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Artificial intelligence and machine learning in production efficiency enhancement and sustainable development: a comprehensive bibliometric review

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This research presents a comprehensive bibliometric review of the role of Artificial Intelligence (AI) and Machine Learning (ML) in enhancing production efficiency and fostering sustainable development. With the increasing focus on sustainability, AI and ML technologies have emerged as pivotal tools for optimizing industrial processes, improving resource management and minimizing environmental impacts. The study analyzes key ML algorithms in various production settings. This study conducts systematic bibliometric analysis using the Scopus database and Bibliometrix R package, examining global trends, key collaborations, and thematic focuses on AI and ML applications in production efficiency and sustainable development. Novel contributions include uncovering underexplored ethical dimensions of AI adoption and emphasizing the pivotal role of SMEs and developing economies in advancing sustainable practices. Key research trends identified include the integration of AI with sustainable energy management, circular economy practices, and precision agriculture. Furthermore, the analysis reveals geographical contributions, with countries like China, the United States, and the United Kingdom leading in research output and impact. Despite the promising advancements, the review identifies gaps in ethical considerations, especially in data privacy and labor market implications, and suggests avenues for future research, including the implementation of AI and ML in developing economies and Small and Medium Enterprises (SMEs).

KEYWORDS

artificial intelligence, machine learning, bibliometrics, sustainable development, production efficiency

Introduction

Artificial Intelligence (AI) and Machine Learning (ML) technologies have become deeply embedded in our daily lives, transforming various industries, particularly in their influence on production processes. Despite the increasing integration of AI and ML in industrial settings, a significant gap exists in understanding their implications for small and medium-sized enterprises (SMEs) and developing economies. Furthermore, ethical challenges, particularly in data privacy and labor market disruptions, remain underexplored. This study's primary research question and purpose is to assess how AI and ML technologies can contribute to production efficiency and promote sustainable development and what gaps exist in their application, particularly in SMEs and developing countries.

To clarify the distinction between AI and ML, the former is a subset of computer science that is dedicated to developing systems, capable of performing tasks that would traditionally require human intelligence, such as visual perception, decision-making and problem-solving (Russell and Norvig, 2021). Contrarily, ML is a specialized area within AI that focuses on creating algorithms that enable computers to learn from data and enhances their performance autonomously without being explicitly programmed (Jordan and Mitchell, 2015).

Recent advancements in computational power and big data technologies have created fertile ground for the rapid development of AI and ML, making them increasingly applicable to production systems (Bitzenis and Koutsoupias, 2024). Moreover, based on specific attributes and desired outcomes, ML algorithms are typically classified into four main categories: supervised, unsupervised, semi-supervised, and reinforcement learning. Each of these categories offers unique applications within industrial processes, tailored to the nature of the tasks they address.

The first category, supervised learning, is one of the most widely used ML algorithms in the industrial settings. In this method, the algorithm is trained on labeled data where the desired output is already known hence the main task is to predict the correct outcome based on the input data. For instance, one application of this algorithm can be observed in predictive maintenance. In this case, the model is trained in historical data containing instances of equipment failure (outputs) and corresponding sensor readings (inputs). This allows the model to predict potential machine failures using real-time sensor data, enabling maintenance to be performed prior to an actual breakdown (Mawson and Hughes, 2019).

Opposite to supervised learning, unsupervised learning's primary focus is to recognize patterns and relationships within the data, as its training relies on unlabeled datasets, meaning that there are no predefined outputs to guide the learning process. Specifically in production efficiency, these algorithms are often used for their clustering techniques to identify patterns in machine performance and customer behavior or for anomaly detection to spot outliers in the data, such as unusual sensor readings that may indicate equipment malfunctions (Murphy, 2022). In addition to these techniques, semi-supervised learning combines a small amount of labeled data with a large volume of unlabeled data for model training. This approach can be beneficial in situations where acquiring labeled data is either time-consuming or costly or when only a few examples are available in a specific domain. On such occasions, a small and labeled sample can be effectively utilized alongside extensive unlabeled sensor data to enhance the model's predictive capabilities.

Lastly, in reinforcement learning, algorithms acquire knowledge by interacting with the environment and by receiving feedback in the form of rewards or penalties, thus enabling them to adjust their strategies and further enhance their overall performance (Sutton and Barto, 2018). Consequently, the primary objective of these algorithms is to maximize cumulative rewards over time, and they are frequently used to optimize processes, such as fine-tuning machine settings on a production line, to achieve optimal speed and energy efficiency while minimizing waste.

AI and ML technologies have emerged to become essential for optimizing production processes and fostering sustainable development. AI's contribution to supply chain optimization via fostering demand and streamlining inventory management, help reduce overstocking, waste and inefficiencies (Kelly, 2024). Other applications may include logistics improvements through enhanced routing and scheduling which lead to lower operational costs and reduced carbon emissions. Additionally, AI-powered robotic automation can enhance precision and speed on production lines hence contributing to resource efficiency and minimizing operational waste.

Moreover, the contribution of AI and ML to promoting sustainable development is crucial, particularly through optimizing energy usage in production processes. AI-based energy management systems can dynamically adjust power consumption to match real-time demands, thereby reducing energy waste, operational costs (Rane et al., 2024), and the carbon footprint of industrial activities. Furthermore, in the context of a circular economy, AI can be utilized in sustainable product design for eco-friendly production methods and material choices, as well as in identifying opportunities for material reuse and recycling, thereby minimizing raw material consumption and production waste (Sulich et al., 2023).

By leveraging advanced algorithms and real-time data, businesses can improve their operational performance while in the meantime aligning with the global sustainability goals. As industries continue to adopt AI and ML technologies, they are paving the way for a more resilient and eco-friendly future where resource utilization is maximized, waste is minimized and environmental stewardship is prioritized (Wang et al., 2023), signifying a major leap forward in the pursuit of a sustainable and efficient industrial environment. Future exploration of these technologies will be essential in unlocking further opportunities for improvement, ensuring that advancements in production not only contribute to economic growth but also support a sustainable future.

