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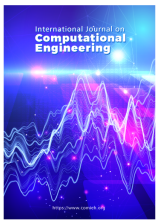

A Simple Bibliometric Insight into Nanocellulose Publications and Research Focus

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***Abstract*—Nanocellulose has garnered increasing attention due to its renewable nature, biocompatibility, and broad range of potential applications, particularly in materials science. This study presents a lightweight bibliometric and text mining analysis to explore recent publication trends, research focuses, and keyword patterns in nanocellulose-related studies. Using metadata retrieved from the Scopus database for the years 2021 to 2025, we compiled a dataset of 2,971 documents that mention "Cellulose," "Nanocellulose," or "Nanocellulose" and are indexed under the subject category of Materials Science. Our methodology involved combining bibliometric visualization using VOSviewer with text analysis tools such as Python-based Latent Dirichlet Allocation (LDA), WordCloud, and matplotlib. The analysis revealed major contributing countries, institutions, journals, and authors. Materials Science and Chemistry were identified as the dominant subject areas, with China emerging as the leading contributor in terms of both publications and funding. Keyword mapping uncovered frequent terms such as "composites," "films," "biodegradability," and "hydrogels," indicating major research themes. In addition, co-citation analysis revealed distinct clusters that connect application-based studies with core nanocellulose material research. The integration of Gen-AI, including concensus.app, further supported the synthesis of emerging patterns and hotspots. This study offers a compact, accessible overview for researchers and stakeholders interested in the evolving landscape of nanocellulose research, helping to inform strategic planning, academic collaboration, and future investigations in the field of sustainable nanomaterials.**

***Keywords*—Nanocellulose; bibliometric; Scopus; trends; visualization; mapping; Python.**

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I. INTRODUCTION

Traditionally, cancer nomenclature has focused primarily on organ location; for instance, "lung cancer" refers to a tumor that originates in the lung tissues. Consequently, many cancers are detected in their later stages due to accuracy problems, resulting in compromised or malfunctioning organ systems, which makes achieving a cure difficult even after treatment. Gene selection aims to identify the most relevant genes that assist in diagnosing tumors precisely and systematically. However, cancer classification remains

Nanocellulose has attracted growing scientific interest due to its renewable origin, biodegradability, and exceptional mechanical, thermal, and barrier properties. Derived from cellulose through various mechanical, chemical, or enzymatic processes, nanocellulose exists primarily in two forms: cellulose nanocrystals (CNCs) and cellulose nanofibrils (CNFs). These materials have opened new possibilities in areas such as nanocomposites, biomedical applications, food packaging, and sustainable engineering solutions. As a result, the number of research articles and innovations related to nanocellulose has grown significantly over the past decade [1], [2]. Given this rapid growth, it becomes increasingly important to understand the current landscape and emerging trends within the nanocellulose research community. While numerous review papers have addressed specific applications or synthesis methods, there is limited literature that offers a broader, data-driven perspective on the evolution of nanocellulose research. Bibliometric analysis provides a useful way to systematically map the scientific output, uncover collaboration networks, identify influential authors and journals, and detect shifts in thematic focus over time [3], [4], [5].

This study focuses on nanocellulose-related publications indexed in the Scopus database between 2021 and 2025, specifically within the subject area of Materials Science. By applying bibliometric tools and text mining techniques, this paper aims to visualize and interpret key trends in keywords,

co-authorship patterns, research clusters, and citation dynamics. Tools such as VOSviewer, Python-based natural language processing libraries, and Scopus's built-in analytics are employed to provide both structured insights and intuitive visual representations [6], [7]. Unlike more extensive scientometric reviews, this paper adopts a lightweight and visual approach, making the findings accessible for both researchers and stakeholders. The goal is not only to map where nanocellulose research has been but also to help anticipate where it may be heading. Through this lens, the study contributes to a better understanding of how knowledge in this field is being generated, disseminated, and applied, particularly in the context of sustainable materials innovation [8], [9], [10].

