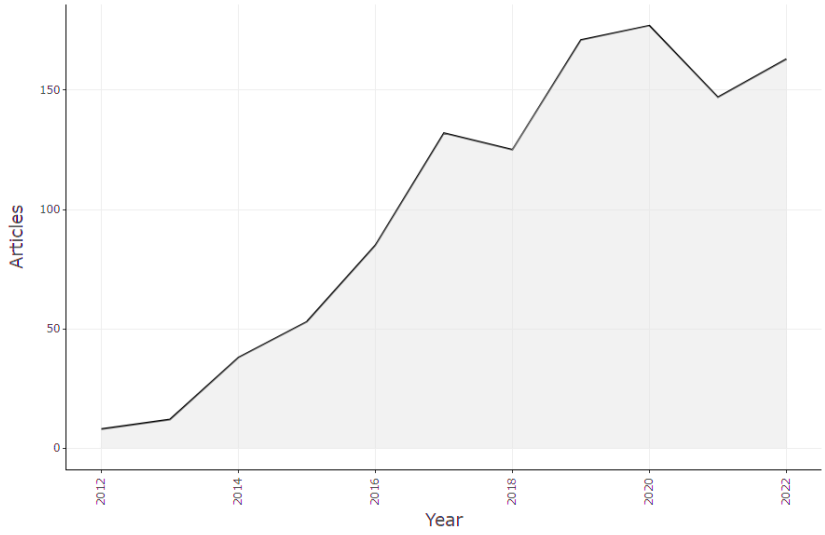

Figure 1: Annual production of articles on Geospatial big data

3.2. Academic collaboration analysis - single-country publications (SCP) and multiple-country publications (MCP)

Academic collaboration enables researchers to develop diverse skills, share new research ideas, and develop productive collaborative networks which increase publication output (Priyanka Kalra 2018). It also plays a significant role in strengthening the research output, the higher the number of collaborations across countries, the stronger the partnerships of collaboration. As shown in Figure 2, China has the highest number of research collaborations and independent article counts. The results also show that Tunisia and South Africa are the only African countries that appear in the Top 20 list of countries on these counts. Tunisia has an SCP of 7, 0, and South Africa an MCP of 3, 2. It has also been observed that Tunisia, Spain, Hungary, Greece, Hong Kong, Netherlands, Poland, and Korea, have no record of research collaborations. In addition, the USA, India, Italy, the United Kingdom, Germany, Canada, Japan, Australia, and France have multiple collaboration ratios of 0.130, 0.097,0.143,0.200,0.063,0.143, 0.077,0.125, 0.286, and 0.333, respectively. Generally, the ratio has shown limited research collaboration, indicating that single-country publications have grown faster than multiple-country publications. The number of research articles from single-country publications is greater than that for multiple-country publications.

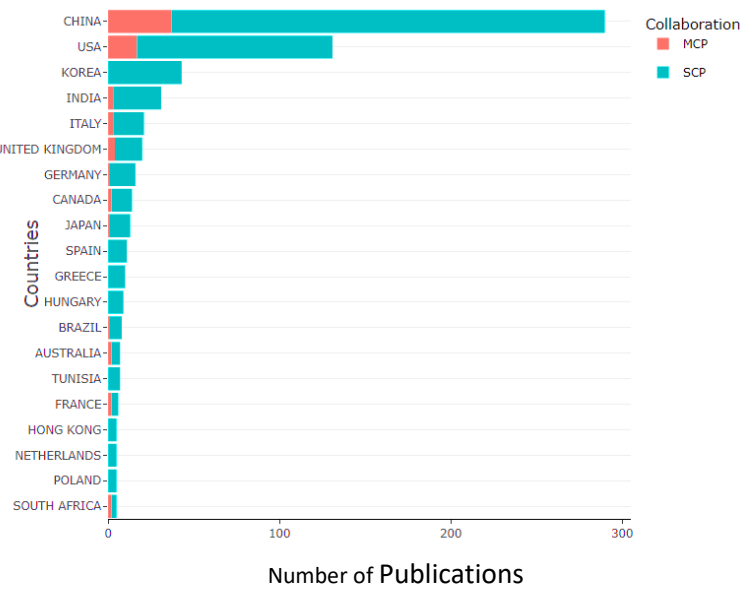

Figure 2: Top 20 collaborations in Geospatial big data in terms of authors' nationalities