Ultimately, to provide a structured overview of the study, the article's structure is the following: section 1 is the Introduction, section 2 outlines the Methodology, section 3 discusses the results of the analysis and section 4 presents the conclusions, including insights into existing research gaps and directions for future endeavors.

Methodology

The choice of the Scopus database for our bibliometric analysis was driven by its comprehensive coverage of peer-reviewed literature across diverse disciplines, making it a valuable resource for our research. Scopus is renowned for its robust indexing of high-quality journals and conference proceedings, ensuring that our analysis incorporates a wide range of relevant publications in fields such as economics, business, social sciences, environmental sciences, and computer science. In addition to that, Scopus offers advanced search functionalities and analytical tools that facilitate the efficient retrieval of pertinent publications based on specified criteria (Pranckutė, 2021).

Building on this study's primary research question, which examines the role of AI and ML technologies in enhancing production efficiency and fostering sustainable development, the methodology was systematically structured to identify and critically analyze gaps in their application, particularly within the contexts of SMEs and developing economies. This central question served as the foundation for the selection of keywords, the formulation of inclusion and exclusion criteria, and the overall analytical framework.

Furthermore, and for the needs of this analysis, we adhered to PRISMA (2020) guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) for the effective management and reporting of manuscripts as shown in Figure 1 (Haddaway et al., 2022).

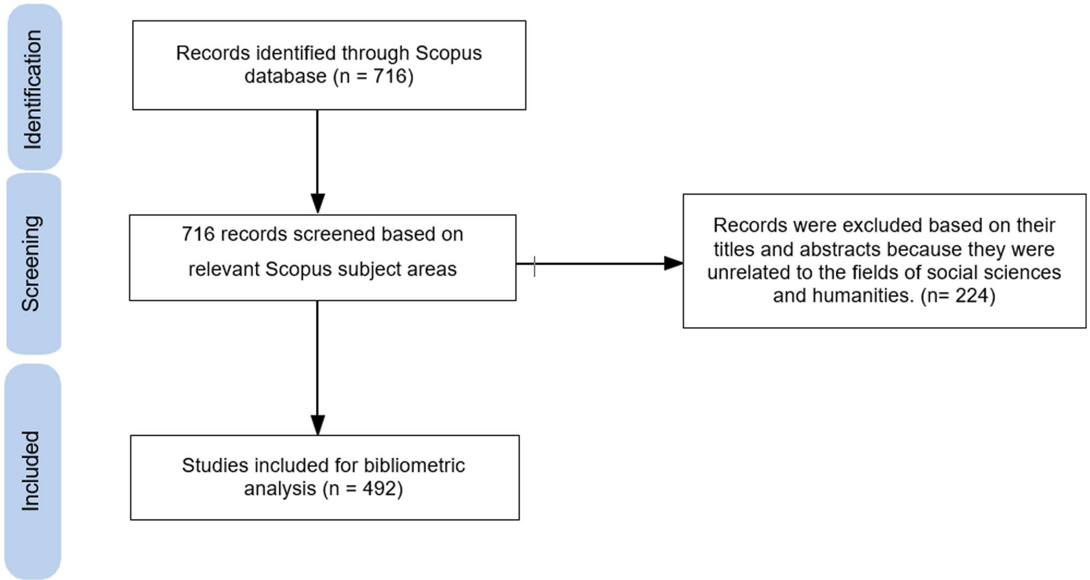

FIGURE 1
The PRISMA 2020 statement.

In this study, set of targeted search terms relevant to the research domain was utilized ("sustainable development," "machine learning," "artificial intelligence," "production efficiency" etc.), focusing on their occurrence in titles, abstracts and author keywords. The search was conducted across the fields of economics, business, social sciences, decision sciences, environmental sciences and computer science. The complete query that was used to construct the dataset is the following:

TITLE-ABS-KEY (("artificial intelligence" OR "AI" OR "machine learning" OR "ML" OR "AI applications" OR "ML applications") AND ("production efficiency" OR "manufacturing efficiency" OR "productivity" OR "process optimization") AND ("sustainable development" OR "economic sustainability" OR "sustainable growth")) AND (LIMIT-TO (SUBJAREA, "ECON") OR LIMIT-TO (SUBJAREA, "BUSI") OR LIMIT-TO (SUBJAREA, "SOCI") OR LIMIT-TO (SUBJAREA, "DECI") OR LIMIT-TO (SUBJAREA, "ENVI") OR LIMIT-TO (SUBJAREA, "COMP")) AND (LIMIT-TO (LANGUAGE, "English")).

Following data extraction, a bibliometric analysis was conducted with the Bibliometrix R package to assess and analyze literature, using statistical techniques to measure the impact, development, and trends within the research topic. Bibliometrics, which involves the quantitative analysis of academic publications to measure their impact and detect patterns in scholarly communication, is widely applied in fields such as education (Oraiopoulou et al., 2024), business and economics (Thomos et al., 2023; Bitzenis et al., 2023), health sciences (Van Nunen et al., 2017) etc., and was used to evaluate key indicators in this analysis. These include descriptive indicators, such as the number of publications, the annual growth rate of scientific production, and average citations, to provide an overview of research activity. The citation analysis sought to identify influential works, while co-authorship analysis explored collaboration patterns among researchers and institutions. Finally, a keyword co-occurrence analysis was performed to uncover key research themes, and the geographical distribution of research outputs was assessed to highlight global contributions (Donthu et al., 2021).

Results

In this section, the key findings of the study are presented, accompanied by comprehensive visual representations, including graphs and tables. These visualizations provide insights into the relationships between various concepts and reveal patterns that shed light on the broader themes within the dataset. The analysis highlights significant associations between specific terms and their underlying meanings, offering a deeper understanding of the textual data and its thematic structure.

