

Chapter 13

The Growing Scientific Interest in Artificial Intelligence for Addressing Climate Change: A Bibliometric Analysis



José Javier Galán Hernández, Ramón Alberto Carrasco González,
and Gabriel Marín Díaz

Abstract Climate change is a reality that can be felt. There are more and more symptoms: droughts, floods, global temperature change... This is causing public opinion to react and worry. The scientific community is no stranger to this feeling and is looking to science and technology, specifically artificial intelligence, for the means and mechanisms to help reduce this impact. This study demonstrates that the scientific community's interest in artificial intelligence and climate change is a constant and growing reality. To achieve this objective, a bibliometric study is used with the following methodology: first, scientific papers related to artificial intelligence and climate change are obtained from the Scopus database, then they are processed through VOSviewer and analyzed by the dimensions of time, topics, and countries, and finally a network map is visualized where it can be seen how climate change is surrounded by areas related to artificial intelligence.

13.1 Introduction

In recent years, the perception of climate change (CC) has increased, the rise in temperature is noticeable, not only as a sensation, affecting entire regions and more directly farmers and ranchers, affecting the processing of commodities [1, 2].

Raw materials are becoming scarce due to their high demand, which is increasing due to a more globalized and consumerist society. Technological development requires greater consumption of minerals and raw materials whose exploitation also affects CC. But technology can also be an ally in combating CC [3–5]. Being able to predict when a catastrophe is going to occur and in which territory, analyze the terrain

J. J. Galán Hernández (✉) · G. Marín Díaz
Dpto. de S. Informáticos y Computación, Facultad de Estudios Estadísticos, Universidad.
Complutense de Madrid, 28040 Madrid, España
e-mail: josejgal@ucm.es

R. A. Carrasco González
Dpto. de Marketing, Facultad de Estudios Estadísticos, 28400 Madrid, España

to optimize planting, use drones in agriculture, intelligently redistribute resources based on algorithmic studies is just the beginning of what artificial intelligence (AI) can do when applied to CC.

The scientific community has realized the need to solve CC and has found in AI an ally to combat it.

This study first presents, in Chap. 2, a state of the art where several scientific studies that relate AI to CC can be seen, but no bibliometric study of the last 5 years has been found that relates it.

Then, a bibliometric study is presented, Chap. 3, with the main objective of demonstrating the constant and growing evolution of scientific interest, based on the number of scientific publications, on AI applied to CC. As a secondary objective, a network of emerging topics related to AI and applied to CC is visualized.

The methodology used and described in Sect. 3.1 consists of six stages: establishment of the objectives of the analysis, data extraction, data preprocessing, multi-dimensional analysis, network extraction, clustering and bibliometric visualization, overall results of the analysis.

13.2 Related Work

Before carrying out this work, a previous study of the scientific literature that made this type of review was carried out, for which a search was made in the Scopus database for reviews of the terms artificial intelligence and climate change in the last 5 years without finding results that addressed these terms in their breadth. But we did find articles, Table 13.1, that reviewed terms related to AI and CC as applied to different areas:

Given the lack of studies that review the scientific production of IA applied to CC, it was decided to carry out this bibliometric study that reviews its production in the last 5 years.

13.3 Bibliometric Study

Based on the need presented in Chap. 2, this chapter presents a novel bibliometric study that reflects the interest of the scientific community in AI applied to CC. First, the methodology used is presented, followed by a description of each stage of the study. This work has been supported by grant PID2022-139297OB-I00 funded by MCIN / AEI / 10.13039/501100011033 and by “ERDF A way of making Europe”.

Table 13.1 Review subcategories

Subject area	Documents [6–43]
Engineering	13
Environmental science	13
Computer science	11
Energy	8
Social sciences	8
Agricultural and biological sciences	7
Earth and planetary sciences	7
Materials science	4
Biochemistry, genetics and molecular biology	2
Chemical engineering	2
Chemistry	2
Economics, econometrics and finance	2
medicine	2
Physics and astronomy	2
Business, management and accounting	1
Mathematics	1
Multidisciplinary	1
Nursing	1

13.3.1 Methodology Used

A proprietary methodology is used in which data science techniques are employed in a bibliometric study, using the CRISP-DM methodology as a basis. The methodology used [44] consists of six stages, which are presented in Fig. 13.1. This chapter describes the methodology of the bibliometric study and each of its stages.