3.3. Distribution of research countries in terms of Geospatial Big Data

Analysis was conducted to discover countries that have worked on Geospatial big data and to quantify the participation of different countries in a study on Geospatial big data. As shown in Figure 3, the study has shown that there is an uneven distribution in terms of countries' participation: − some countries tend to be more involved than others, while some have not yet published articles on Geospatial big data. North America shows the greatest involvement with a total number of 489 scientific articles, and South America (Brazil and Columbia) with 35 and three respectively. East Asia (China) reflects the greatest participation, with 818 articles produced Most of the Asian countries are participating but their involvement is limited (e.g., Iraq two) and as seen in Figure 3, scientific publications by African countries are extremely limited. This might be because of the challenges and hurdles that are encountered when working with Geospatial big data or poor response to awareness on the topic. China and the United States of America (USA) have attained the topmost levels in producing articles and have maintained their high production rates until recent times.

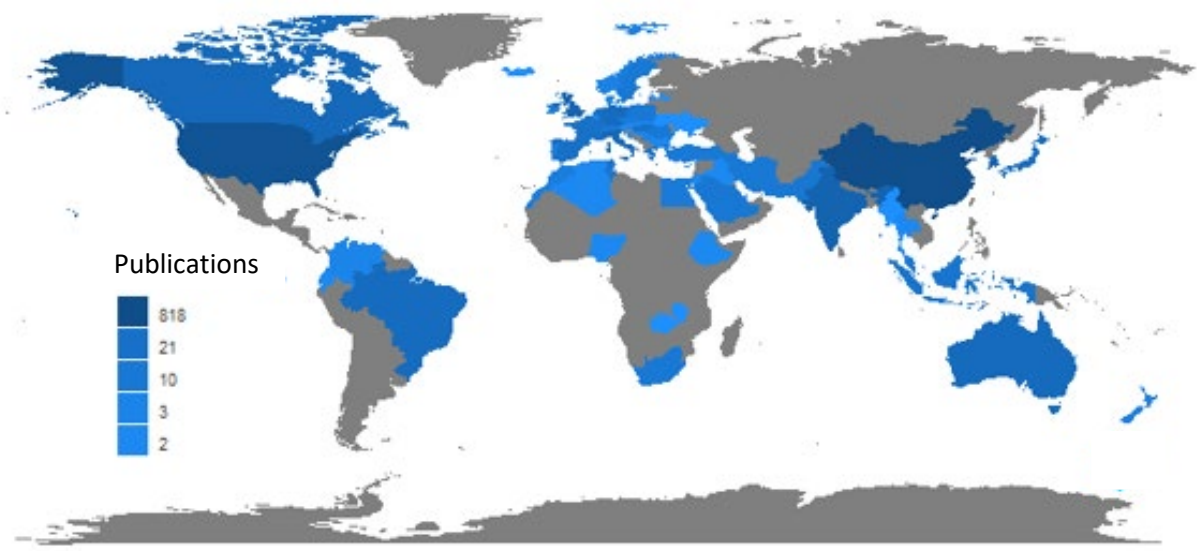

Figure 3: Distributions of research countries in terms of their publication of Geospatial big data

3.4. Top Affiliations in production of articles on Geospatial big data

In a similar vein, the most relevant of the universities affiliated with many publications include Wuhan University (N=117), the China University of Geoscience (n=40), the Institute of Geographic Sciences and Natural Resources Research, the Chinese University (Hong Kong), the University of Minnesota, the University of Illinois, Zhejiang University, Peking University, and Sun Yat-sen University. As shown in Figure 4, the number the top 10 universities, with many publications in Geospatial big data and an annual rise in affiliative production over time is depicted. Most of the universities are in China and no university in Africa appeared in the Top 20 list. Therefore, universities that are lagging should step up and publicise Geospatial big data articles available. Their non-involvement might be a result of a lack of sensitisation or challenges in handling Geospatial big data, which makes them shy away from such research. Conferences and seminars should be organized by the departmental authorities to sensitize the related domain on this newly emerged term, Geospatial big data, which was first identified in the year 2012 in online databases (Web of Science and Scopus).