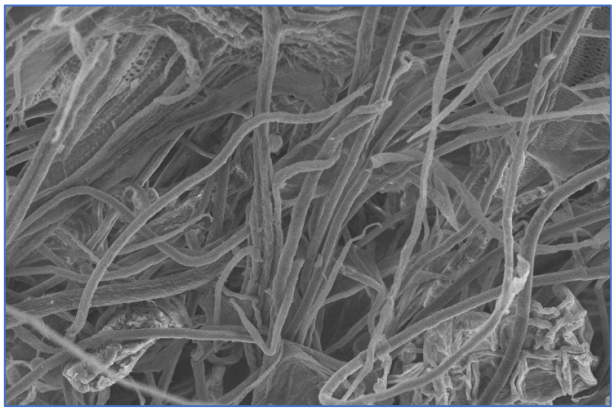


Fig. 1 Illustration of Nanocellulose [11]

II. Material and Method

This study applies a descriptive quantitative approach using bibliometric and text analysis methods to explore recent research trends in cellulose-based nanomaterials within the field of materials science. The dataset was collected from the Scopus database using a targeted search query designed to retrieve articles published between 2021 and 2025 that specifically mention "Cellulose," "Nanocellulose," or "Nano-cellulose" in the context of "nano" and "cellulose" research and are categorized under the subject area "Materials Science." The metadata extracted includes article titles, abstracts, authors, affiliations, publication years, keywords, and journal sources. Bibliometric analysis was carried out using VOSviewer to visualize networks of co-authorship, keyword co-occurrence, and citation links. For text mining, Python libraries such as NLTK, spaCy, and Gensim were used to clean the text data and extract research topics through Latent Dirichlet Allocation (LDA). Additional visualizations like keyword trends were created with WordCloud and matplotlib, while Scopus-AI provided further support in synthesizing insights from the data. To ensure reliability, the study relies on trusted sources and cross-validates findings using multiple analytical tools [12], [13], [14].

The dataset was downloaded using a specific search query applied to a scientific database: TITLE-ABS-KEY (nano AND cellulose) AND (LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2023) OR LIMIT-TO (PUBYEAR , 2024) OR LIMIT-TO (PUBYEAR , 2025)) AND (LIMIT-TO (SUBJAREA , "MATE")) AND (LIMIT-TO (EXACTKEYWORD , "Cellulose") OR LIMIT-TO (EXACTKEYWORD , "Nanocellulose") OR LIMIT-TO (EXACTKEYWORD , "Nano-cellulose")). This query was designed to filter scientific articles that are relevant to the topic of nano and cellulose within the subject area of materials science (MATE), while limiting the publication years from 2021 to 2025. As a result, only articles that explicitly include keywords such as "Cellulose," "Nanocellulose," or "Nano-cellulose" were retrieved, ensuring that the dataset is focused and aligned with current research trends in cellulose-based nanomaterials [15], [16], [17].

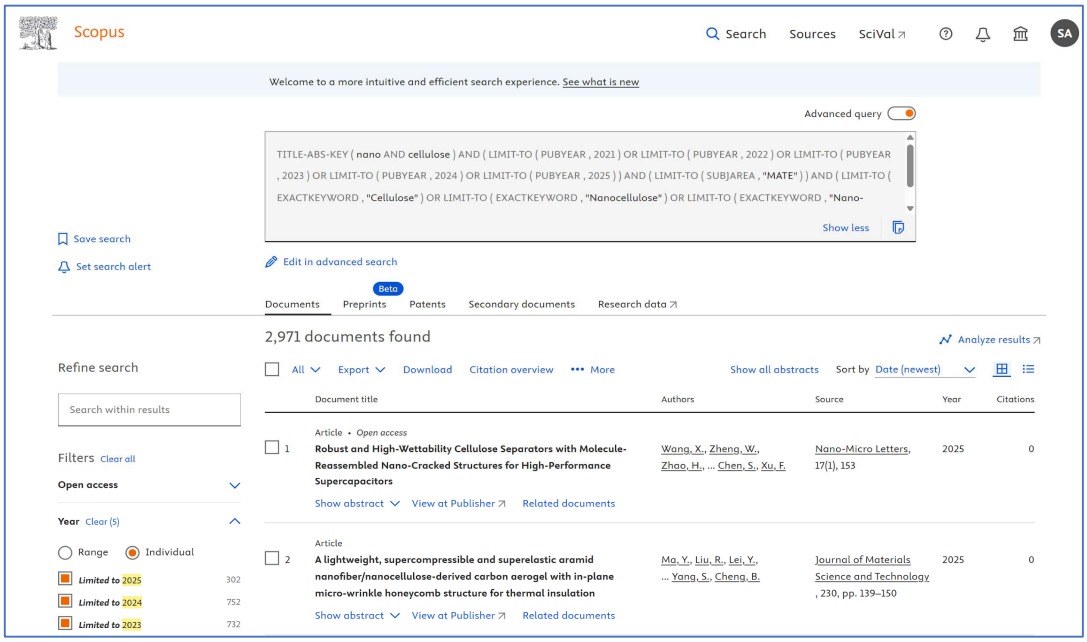


Fig. 2 Query view when downloading dataset [18]