13.3.2 Set the Objectives of the Analysis

This chapter mainly determines the research topic, the years to be investigated and the source to be used. This study uses as a source the Scopus database, a widely accepted source of information in the scientific community [45]. The bibliometric study analyzes the scientific production on the relationship between artificial intelligence and climate change and will be studied in the last 5 years to analyze the growing scientific interest, the interest of each country in this type of scientific production and the main topics, as well as the related emerging areas through the visualization of the main cluster network.

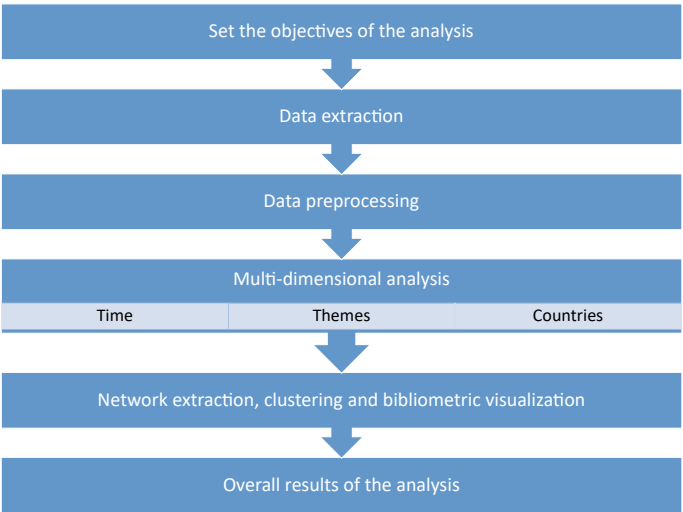


Fig. 13.1 Methodology for bibliometric study

13.3.3 Data Extraction

Once the objectives were established, the data were obtained. For this study, the Scopus data source was consulted, in which the terms “artificial intelligence” and “AI” were used at the same time as “climate change” or “climate emergency” in the query:

TITLE-ABS ((“artificial intelligence” OR “ai”) AND (“climate change” OR “climate emergency”)).

This consultation has been carried out in June 2023 limiting it to the period 2018–2022, both inclusive.

13.3.4 Data Preprocessing

From the results obtained in the extraction, we select those that are really related to the object of study. For this purpose, the VOSViewer tool is used [46], which allows to automate a co-occurrence analysis between words and to manually select the terms relevant to the study for the analysis.

13.3.5 Multi-Dimensional Analysis

On the preprocessed data, the dimensions time, countries, and topics are analyzed. First of all, it is worth noting the incredible increase in the number of scientific publications related to AI and CC in the last 5 years, Fig. 13.2. Number of documents in period 2018–2022. The 2018–2022 period began with an annual production of less than 100 articles, while in its final stage, it reached 400 articles. The pandemic suffered by COVID-19 and the climatological effects influence the collective consciousness [47] and warn about CC. It is clearly demonstrated that the global awareness of CC is received by the scientific community and attempts to solve it through the use of technology, specifically through AI.

In the period analyzed, the United States and China have led the scientific production related to AI and CC, while Spain and France are in last place as producers of content in this regard, although they also generate a remarkable volume, being among the top 10 producers, Fig. 13.3. Documents by country or territory.

It is interesting to see how the areas that mainly cover the application of AI on the CC are not only the classic engineering or computer science, Fig. 13.4. *Documents by subject area*, also the areas related to sustainability are beginning to be interested.

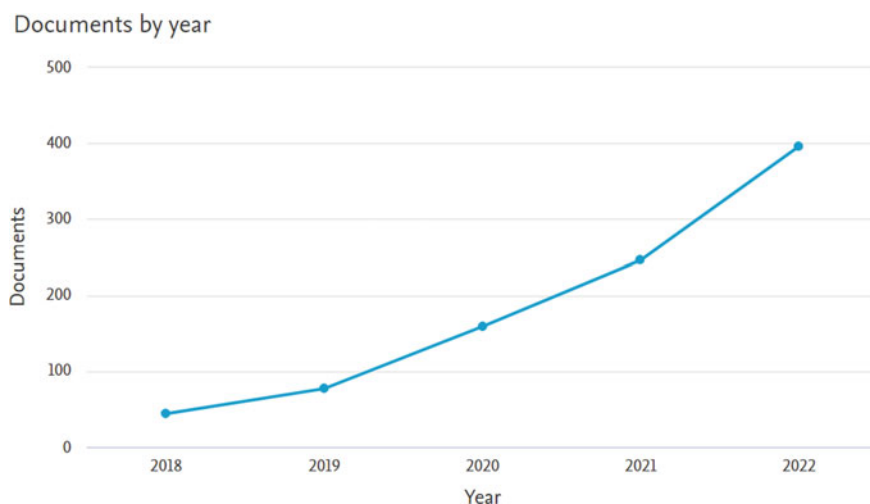


Fig. 13.2 Number of documents in period 2018–2022

Documents by country or territory

Compare the document counts for up to 15 countries/territories.