Figure 2 shows the annual scientific publications over the years from 2000 to 2024. The data indicate a steady increase in the annual number of scientific publications with a sharp rise in recent years. From 2000 to 2018, the growth is relatively slow and stable, with a nearly flat trend, indicating limited research output during this period suggesting that research on the application of AI and ML in production efficiency and sustainable development was either in its early stages or not yet a major area of focus within the academic community. A discernible shift occurs in 2019, marked by a gradual increase in the volume of publications. This shift coincides with a growing recognition of AI/ML technologies as pivotal tools for addressing critical challenges in production and sustainability. The upward trend accelerates significantly post-2020, with the data reflecting an exponential surge in scientific publications. This marked increase is particularly prominent from 2021 to 2024, signaling an intensified research interest in this field.

As shown in Table 1, the dataset spans the period from 2000 to 2024, encompassing a total of 291 sources and 492 documents. The field exhibits a notable annual growth rate of 24.24% in scientific production, reflecting a consistent upward trend in research activity

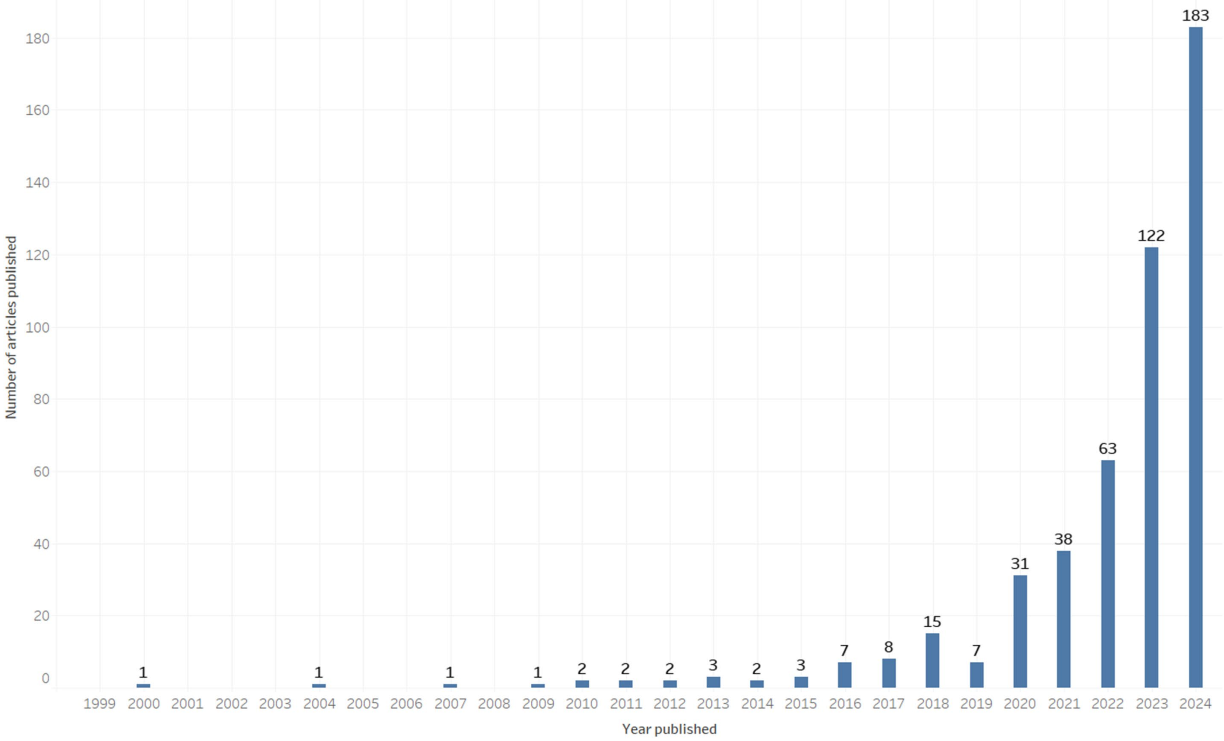

FIGURE 2
Annual scientific publications.

TABLE 1 Descriptive results.

Description	Results
Timespan	2000:2024
Sources (journals, books, etc.)	291
Documents	492
Annual growth rate %	24.24
Document average age	1.95
Average citations per doc	11.51
References	26,378
Keywords plus (ID)	4,945
Author's keywords (DE)	1,692
Authors	1905
Authors of single-authored docs	35
Single-authored docs	40
Co-authors per doc	4.27
International co-authorships %	24.59
Article	235
Book	3
Book chapter	26
Conference paper	165
Conference review	6
Letter	1
Review	55
Short survey	1

and the importance of AI and ML in sustainable production and environmental practices. Furthermore, approximately 24.59% of these publications involve international co-authorship, emphasizing the collaborative nature of research within this field. The relatively low average document age of 1.95 years suggests that this is an evolving field with much of the research being recent and potentially reflective of the growing interest in AI-driven solutions for sustainability. Each document, on average, has been cited 11.51 times, indicating a moderate level of engagement with the work published in this discipline (Table 1).

In this figure, the most relevant keywords used in research papers are presented, providing insights into the thematic focus of literature. The most frequently occurring term is "sustainable development" with 396 occurrences, confirming that the primary objective of AI and ML research in this context is to drive sustainability in production and industrial processes. Following closely is "machine learning" and "artificial intelligence" which appear 238 and 164 times, respectively. This reflects the technological backbone of the research, with AI and ML technologies at the core of strategies aimed at improving production efficiency. Also, the keyword "decision making" with 70 occurrences, further suggests that these technologies are being applied to enhance decision-making processes in production systems, which is crucial for optimizing resourcing and minimizing waste. Other terms such as "crops," "Internet of Things" (IoT) and "productivity," show that AI and ML applications in agriculture and IoT integration are significant subthemes in this research field, focusing on boosting productivity while adhering to sustainability principles. Finally, the presence of "China" as a relevant keyword, reflect the country's prominence in both the research and application of AI and ML technologies in this domain (Figure 3).

Figure 4 is a word cloud and serves as a valuable supplement to Figure 3, offering alternative visualization of term frequency within the dataset. While both visuals highlight the most frequently occurring terms, the word cloud extends the analysis by including additional terms that are not explicitly ranked in Figure 3 (e.g., "biomass," "deep learning," "optimization), providing deeper insights into the broader thematic landscape, showcasing the diverse subtopics present within the dataset.