The image shows an advanced search process in Scopus to generate a metadata dataset of scientific publications related to the topic "nano and cellulose." The query filters results using several parameters: keywords in the title, abstract, and author keywords (TITLE-ABS-KEY), publication years limited to 2021 through 2025 (PUBYEAR), and subject area restricted to materials science (SUBJAREA, "MATE"). It also includes specific terms using EXACTKEYWORD such as "Cellulose," "Nanocellulose," and "Nano-Cellulose" to broaden the scope. The search yields 2,971 relevant documents, which can be exported as a metadata dataset containing information such as document title, authors, source journal, publication year, and citation count, as shown in the top two results from 2025 [19], [20], [21].

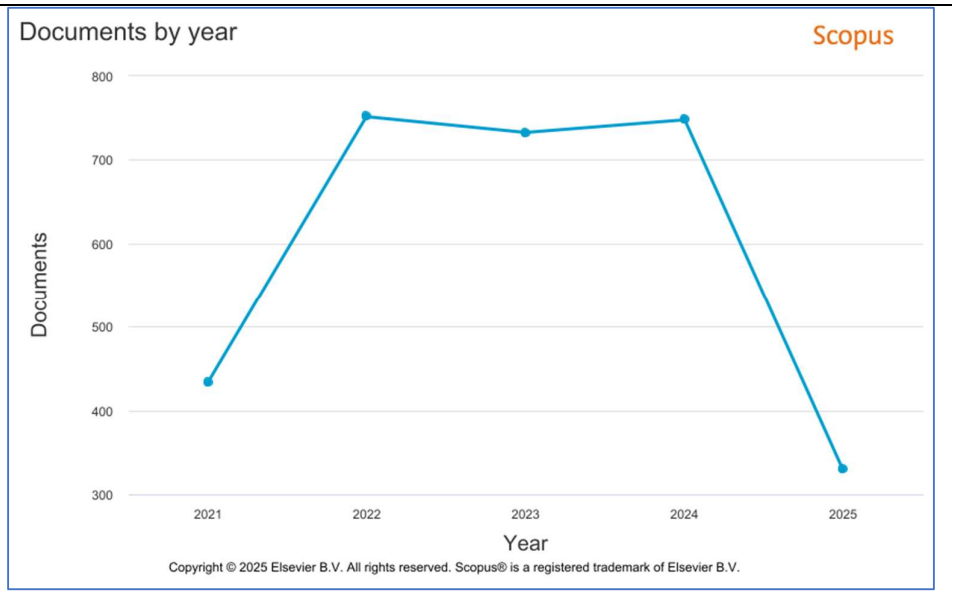
III. Result and Discussion

This section presents the findings and analysis derived from all stages described in Methodology. The study results begin with an initial exploration of the dataset to extract basic statistical insights, followed by a review of Scopus's built-in visualization tools to observe general trends. Further in-depth analysis was conducted using VOSviewer for bibliometric mapping and Python for customized data processing. Machine learning techniques were then applied to the metadata to discover latent patterns and research directions. To complement these methods, generative AI tools such as Scopus-AI and other consensus-driven platforms were employed to enhance the interpretation of findings. The results of these comprehensive study stages are presented and discussed in the following subsections [22], [23], [24].