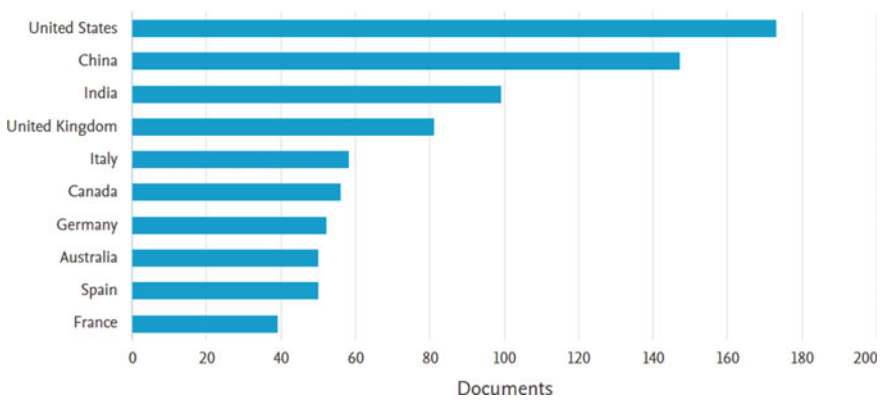


Fig. 13.3 Documents by country or territory

Documents by subject area

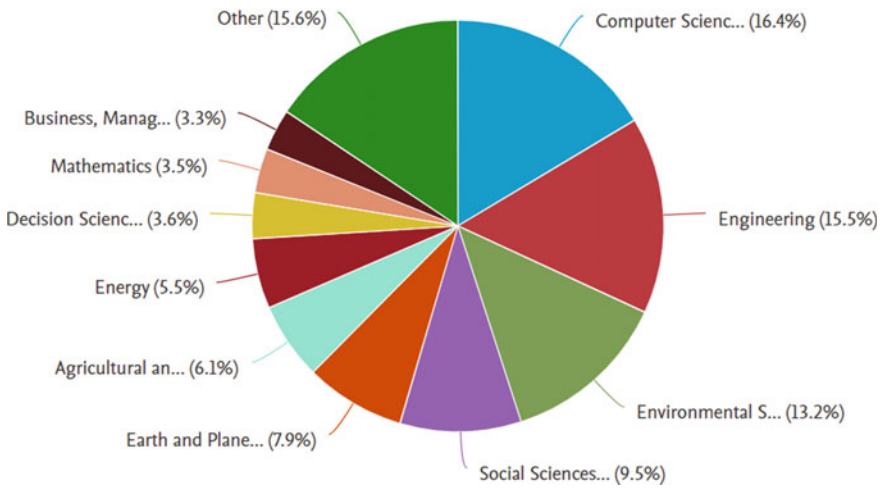


Fig. 13.4 Documents by subject area

13.3.6 Network Extraction, Clustering, and Bibliometric Visualization

Now that the main dimensions have been analyzed, using the VOSViewer tool, we obtain the main cluster that surrounds the main term Climate Change, with which the network is visualized, Fig. 13.5. Network extraction.