Figure 5 represents a temporal analysis of the most frequent occurring terms in the dataset, offering insights into the evolution of research focus over time. The horizontal lines indicate the span of years during which each term has been prominent in the literature, the size of the bubbles represent the term frequency and the location of the bubble the time in which the term appeared most. Key terms such as "sustainable development," "machine learning," and "artificial intelligence" have maintained consistent relevance over an extended period, reflecting the sustained interest in these areas. The larger bubble sizes associated with these terms suggest their dominance in the field, with frequencies nearing or exceeding 300 occurrences.

Other terms such as "crops," "farms" and "environmental impact," have gained traction more recently, revealing a growing interest in their application within sustainability and agriculture contexts. Similarly, terms like "productivity," "process optimization" and "decision support systems," highlight the practical and solutions-oriented nature of recent research, particularly as these topics have gained attention in the past few years. Also, the presence of terms like "natural language processing systems" and "biogas," suggests emerging research directions that are gaining momentum but remain less frequent in comparison to dominant topics. This temporal distribution helps track the evolving priorities and trends in AI, ML and sustainability, demonstrating how some concepts have matured over time while others are still developing.

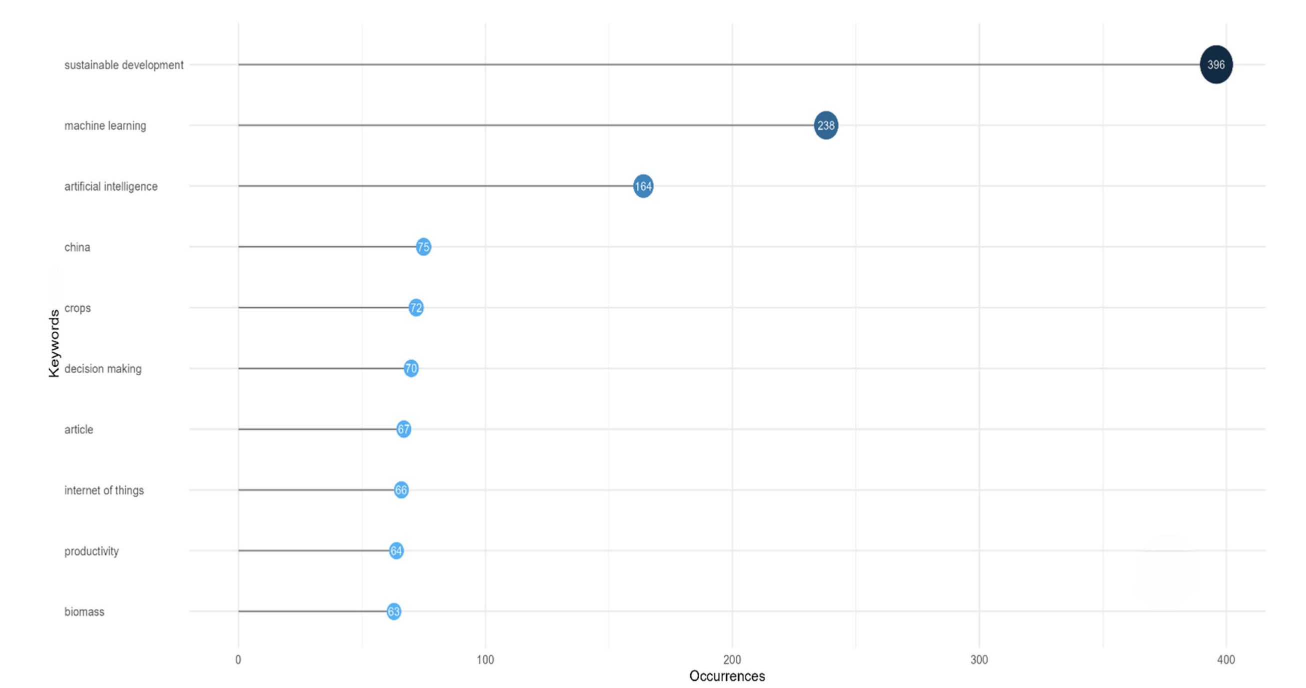

FIGURE 3
Most relevant words.

FIGURE 4
Wordcloud.

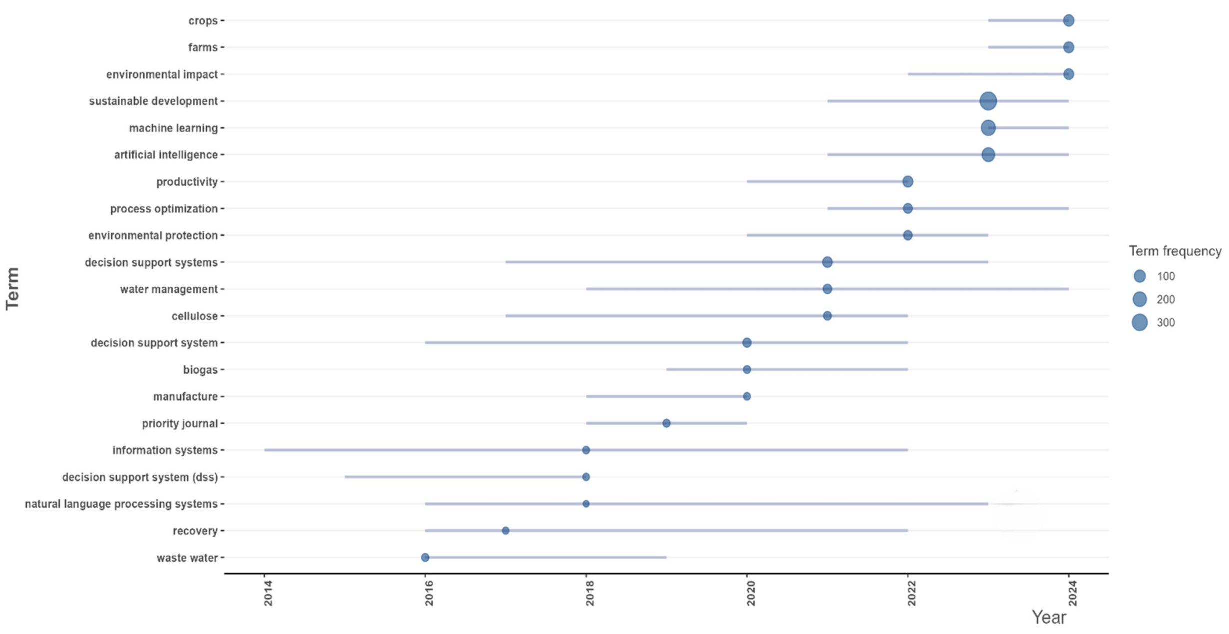

FIGURE 5
Trending themes.