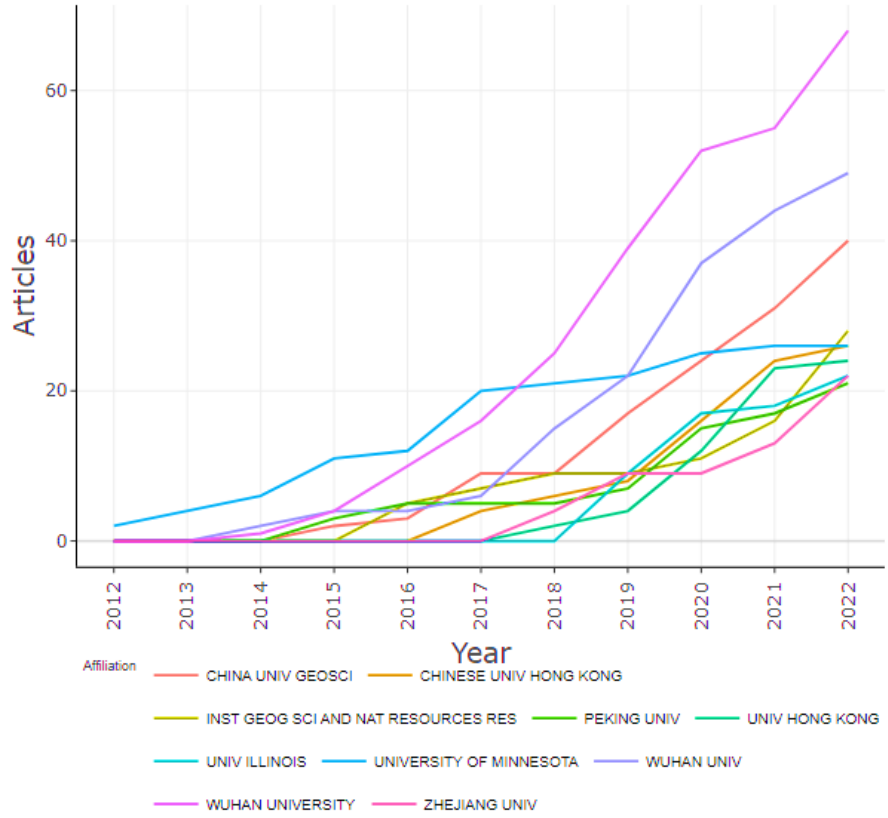

Figure 4: Top 10 universities affiliated with the production of Geospatial big data over time.

3.5. Most cited publications or authors in the field of Geospatial data

3.5.1. Authors' production of Geospatial big data annually

Figure 5 reveals the production over time of Geospatial big data by the Top 20 authors. The size of the circle shows the number of articles, and the shade of the colour shows the number of citations. A larger circle shows greater article production, while a small circle shows lower article production. Na N was the first publisher to write on Geospatial big data in the year 2012; however, as seen in Figure 5, his work did not attract any citations. The first and second articles on Geospatial big data were presented at the first International Conference on Advances in Geographic Information Systems (ACM SIGSPATIAL) on analytics for big Geospatial data, Big Spatial 2012 and at the 11th ACM International Workshop on Data Engineering for Wireless and Mobile Access, respectively. Wang Shuliang emerged as the second author with two articles in the year 2013. The study focused on spatial data mining in the context of big data and big spatial data mining. The study was presented at the International Conference on Parallel and Distributed Systems (ICPADS) and at the 2013 Institute of Electrical and Electronics Engineers (IEEE) International Conference on Big Data, respectively. Figure 5 also shows that most of the authors have been consistent over the years in producing articles on the topic. The level of consistency among the authors has shown a level of expertise in the domain

of Geospatial big data. Among the 20 top authors, Yang et al. (2017) have the highest total citation (Tc-535), based on their articles produced annually. Their articles, published in 2017, gave rise to 89.167% total citations per year. Among the four articles published by Yang et al. (2017), their Big data and Cloud Computing Innovations: Opportunities and Challenges attracted the highest number of citations, namely, (Tc=413, resulting in 68.833% total citations per year. Other top-third authors attaining large numbers of annual citations on Geospatial big data include Liu Y (Tc = 454), Liu X 2015 (Tc =435), LI Z (Tc =431), etc. These authors have shown themselves to be influential in the field of Geospatial big data.