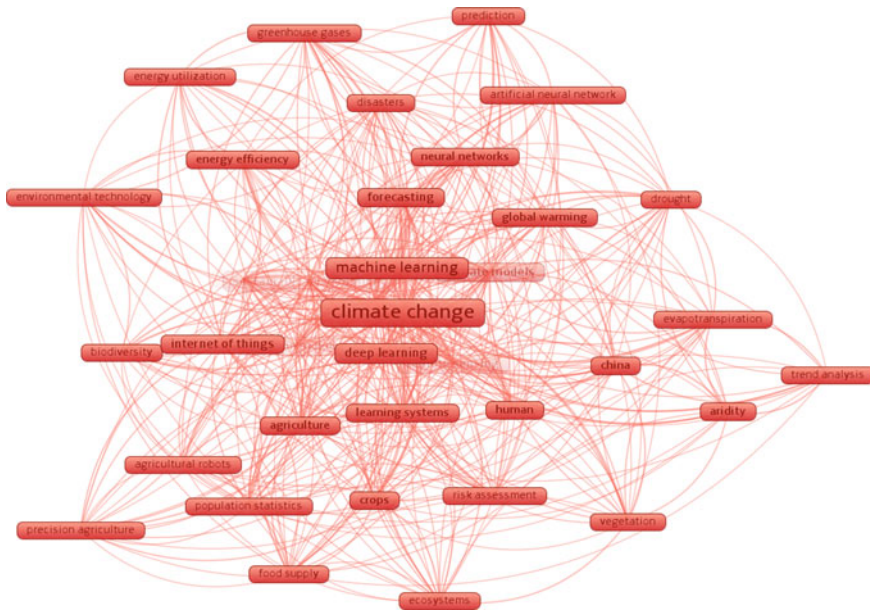


Fig. 13.5 Network extraction

This network is obtained from the bibliometric study, which clearly shows the emerging areas related to CC that are part of the AI environment, such as: machine learning, deep learning, internet of things, learning system, agricultural robots, or neural networks.

13.3.7 Overall Results of the Analysis

During the different stages of the methodology employed, the period 2018–2022 has been analyzed to evaluate the scientific interest on AI applied to CC. The following results stand out in this analysis:

- There is a constant and growing interest from the scientific community to investigate AI in relation to CC.
- The United States is leading this research.
- Countries that traditionally have a good climate, such as Spain and France, are emerging as countries interested in IA research with CC.
- Research on AI applied to CC goes beyond the area of knowledge of engineering and is a research to be considered in other disciplines such as sustainability.
- Emerging areas related to AI such as machine learning or neural network are emerging around CC.

13.4 Conclusions

The main conclusions of this study are as follows:

- There is a significant increase in the number of scientific publications related to Artificial Intelligence (AI) and Climate Change (CC) in the last 5 years, indicating a growing interest from the scientific community in investigating this area.
- The United States and China are the leaders in scientific production related to AI and CC, while Spain and France also generate a notable volume of content in this field.
- Research on the application of AI to CC extends beyond traditional engineering and computer science disciplines, encompassing other areas such as sustainability.
- Emerging areas related to AI in the context of CC are identified, including machine learning, deep learning, the Internet of Things, learning systems, agricultural robots, and neural networks.

In summary, this study demonstrates a growing interest from the scientific community in exploring the role of AI in addressing Climate Change. It highlights a global awareness of CC and an effort to leverage AI technology to tackle this challenge. The results also emphasize the importance of international collaboration in research and the need to approach CC from multiple disciplines.

References

1. Sivonen, J.: Attitudes toward global and national climate policies in Finland—the significance of climate change risk perception and urban/rural-domicile. *GeoJournal* **88**(2), 2247–2262 (2023)
2. Van Baal, K., Stiel, S., Schulte, P.: Public perceptions of climate change and Health—a cross-sectional survey study. *Int. J. Environ. Res. Public Health* **20**(2) (2023)
3. Alexandridis, N., Feit, B., Kihara, J., Luttermoser, T. et al.: Climate change and ecological intensification of agriculture in sub-saharan Africa—a systems approach to predict maize yield under push-pull technology. *Agric. Ecosyst. Environ.*, 352 (2023)
4. Kim, G.: Development of groundwater utilization technology to solve drought problems in the era of climate change. *J. Geol. Soc. Korea* **59**(1), 1–2 (2023)
5. Zagrebelnaya, N.S., Sheveleva, A.V.: Applying digital technology to combat climate change in Russia and the EU. In: *Current Problems of the Global Environmental Economy Under the Conditions of Climate Change and the Perspectives of Sustainable Development*, pp. 143–154. Springer, Cham (2023)
6. Ahmed, M., Hayat, R., Ahmad, M., et al.: Impact of climate change on dryland agricultural systems: a review of current status, potentials, and further work need. *Int. J. Plant Prod.* **16**(3), 341–363 (2022)
7. Aminifar, F., Abedini, M., Amraee, T., Jafarian, P., et al.: A review of power system protection and asset management with machine learning techniques. *Energy Syst.* **13**(4), 855–892 (2022)
8. Arriola, I.C.M., Santana-Cárdenas, S., Uriarte, P.J.L., Magaña-González, C.R.: Food insecurity and food vulnerability in communities: a systematic review. *Revista Espanola de Nutrición Comunitaria* **28**(1), 133–143 (2022)
9. Badejo, O., Skaldina, O., Gilev, A., Sorvari, J.: Benefits of insect colours: a review from social insect studies. *Oecologia* **194**(1–2), 27–40 (2020)