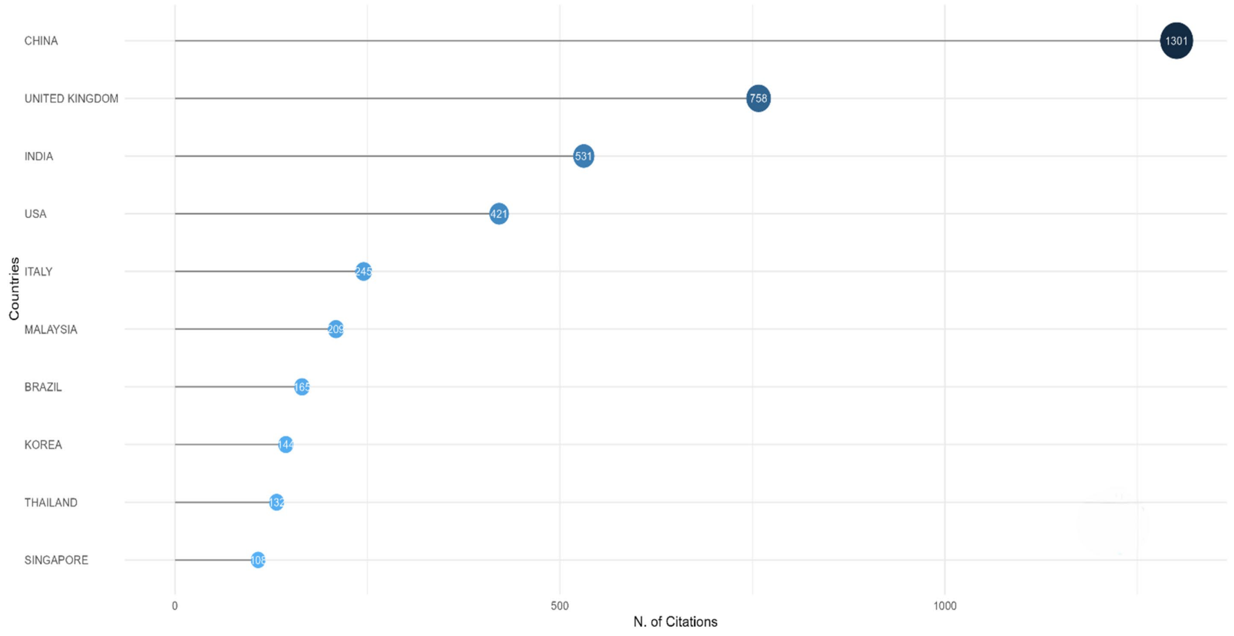

FIGURE 6
Most cited countries.

Figure 6 highlights the countries that have made the most impactful contributions to research on AI and ML for production efficiency and sustainable development, as measured by the total number of citations. The results reveal that China emerges as the predominant leader, with 1,301 citations, indicating a substantial influence on the intellectual discourse surrounding this topic. However, when examining the average citations per article, the United Kingdom emerges as the most influential with 58.30 citations per article, followed by Singapore (54) and USA (23.40) suggesting that although countries like China and India produce a high volume of research, countries such as the UK and Singapore produce more impactful studies (Table 2). This is followed by the United Kingdom with 758 citations, India with 531 citations and the United States with 421 citations. These figures highlight the substantial academic contributions from both established research hubs and emerging research economies. The prominence of Asian countries (Figure 6)

TABLE 2 Most cited countries.

Country	Total citations	Average article citations
China	1,301	13.60
United Kingdom	758	58.30
India	531	6.50
USA	421	23.40
Italy	245	17.50
Malaysia	209	16.10
Brazil	165	20.60
Korea	144	24.00
Thailand	132	26.40
Singapore	108	54.00

suggests that the region is at the forefront of integrating AI and ML technologies to address the dual challenges of production efficiency and promoting sustainability. These findings also suggest that AI and ML research is not confined to a specific region but has garnered significant attention across the globe.

Figure 7 illustrates a co-occurrence network, mapping out the relationships between key terms associated with the research topic. The connections between the terms reflect their frequency of appearance in the same documents, suggesting shared research contexts or themes. The central and the largest node is "Sustainable Development," signifying its critical role within the research landscape. This is further reinforced by its connections to a multitude of terms, including "Artificial Intelligence (AI)," "climate change," "carbon dioxide," and "economic development," demonstrating the centrality of sustainable development in addressing global environmental and economic challenges, with AI increasingly being recognized as a vital tool in these efforts. Also, the significant node for "Artificial Intelligence (AI)," which is closely linked to "Sustainable Development," emphasized the growing integration of AI in various sustainability-related fields.

Another major node, depicted in blue, is "Machine Learning" highlighting its emerging significance in sustainability research. The dense web of connections surrounding this node points to ML pivotal role in applications like "precision agriculture," "crop yield," "energy efficiency," and "data analytics." These terms illustrate how ML is being used to improve efficiency in sectors like agriculture and energy, which are central to sustainable development. Finally, the two major clusters relate to a network of gray lines, visualizing the increasingly interdisciplinary nature of research that merges AI and ML with sustainability efforts (Figure 7).