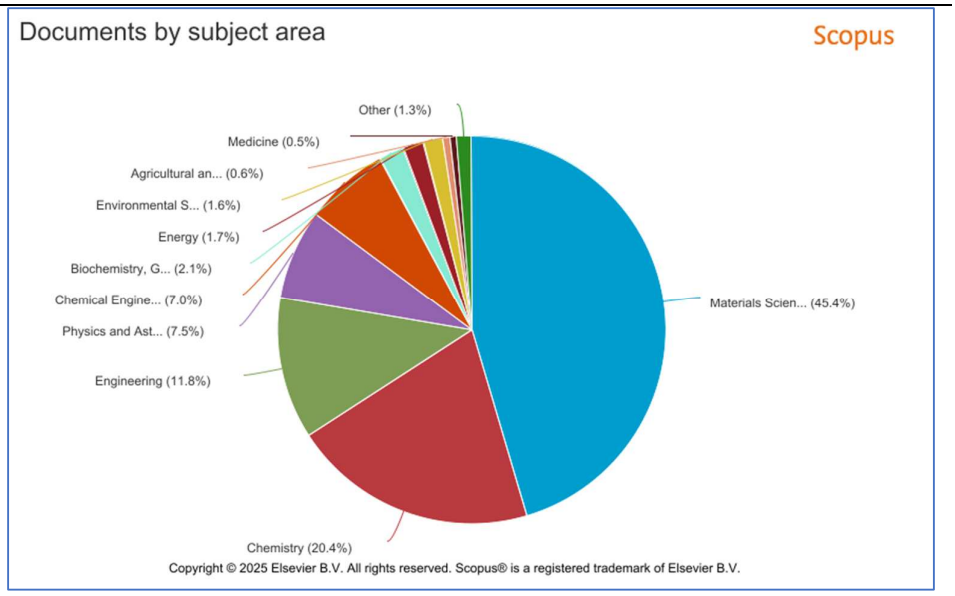
The dataset consists of 2971 entries, each characterized by 46 columns of varying data types. The columns encompass a range of information, including author details (names, IDs, affiliations), publication metadata (title, year, source, volume, issue, pages), citation counts, digital identifiers (DOI, Link), content-related information (abstract, keywords), funding details, references, and publication specifics (publisher, ISSN, language, document type, open access status). While most columns have complete or near-complete data, some columns like 'Art. No.', 'Page start', 'Page end', 'Molecular Sequence Numbers', 'Chemicals/CAS', 'Tradenames', 'Manufacturers', 'Editors', 'Sponsors', 'Conference details', 'ISBN', 'CODEN', and 'PubMed ID' have substantial missing data, with 'Molecular Sequence Numbers' being entirely empty. The dataset appears to be comprehensive, covering various aspects of scholarly publications, with the number of null values varying across columns [25], [26].

The default built-in visualization tools on the Scopus web platform provide a quick and user-friendly overview of research trends, authorship, collaboration networks, and subject area distribution. These visualizations typically include bar charts, line graphs, and pie charts that represent metrics such as publication output over time, top contributing authors and institutions, and geographic distribution of research. While these tools are helpful for initial exploration, they offer limited customization and analytical depth compared to specialized bibliometric software, making them more suitable for general overviews rather than detailed analysis [27], [28].

TABLE I
Scopus Built-in Visualizations [29]

Category	Visualization
Scopus-Analyze-Year	

Scopus-Analyze-Subject



The following is an interpretation of all the built-in visualizations from Scopus for the downloaded dataset, providing initial insights before conducting analysis using various tools. The Scopus database offers a compelling glimpse into the landscape of scientific research, revealing a pronounced concentration in specific disciplines. Materials Science emerges as the dominant field, commanding a substantial 45.4% of the documented research. This significant share underscores the ongoing emphasis and importance of materials-related studies in the scientific community. Following closely behind Materials Science is Chemistry, which accounts for 20.4% of the documents. Engineering and Physics contribute substantially as well, holding 11.8% and 7.5%, respectively. This distribution highlights the core areas driving scientific advancement and innovation, reflecting the current priorities and focal points of scholarly investigation. Analyzing document trends over recent years reveals intriguing dynamics. Between 2021 and 2024, sources such as Carbohydrate Polymers and Cellulose experienced a growth trajectory in document counts, indicating increasing interest and activity in these areas. However, 2025 brought a shift, with many sources experiencing a decline, signaling potential changes in research focus or funding [30], [31].

The financial backing of scientific research demonstrates a strong influence from Chinese institutions. The National Natural Science Foundation of China and the Ministry of Science and Technology of China emerge as the top funding sponsors, surpassing contributions from other international entities. This highlights China's growing investment and prominent role in shaping the direction of global scientific endeavors. In terms of publication types, articles overwhelmingly dominate, comprising 83.0% of the documents. Reviews serve as a significant secondary source of information, accounting for 12.0%. Geographically, China leads in the number of document contributions, reflecting its increasing prominence in the global research arena. Within the author landscape, Rojas, O.J. stands out as the most prolific contributor, while the Ministry of Education of the People's Republic of China, along with Nanjing Forestry University, are the leading affiliations. These insights provide a multi-faceted view of the data, revealing key trends, influential players, and dominant themes within the Scopus database [32], [33].