10. Balogun, A., Tella, A., Baloo, L., Adebisi, N.: A review of the inter-correlation of climate change, air pollution and urban sustainability using novel machine learning algorithms and spatial information science. *Urban Climate*, 40 (2021)
11. Bertoglio, R., Corbo, C., Renga, F.M., Matteucci, M.: The digital agricultural revolution: a bibliometric analysis literature review. *IEEE Access* **9**, 134762–134782 (2021)
12. Bhaga, T.D., Dube, T., Shekede, M.D., Shoko, C.: Impacts of climate variability and drought on surface water resources in sub-saharan Africa using remote sensing: a review. *Remote Sensing* **12**(24), 1–34 (2020)
13. Bikomeye, J.C., Balza, J.S., Kwarteng, J.L., Beyer, A.M., Beyer, K.M.M.: The impact of greenspace or nature-based interventions on cardiovascular health or cancer-related outcomes: a systematic review of experimental studies. *PLoS ONE*, 17 (2022)
14. Chatterjee, J., Dethlefs, N.: Scientometric review of artificial intelligence for operations & maintenance of wind turbines: the past, present and future. *Renew. Sustain. Energy Rev.*, 144 (2021)
15. Chiloane, C., Dube, T., Shoko, C.: Impacts of groundwater and climate variability on terrestrial groundwater dependent ecosystems: a review of geospatial assessment approaches and challenges and possible future research directions. *Geocarto Int.* **37**(23), 6755–6779 (2022)
16. Dayioğlu, M.A., Türker, U.: Digital transformation for sustainable future-agriculture 4.0: a review. *Tarım Bilimleri Dergisi* **27**(4), 373–399 (2021)
17. Debrah, C., Chan, A.P.C., Darko, A.: Green finance gap in green buildings: A scoping review and future research needs. *Build. Environ.*, 207 (2022)
18. Dwivedi, K.A., Huang, S., Wang, C.: Integration of various technology-based approaches for enhancing the performance of microbial fuel cell technology: a review. *Chemosphere*, 287 (2022)
19. Hamitouche, M., Molina, J.: A review of AI methods for the prediction of high-flow extremal hydrology. *Water Resour. Manage* **36**(10), 3859–3876 (2022)
20. Ibrahim, K.S.M.H., Huang, Y.F., Ahmed, A.N., Koo, C.H., El-Shafie, A.: A review of the hybrid artificial intelligence and optimization modelling of hydrological streamflow forecasting. *Alex. Eng. J.* **61**(1), 279–303 (2022)
21. Jain, P., Coogan, S.C.P., Subramanian, S.G., Crowley, M., Taylor, S., Flannigan, M.D.: A review of machine learning applications in wildfire science and management. *Environ. Rev.* **28**(4), 478–505 (2020)
22. Kaginalkar, A., Kumar, S., Gargava, P., Niyogi, D.: Review of urban computing in air quality management as smart city service: an integrated IoT, AI, and cloud technology perspective. *Urban Climate*, 39 (2021)
23. Karyono, K., Abdullah, B.M., Cotgrave, A.J., Bras, A.: The adaptive thermal comfort review from the 1920s, the present, and the future. *Develop. Built Environ.*, 4 (2020)
24. Kong, L., Wang, L., Li, F., Guo, J.: Toward product green design of modeling, assessment, optimization, and tools: a comprehensive review. *Int. J. Adv. Manuf. Technol.* **122**(5–6), 2217–2234 (2022)
25. Masoudi Soltani, S., Lahiri, A., Bahzad, H., Clough, P., Gorbounov, M., Yan, Y.: Sorption-enhanced steam methane reforming for combined CO₂ capture and hydrogen production: a state-of-the-art review. *Carbon Capture Sci. Technol.*, 1 (2021)
26. Phy, S.R., Sok, T., Try, S., Chan, R., Uk, S., Hen, C., Oeurng, C.: Flood hazard and management in Xambodia: A review of activities, knowledge gaps, and research direction. *Climate* **10**(11) (2022)
27. Polymeni, S., Athanasakis, E., Spanos, G., Votis, K. & Tzovaras, D.: IoT-based prediction models in the environmental context: a systematic literature review. *Internet of Things*, 20 (2022)
28. Roslim, M.H.M., Juraimi, A.S., Che'ya, N.N., Sulaiman, N., Manaf, M.N.H.A., Ramli, Z. & Motmainna, M.: Using remote sensing and an unmanned aerial system for weed management in agricultural crops: a review. *Agronomy* **11**(9) (2021)
29. Sapienza, M., Nurchis, M.C., Riccardi, M.T., Bouland, C., Jevtić, M., Damiani, G.: The adoption of digital technologies and artificial intelligence in urban health: a scoping review. *Sustainability* **14**(12) (2022)