Table 3 presents the most cited publications within the dataset. For the purposes of this analysis, we will consider only the first four publications with an average of more than 30 citations per year, ensuring that our evaluation centers on the most impactful and widely recognized contributions to the field. Notably, leading this list is Sharma et al. (2022), published in Computers and Operations Research, with a total of 427 citations and an average of 85.40 citations per year. Sharma's research focuses on AI-driven optimization in manufacturing processes, particularly predictive maintenance and supply chain management. His work has significantly contributed to economic sustainability by demonstrating how AI can improve production efficiency, reduce costs, and optimize resource allocation, making it a crucial reference for AI and ML applications in industrial efficiency (Sharma et al., 2020). Other highly cited works include Li et al. (2021), with 99 citations, published in the Chemical Engineering Journal and contributing to environmental sustainability using AI in energy-intensive chemical engineering processes. Li's research explores AI's role in reducing energy consumption and optimizing carbon emissions management, which is vital for industries aiming to meet sustainability goals. His study is especially relevant to energy efficiency and resource optimization, critical aspects of sustainable

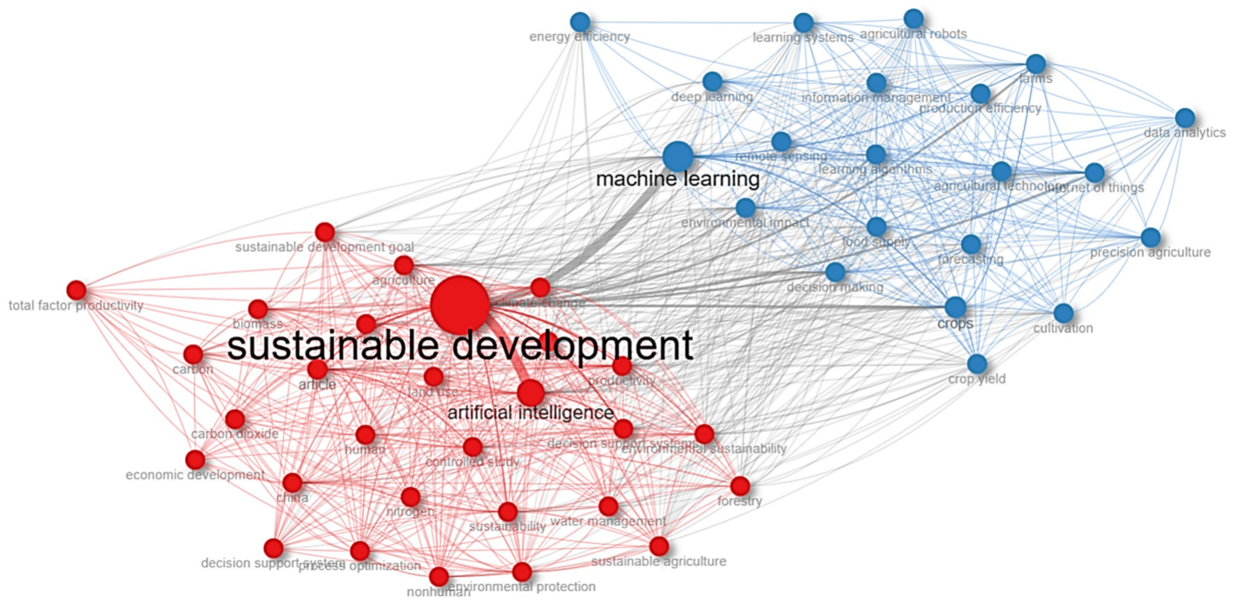

FIGURE 7
Co-occurrence network.

industrial practices (Li et al., 2021). In addition to the above, other notable works are Li et al. (2022), with 97 citations, published in Technological Forecasting and Social Change, addresses the integration of AI and automation in supply chain management, Hughes et al. (2020), with 95 citations, examining AI's role in production planning and control. These studies have significantly shaped the field of AI and ML applications in sustainable development, contributing to economic, environmental and social sustainability.

Figure 8 is a thematic map which provides an insightful visualization of the conceptual structure within the research domain of AI and ML in production efficiency enhancement and sustainable development. The map categorizes research themes into four quadrants based on their density (development degree) and centrality (relevance degree). Motor themes (upper-right quadrant) are well-developed and highly significant to the field, indicating their centrality in driving research and applications. Niche themes (upper-left quadrant) are specialized and well-developed but less critical to the core research agenda. Basic themes (lower-right quadrant) are fundamental to the domain, with high relevance but limited development. Lastly, emerging or declining themes (lower-left

TABLE 3 Most cited publications.

Paper	Total citations	Total citations per year
Sharma et al. (2020), Comp Oper Res	427	85.40
Li et al. (2021), Chem Eng J	99	24.75
Li et al. (2022), Technol Soc	97	32.33
Hughes et al. (2020), Prod Plann Control	95	31.67
De Lucia et al. (2020), Sustainability	95	19.00
Li et al. (2020), Int J Prod Res	91	18.20
Alahi et al. (2023), SENSORS	90	45.00
Sharma et al. (2018), Neural Netw	88	12.57
Da Silva et al. (2020), Comput Ind Eng	88	17.60
Sharma et al. (2022), Comput Electron Agric	82	27.33