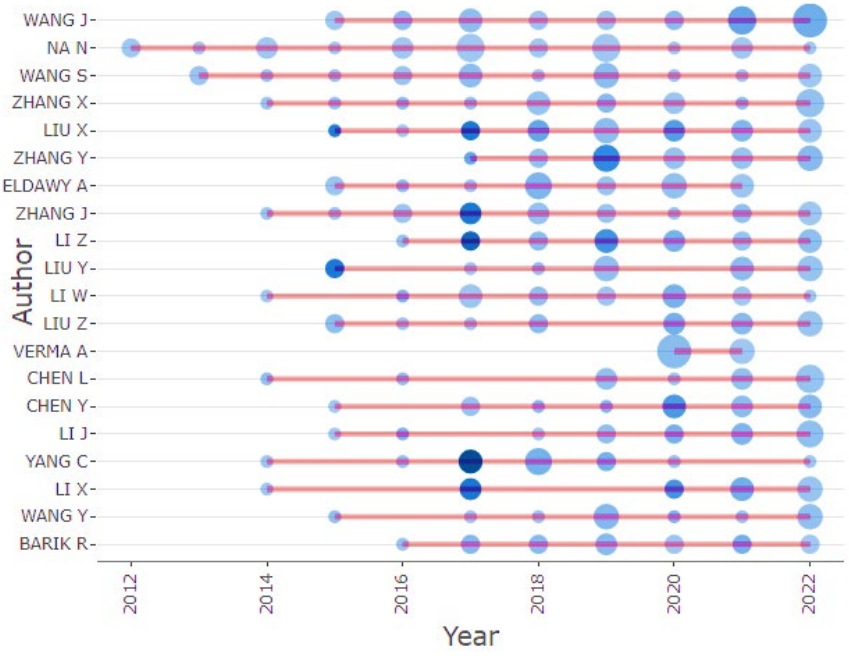

Figure 5. Authors' publications on Geospatial big data over time

3.5.2. Top 10 globally cited documents and publishers on Geospatial big data

The most cited document, as shown in Table 1 below, was produced by Liu et al. (2015) and published in the Annals of the Association of American Geographers. It earned 435 citations, accounting for 54.38% of the total citations per year. The other 10 most cited documents revolve around several topics on Geospatial big data: challenges and opportunities; the Google Earth Engine for geo-big data applications: a meta-analysis and systematic review; **s**ensing the spatial distribution of urban land use by integrating points of interest; Google's Word2Vec model, Simba: efficient in-memory spatial analytics; mapping fine-scale population distributions at the building level by integrating multisource Geospatial big data; using multi-source Geospatial big data to identify the structure of polycentric cities: a case study competition among methods for analysing large spatial data.

Table 1. Top 10 globally cited documents and publishers

Paper	DOI	Total Citations	TC per Year	Normalized TC
LIU Y, 2015, ANN ASSOC AM GEOGR	10.1080/00045608.2015.1018773	435	54.38	15.99
YANG C, 2017, INT J DIGIT EARTH	10.1080/17538947.2016.1239771	413	68.83	24.26
LI S, 2016, ISPRS-J PHOTOGRAMM REMOTE SENS	10.1016/j.isprsjprs.2015.10.012	242	34.57	13.33
LEE JG, 2015, BIG DATA RES	10.1016/j.bdr.2015.01.003	240	30.00	8.82
TAMIMINIA H, 2020, ISPRS-J PHOTOGRAMM REMOTE SENS	10.1016/j.isprsjprs.2020.04.001	232	77.33	20.13
YAO Y, 2017, INT J GEOGR INF SCI-a	10.1080/13658816.2016.1244608	210	35.00	12.34
XIE D, 2016, PROC ACM SIGMOD INT CONF MANAGE DATA	10.1145/2882903.2915237	182	26.00	10.03
YAO Y, 2017, INT J GEOGR INF SCI	10.1080/13658816.2017.1290252	144	24.00	8.46
CAI J, 2017, REMOTE SENS ENVIRON	10.1016/j.rse.2017.06.039	142	23.67	8.34
HEATON MJ, 2019, J AGRIC BIOL ENVIRON STAT	10.1007/s13253-018-00348-w	140	35.00	14.01

3.6. Core research area and future research directions

3.6.1. Most frequent word in Geospatial big data articles according to Keyword Plus

Figure 6 shows that the most frequent words used in the field of Geospatial big data are big data, remote sensing, data handling, information management, spatial data, data mining, geospatial, visualization, data analytics, and data analysis. As shown later in Figure 7, the study identified the trend in the keywords used in Geospatial big data according to Keyword Plus Keyword generally (authors: Keyword or Keyword Plus) is very important in an article as it represents the author's opinion of the most important words used in an article. It helps to identify the trending research topics that are popular or, on the other hand, only a few, and to determine whether there is an increase or a decrease in the use of a particular keyword. Key Word Plus is effective in bibliometric analysis when investigating the knowledge structure of scientific fields (Zhang et al., 2016). It pinpoints the research topics that are popular, or less popular ,across documents (Pesta et al., 2018). The size of the circle shows the occurrence of the words. It shows that big data, data handling, remote sensing, land use, information management, spatial data, and data storage are the top six words most frequently used in the article. Words such as big datum, spatial computing, algorithm, program processing, and design were often seen in articles published within four years of the first published article on Geospatial data (2012-2015), whereafter spatial database, query language, GIS, data handling,

information management, remote sensing, and land use were observed in articles published from 2015-2020.