The following presents the results of the study generated using VOSviewer along with their interpretations. These findings highlight key patterns, relationships, and trends identified from the bibliometric analysis, providing insights into the research landscape, thematic clusters, and the most influential keywords and publications within the dataset [34], [35].

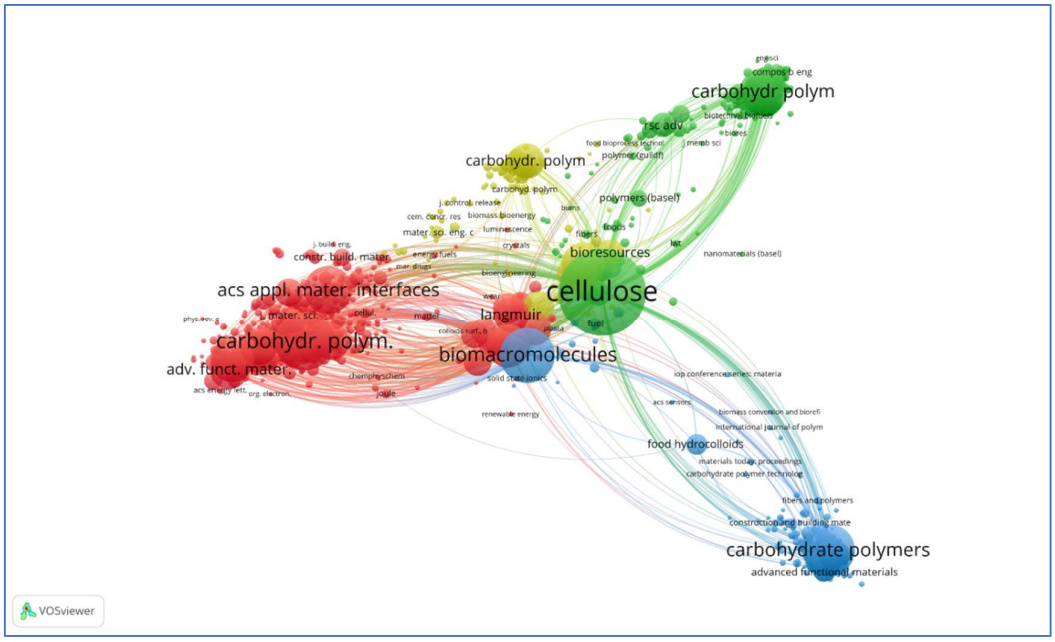


Fig. 3 Co-citation_cited sources [36]

The VOSviewer map positions "cellulose" as the dominant hub connecting four thematic clusters of journals and research foci. The green cluster, anchored by titles like Carbohydrate Polymers and Polymers (Basel), centers on fundamental biopolymer chemistry and biorefineries, with links to "Langmuir" and "Bioresources" reflecting surface analysis and feedstock valorization. To the right, the smaller blue cluster, led by Food Hydrocolloids and Carbohydrate Polymers, emphasizes hydrogel formation, rheology, and food-grade applications of cellulose derivatives. On the left, the red cluster around ACS Applied Materials & Interfaces, Advanced Functional Materials, and Carbohydrate Polymers denotes high-impact work in nanocellulose composites, surface modification, and functional device fabrication. Interspersed yellow nodes (e.g., Renewable Energi, Materials Science & Engineering) highlight sustainability and process-engineering perspectives that bridge these domains. The dense web of colored lines illustrates frequent cross-citation and methodological overlap, underscoring how core insights into cellulose structure unite diverse applications in materials science, biomedicine, and environmental engineering [37], [38].