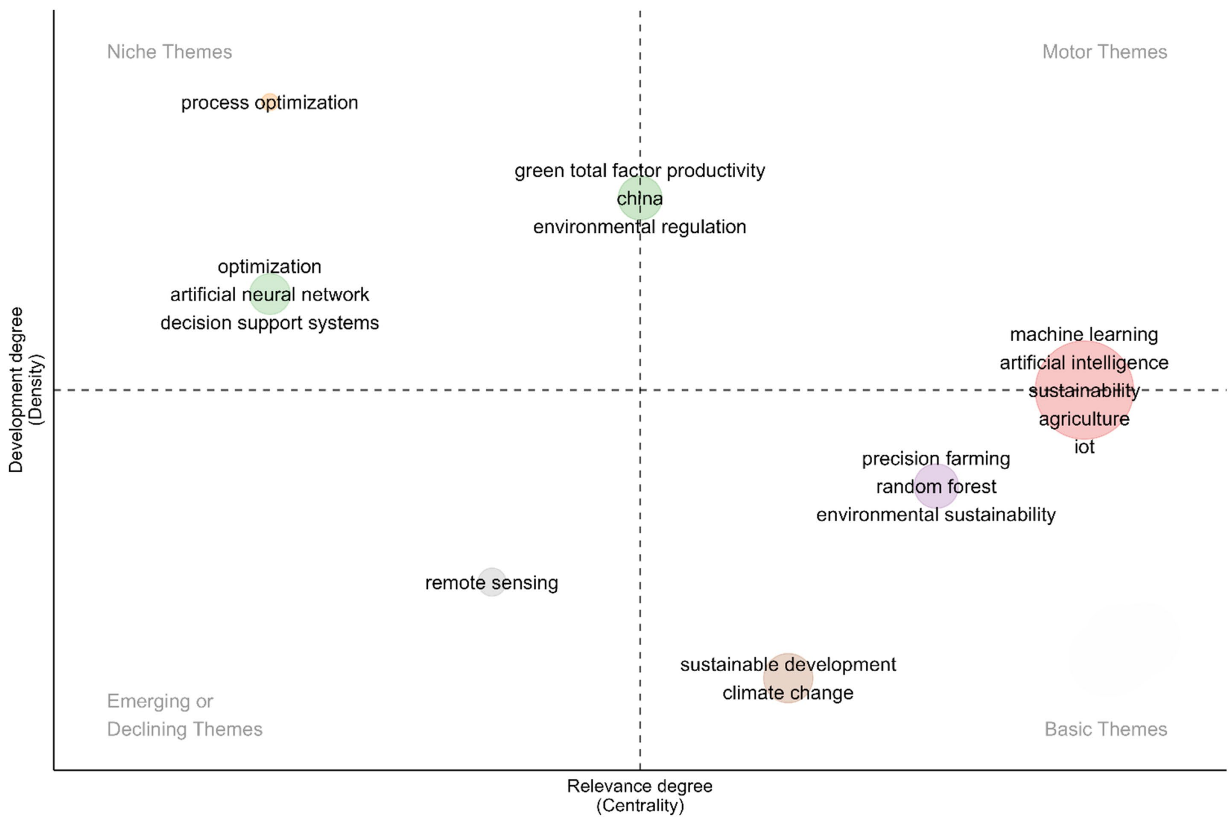

FIGURE 8
Thematic map.

quadrant) represent areas with low centrality and density, signifying either nascent or diminishing relevance within the research landscape (Agbo et al., 2021).

As seen in Figure 8, in the Motor Themes quadrant, highly relevant and well-developed topics such as "machine learning," "artificial intelligence," "sustainability," "agriculture," and "IoT" dominate, indicating their pivotal role in advancing the field. In addition to the above, in the Basic Themes quadrant, foundation topics such as "environmental sustainability," "precision farming," and "random forest" are included, suggesting their importance in shaping the research area, even though they require further development. In the Niche Themes quadrant, specialized areas like "process optimization" and "decision support systems" highlight their depth and development but are more peripheral to the main research focus. Meanwhile, the Emerging or Declining Themes quadrant features "remote sensing," "sustainable development" and "climate change," reflecting their potential as burgeoning areas of interest or waning emphasis. These findings underscore the diverse focus areas within the field, ranging from core technologies and methods to evolving and specialized applications (Figure 8).

Figure 9 is a country collaboration map which visually highlights the global patterns of research collaboration in the field of AI and ML in production efficiency enhancement and sustainable development (Almulhim et al., 2021). This figure is further enhanced with Table 4 which shows the frequency of collaborative research between the top 10 pairs of countries within this field. As seen in Table 4, China emerges as the dominant hub of collaborations, leading the field with strong research ties to the USA with 8 collaborations, the United Kingdom with 6 and Pakistan with 5. These partnerships reflect China's significant investment in AI and sustainability-related research, positioning itself as a global leader. In addition to global partnerships, China also maintains a strong regional focus with collaborations involving Korea with 4 collaborations and Hong Kong with 3. Partnerships with nations such as Pakistan, Iran, Saudi Arabia, and Singapore (3 collaborations each) highlight China's strategic efforts to foster research ties within Asia and the Middle East. Meanwhile, the USA, another major player in the field, demonstrates its global influence with a notable of 5 collaborations with India, reflecting growing research contributions from developing economies. Furthermore, Figure 9 also highlights the limited participation from underrepresented regions like Africa and Latin America, signaling the need for more inclusive efforts to incorporate these areas into global sustainability research.

Overall, the map's darker shades over countries like China, the USA, and the UK emphasize their leadership in research output and collaborations. The connecting lines between Asia, North America, and Europe further illustrate the dominance of transcontinental research networks. However, the absence of strong connections in regions like Africa and parts of Latin America suggests an opportunity to foster greater inclusivity, ensuring global participation in addressing

TABLE 4 Frequency table of collaborative research.

From	To	Frequency
China	USA	8
China	United Kingdom	6
China	Pakistan	5
India	USA	5
China	Korea	4
China	Australia	3
China	Hong Kong	3
China	Iran	3
China	Saudi Arabia	3
China	Singapore	3