30. Shah, A., Shah, K., Shah, C., Shah, M.: State of charge, remaining useful life and knee point estimation based on artificial intelligence and machine learning in lithium-ion EV batteries: a comprehensive review. *Renew. Energy Focus* **42**, 146–164 (2022)
31. Sharif, M.Z., Di, N., Liu, F.: Monitoring honeybees (*apis* spp.) (hymenoptera: Apidae) in climate-smart agriculture: a review. *Appl. Entomol. Zoology* **57**(4), 289–303 (2022)
32. Subramaniam, S., Raju, N., Ganesan, A. et al.: Artificial intelligence technologies for forecasting air pollution and human health: a narrative review. *Sustainability* **14**(16) (2022)
33. Tardaguila, J., Stoll, M., Gutiérrez, S., Proffitt, T., Diago, M.P.: Smart applications and digital technologies in viticulture: a review. *Smart Agric. Technol.*, 1 (2021)
34. Vidas, L., Castro, R.: Recent developments on hydrogen production technologies: State-of-the-art review with a focus on green-electrolysis. *Appl. Sci.* **11**(23) (2021)
35. Waltersmann, L., Kiemel, S., Stuhlsatz, J., Sauer, A., Miehe, R.: Artificial intelligence applications for increasing resource efficiency in manufacturing companies—a comprehensive review. *Sustainability* **13**(12) (2021)
36. Wang, D., Cao, W., Zhang, F., Li, Z., Xu, S., Wu, X.: A review of deep learning in multiscale agricultural sensing. *Remote Sens.* **14**(3) (2022)
37. Wong, W.Y., Al-Ani, A.K.I., Hasikin, K., et al.: Water, soil and air pollutants' interaction on mangrove ecosystem and corresponding artificial intelligence techniques used in decision support systems—a review. *IEEE Access* **9**, 105532–105563 (2021)
38. Yang, L., Driscoll, J., Sarigai, S., Wu, Q., Chen, H. & Lippitt, C. D.: Google earth engine and artificial intelligence (AI): a comprehensive review. *Remote Sens.* **14**(14) (2022)
39. Yang, L., Driscoll, J., Sarigai, S., Wu, Q., Lippitt, C.D., Morgan, M.: Towards synoptic water monitoring systems: a review of AI methods for automating water body detection and water quality monitoring using remote sensing. *Sensors* **22**(6) (2022)
40. Zalnezhad, A., Rahman, A., Nasiri, N. et al.: Artificial intelligence-based regional flood frequency analysis methods: a scoping review. *Water* **14**(17) (2022)
41. Zhang, H., Xu, Y., Kanyerere, T.: A review of the managed aquifer recharge: Historical development, current situation and perspectives. *Phys. Chem. Earth*, 118–119 (2020)
42. Zhao, L., Nazir, M.S., Nazir, H.M.J., Abdalla, A.N.: A review on proliferation of artificial intelligence in wind energy forecasting and instrumentation management. *Environ. Sci. Pollut. Res.* **29**(29), 43690–43709 (2022)
43. Zhao, X., Kim, J., Warns, K. et al.: Prognostics and health management in nuclear power plants: an updated method-centric review with special focus on data-driven methods. *Frontiers Energy Res.*, 9 (2021)
44. Galán, J.J., Carrasco, R.A., LaTorre, A.: Military applications of machine learning: a bibliometric perspective. *Mathematics* **10**, 1397 (2022)
45. Kashi, A., Shah, M.E.: Bibliometric review on sustainable finance. *Sustainability* **15**(9) (2023)
46. Owolabi, T.A., Sajjad, M.: A global outlook on multi-hazard risk analysis: a systematic and scientometric review. *Int. J. Disaster Risk Reduct.* **92** (2023)
47. Vo, T.P.T., Ngo, H.H., Guo, W. et al.: Influence of the COVID-19 pandemic on climate change summit negotiations from the climate governance perspective. *Sci. Total Environ.* **878** (2023)