Figure 6. Word cloud of 50 words frequently used in Geospatial big data.

In Figure 7, within the last four years, the topics have shifted to machine learning, prediction, urbanization, classification, and cities. This trend in the topic has shown that articles on Geospatial big data do indeed change and align with the advances in technological techniques and tools. To assess the research directions in Geospatial big data, it was observed through keyword analysis that remote sensing, information management, digital storage, data mining, data visualization, and Geographic Information System, are amongst the areas of research in Geospatial big data. However, the presence of Geospatial big data in applications in the social media, urban areas, and disaster management, is still very limited. Because of geotagging, social media, which comprise unstructured and semi-structured data, have been identified as a huge source of big data (Adamala, 2017; Bello-Orgaz et al., 2016; Chan, 2013; Liu et al., 2015; Zhao & Sui, 2017) and Geospatial data. Thus, these two components would be an important direction to head for in future research.

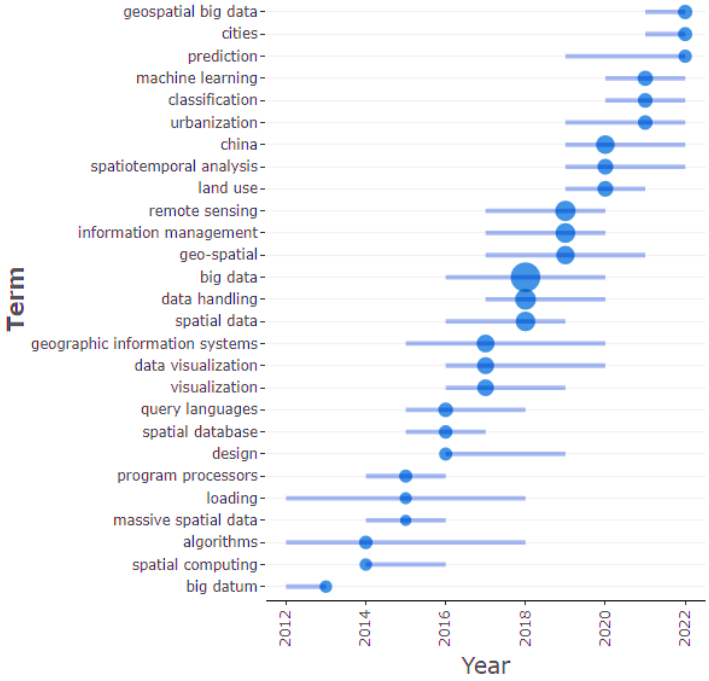

Figure 7. Annual trends in Geospatial big data topics according to Keyword Plus

The production in African countries of scientific publications on Geospatial big data is very limited among the Top 20 developed countries, thus indicating that the research output in emerging nations is weak. It is worthy of note that Eastern Europe has also not yet published on such a topic. Machine learning techniques and artificial intelligence are still in their infancy. The term, machine learning, was first seen in a Geospatial big data paper in 2020 and there have since been only a few studies that have used these techniques. Further studies should employ the techniques in Geospatial big data. In terms of bibliometric analysis, further studies should incorporate more databases in their analyses to include a wider range of research contexts and directions.

4. Conclusion

The scientific findings from these reviewed studies show that the term, Geospatial big data, first appeared in 2012 and that it has captured the attention of researchers ever since. The largest number of publications (177 articles) was seen in the year 2020, which was when the Covid-19 pandemic struck. The country that has the largest number of published articles on Geospatial data is China, followed by the United States of America (USA). These two countries have experienced a sharp rise in production in recent years (2019 - 2022). The most globally influential team of authors is Liu Yet et al (2015), with 435 citations, while the paper with the largest number of average citations per year is that by Yang C. (2017). China has been

observed to have the largest number of research collaborations. Among the African countries, South Africa and Tunisia are the only two countries appearing in the Top 20 list of countries, with a single and multiple country publications of 7, 0 for Tunisia and 3, 2 for South Africa, respectively. The top three leading institutions in the world in terms of publications in this area are Wuhan University, China University, and the Institute of Geographic Sciences. The study further provides their core research area and future research directions.

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