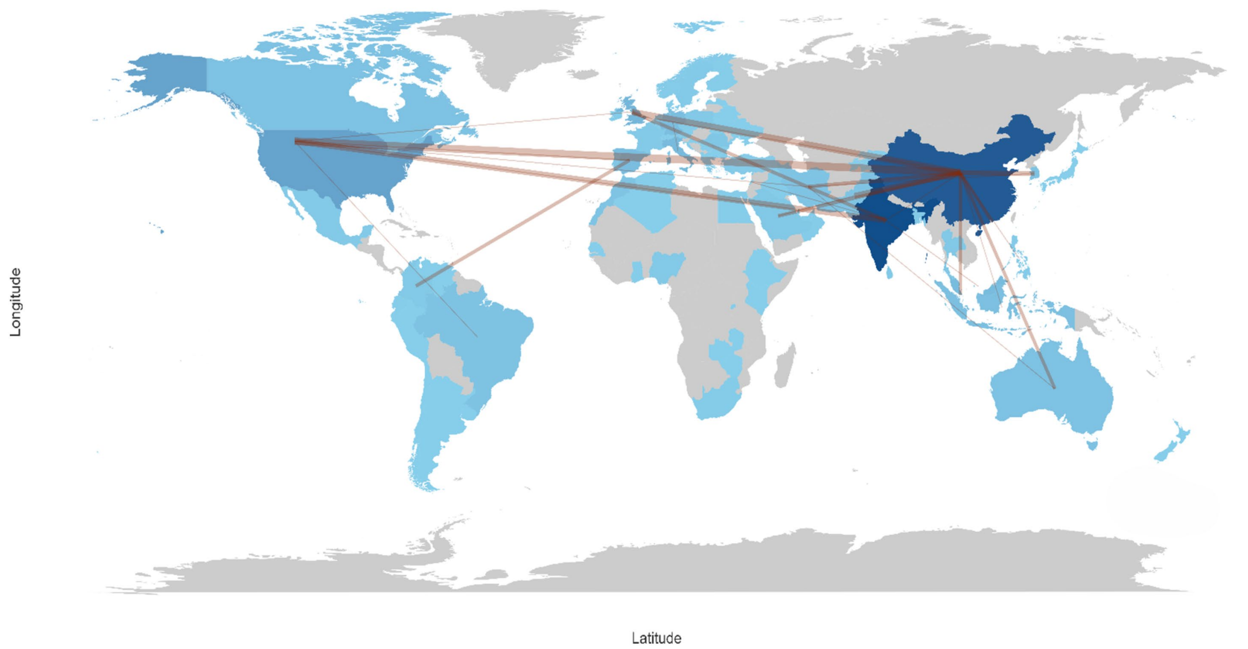

FIGURE 9
Country co-authorship network map.

critical challenges in production efficiency and sustainable development through AI and ML innovations.

Conclusion

In summary, the bibliometric analysis conducted on the application of AI and ML in enhancing production efficiency and promoting sustainable economic development revealed valuable insights on the progression and impact of these technologies. The findings indicate that AI and ML have become indispensable tools for optimizing production processes and managing resources, thereby fostering sustainable growth across diverse industries. Significant trends, including the rise of deep learning, data mining, and the Internet of Things (IoT), have emerged as crucial drivers of innovation (Figure 3). Moreover, collaborations among researchers, institutions, and countries have increased, highlighting the global character of research efforts in this field (Table 2).

Furthermore, the analysis also shows that China and the United States are the leading contributors in terms of research output and impact, with substantial contributions coming from the agriculture and manufacturing sectors (Table 2). Notably, the study also reveals the underrepresentation of EU countries in AI and ML research on sustainable production, despite their significant investments and initiatives in sustainable technology. This gap suggests that while countries like China have made substantial contributions, there is a need for more visibility and research output from the EU to ensure global representation in this field. Furthermore, there is a marked lack of research contributions from developing economies, particularly in Africa, South America, and parts of Asia, where AI and ML applications could have transformative impacts on local economies and sustainability initiatives. Key research themes that have emerged include productivity optimization, decision support systems, and environmental protection (Figure 5), highlighting the versatility and relevance of AI and ML in both economic and ecological contexts.

Despite these promising trends, notable gaps in literature continue to persist. For instance, the analysis underscores the need for further exploration of the ethical implications of AI in production, particularly concerning data privacy and labor market disruptions. Also, there is a noticeable gap in research regarding the long-term economic and social sustainability of AI-driven systems, especially in low-income and developing countries.

Additionally, this study has certain limitations that should be acknowledged. The analysis is based exclusively on publications indexed in the Scopus database, which might result in excluding relevant studies available in other databases, potentially narrowing the scope of the findings. Furthermore, the reliance on a descriptive bibliometric methodology limits the ability to draw causal inferences or predictive insights from the data. Despite these limitations, the findings contribute to existing literature by confirming the dominance of developed countries, such as China, the USA, and the UK, in AI/ML research while highlighting the underrepresentation of regions like Africa and South America. Additionally, the analysis reveals limited focus on AI/ML applications in industries beyond agriculture and manufacturing, such as healthcare and education, particularly in developing economies. These insights underscore the need for more inclusive research efforts that address geographic and sectoral disparities in the field.

Future research could focus on several directions. First, it is essential to examine the broader social and ethical implications of AI and ML in production, including their effects on labor markets, privacy concerns, and the potential for increasing inequality. Also, future research should address the existing geographic imbalances by promoting greater participation from EU countries and developing economies in AI/ML studies related to sustainable production. Encouraging collaborative research efforts and fostering cross-border partnerships will help ensure that AI and ML technologies benefit a broader range of regions, particularly those with unique socio-economic challenges. Investigating the potential of AI and ML in developing countries will not only help bridge this research gap but also provide tailored solutions that align with the sustainability goals of these regions. Other potential research avenues include interdisciplinary approaches that integrate ML with other fields for a more comprehensive understanding of sustainable production processes, longitudinal studies to assess the long-term impacts of AI and ML on production efficiency and sustainability, and investigations focused on Small and Medium Enterprises (SMEs) to explore how these technologies can be scaled to benefit them, given that large corporations often dominate this technological landscape. Lastly, considering the inclusion of other databases such as Web of Science or IEEE Xplore in future studies could provide a more comprehensive understanding of the field, ensuring a broader representation of research contributions.

To conclude, investigating these areas will deepen our understanding of the role of AI and ML assume in optimizing production efficiency and promoting sustainable development, while also facilitating equitable access to their benefits across various sectors and regions.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

AB: Writing – original draft, Writing – review & editing. NK: Writing – original draft, Writing – review & editing. MN: Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The authors declare that no Generative AI was used in the creation of this manuscript.

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