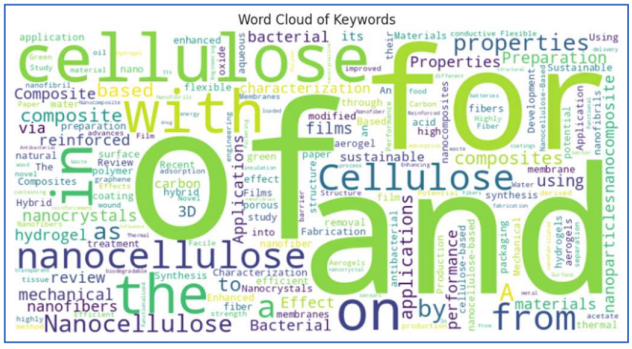


Fig. 4 Word cloud of keywords

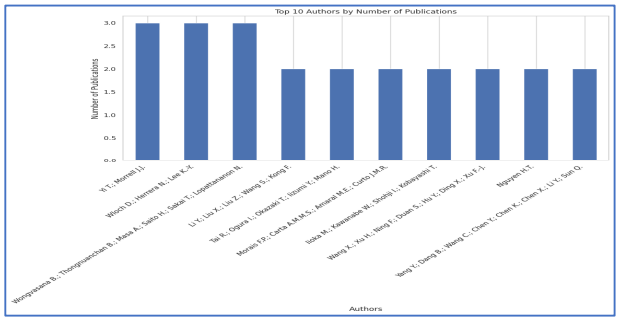


Fig. 5 Top 10 authors by number of publications

The bar chart, titled "Top 10 Authors by Number of Publications," highlights the most prolific authors based on the number of publications. Yi T.; Morrell J.J., Wloch D.; Herrera N.; Lee K.-Y., and Wongvasana B. et al. are tied at the top, each with approximately 3 publications. Tai R. et al., Morais F.P. et al., Iioka M. et al., Wang X. et al., Yang Y. et al., Nguyen H.T., and Li Y. et al. follow, each having approximately 2 publications. Overall, the chart indicates a relatively even distribution of publications among the top authors, with a small group leading in the number of publications [34], [39].

The following is additional information from one of the Gen-AI tools, Consensus.app. Nanocellulose refers to cellulose materials engineered at the nanoscale, offering exceptional characteristics such as high tensile strength, low density, biodegradability, and biocompatibility. It is derived from various sources including plants, bacteria, and algae, and has emerged as a promising sustainable material for a range of applications. There are three main types of nanocellulose—cellulose nanocrystals (CNCs), cellulose nanofibers (CNFs), and bacterial nanocellulose—each with distinct structural and functional properties [40]. These are typically produced through mechanical, chemical, or enzymatic processes, with surface modifications applied to enhance compatibility and

functionality in different contexts. Nanocellulose exhibits advantageous properties such as high surface area, non-toxicity, and strong hydrogen bonding, making it suitable for numerous fields including composites, biomedical engineering, coatings, and environmental solutions. Surface modifications, such as sulfonation or hydrophobic treatments, are commonly used to tailor its properties for specific applications like drug delivery, water purification, and flexible electronics. However, challenges such as energy-intensive production, hydrophilicity, and scalability remain. Future research aims to overcome these barriers by optimizing fabrication methods and expanding its commercial potential across various industries [41], [42].

TABLE II
APPLICATIONS OF NANOCELLULOSE [43], [44]

Application Area	Examples and Benefits
Composites & Materials	Reinforcement in plastics, plywood, and all-cellulose composites for improved strength and reduced emissions
Coatings & Films	Advanced coatings with antimicrobial, barrier, or optical properties; flexible screens
Biomedical	Drug delivery, tissue engineering, wound healing, dental repair, and temporary implants
Environmental & Energy	Water purification, catalysis, fuel cells, and biofuel production
Paper & Packaging	Papermaking, food packaging, security papers, and coating additives

IV. CONCLUSION

This study provides a concise yet comprehensive bibliometric overview of nanocellulose research within the materials science domain from 2021 to 2025. By leveraging tools such as VOSviewer, Python-based text analysis, and Scopus's built-in analytics, we identified prominent authors, influential institutions, and core journals shaping the research landscape. Keyword co-occurrence and topic modeling reveal a strong emphasis on sustainable applications, nanocomposite development, and biopolymer engineering, with China emerging as a dominant contributor in both funding and scholarly output. The analysis also highlights a shifting research focus in recent years, with declining publication growth in 2025 suggesting either a maturation phase or redirection of interest toward more applied domains. The integration of machine learning and visual analytics offered valuable insights into the evolution and diversity of research themes. These findings not only enrich our understanding of the academic discourse on nanocellulose but also serve as a guide for future exploration, collaboration, and innovation in renewable nanomaterials.

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