Original Article
ISSN (Online): 2582-7472

ShodhKosh: Journal of Visual and Performing Arts
January-June 2024 5(1), 3200–3209

BIOMASS RESEARCH IN INDIA: MEASURING SCIENTIFIC GROWTH AND GLOBAL LINKAGES THROUGH SCIENTOMETRICS

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ABSTRACT

This study presents a Scientometric analysis of biomass research in India period from 2013 to 2022. By utilizing bibliographic data from the Scopus database, the research investigates the growth, key contributors, institutional impact, funding sources, and emerging trends. The analysis reveals a significant increase in research output, with a notable rise in publications, underscoring the growing importance of biomass as a sustainable energy source in India. Key research themes identified through Multiple Correspondence Analysis (MCA) include biofuels, microalgae, and carbon management, which are central to the field. Author impact analysis highlights a group of influential researchers whose work has substantially shaped the biomass research landscape. Institutional contributions are led by Banaras Hindu University and the Indian Institutes of Technology, which are at the forefront of this research area. The co-authorship network analysis reveals strong collaboration between Indian institutions and international partners, contributing to the global advancement of biomass research.

Keywords: Biomass Research, Scientometric Analysis, India, Research Trends, Institutional Contributions, Research Output, Funding Agencies, Co-Authorship Networks, Emerging Research Themes

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DOI
10.29121/shodhkosh.v5.i1.2024.5759

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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1. INTRODUCTION

The study of biomass has emerged as a significant field of scientific enquiry, particularly in connection to the production of sustainable energy, conservation of the environment, and the global pursuit of renewable resources. Due to its diverse ecological systems and significant agricultural output, India provides a unique setting for the study of biomass. Recently, Indian scholars and institutions have increasingly contributed to the global discourse on biomass, particularly addressing topics related to bioenergy, waste management, and the progress of ecologically sustainable technologies. The aim of this study is to do a scientometric mapping of biomass research in India by analysing the academic output developed over the past decade. Scientific scientometrics is a quantitative methodology used to assess the impact and advancement of scientific research. This analysis offers valuable perspectives on the trends, collaborations, and subject areas of focus within a specific field of study. The objective of this study is to identify key

contributors, important institutions, and the evolution of research subjects in the field of Indian biomass research by analysing publication patterns, citation metrics, and collaboration networks. In light of the growing emphasis on sustainable development and the transition towards renewable energy sources in India, the analysis is particularly relevant. An exhaustive examination of the trajectory of biomass research can offer significant perspectives for policy formulation, guide future research areas of concentration, and foster collaboration among scholars, industry, and government. By doing a focused analysis of India's contribution to the development of biomass research on a global scale, this paper enriches the current scientometric literature. The objective of this study is to examine the scientometric patterns in biomass research in India within a decade. It comprises an examination of the academic contributions, patterns of collaboration, and thematic developments that have shaped this significant subject.

2. REVIEW OF LITERATURE

A thorough examination of the literature of biomass research in India should include a range of studies that investigate the expansion and progress of this discipline, the main topics and patterns, and the impact of institutions and authors. The present study consolidates these elements by integrating recent research and investigations conducted by Chandra et al. (2024), Jahanshahi et al. (2023), Krishnamoorthy et al. (2023), Vaishya et al. (2022), Xu et al. (2024), Asghar et al. (2023), and Iftikhar et al. (2023). In India, the research output on biomass has shown substantial expansion throughout the last ten years. The growth observed can be attributed to the growing focus on sustainable energy sources at both global and national levels, with biomass becoming recognised as a feasible substitute for fossil fuels.

2.1. OBJECTIVES OF THE STUDY

The objectives of the research on biomass in India are as follows:

1) Analyze the overall growth and distribution of biomass research in India.
2) Identify Key Research Themes and Concepts.
3) Examine research partnerships among authors, institutions, and countries.
4) Assess the influence and contributions of leading researchers in the field.
5) Investigate the role of academic and research institutions in advancing biomass studies.
6) Identify key funding bodies and their impact on biomass research.
7) Study shifts in research focus over time and emerging areas of interest.

3. RESEARCH METHODOLOGY

The research methodology for this Scientometric analysis involves an examination of the bibliographic data related to biomass research in India, covering the period from 2013 to 2022. The data was sourced from the Scopus database using a precise search query: TITLE-ABS-KEY (biomass) AND PUBYEAR > 2012 AND PUBYEAR < 2022 AND (LIMIT-TO (AFFILCOUNTRY, "India")) AND (LIMIT-TO (DOCTYPE, "ar")). This query was designed to retrieve articles focused on biomass research, authored by Indian researchers, and published in peer-reviewed journals. The inclusion criteria were limited to English-language articles categorized as 'final' publications. The analysis involves a detailed investigation of various bibliometric indicators, including publication trends, authorship patterns, citation analysis, and collaborative networks, to gain insights into the research landscape of biomass in India. The data extracted will be systematically processed and analysed using bibliometric tools to identify key research themes, prolific authors, and influential publications, thereby mapping the evolution and impact of biomass research in the specified period. This Scientometric study was conducted using a combination of Bibliometrix, Biblioshiny, and VOSviewer. Bibliometrix, an R package, and its user-friendly interface, Biblioshiny, were employed for the comprehensive analysis of bibliographic data, allowing for the assessment of various bibliometric indicators such as publication trends, authorship patterns, and citation metrics. VOSviewer was utilized for visualizing and mapping collaborative networks, co-authorship patterns, and keyword co-occurrences, providing an in-depth understanding of the research dynamics in the field of biomass in India. These tools enabled a robust and detailed analysis, offering valuable insights into the evolution and impact of biomass research from 2013 to 2022.

4. DATA ANALYSIS, RESULTS AND DISCUSSION

Annually output of India in biomass research

Table 1 Annual Production of India in Biomass Research

Table 1: Annual Production of India in Biomass Research	
Year	**Articles**
2013	1106
2014	1282
2015	1354
2016	1457
2017	1482
2018	1597
2019	1763
2020	2047
2021	2326
2022	2696

Table 1 shows that biomass research articles in India have steadily increased from 2013 to 2022, demonstrating greater interest and financial commitment. Indian scientists published 1,106 biomass articles in 2013. The number of articles increased annually, peaking at 1,282 in 2014 and 1,354 in 2015. The trend continued with 1,457 articles in 2016 and 1,482 in 2017. Increased articles followed, with 1,597 in 2018 and 1,763 in 2019. Final three years of research saw significant growth, with 2,047 papers in 2020, 2,326 in 2021, and 2,696 in 2022. The rising annual publication volume shows that biomass research in India is becoming more important due to the need for sustainable energy and creative environmental solutions.

Most Global Cited Documents of India in Biomass Research

Table 2 Most Global Cited Documents of India in Biomass Research

Table 2: Most Global Cited Documents of India in Biomass Research			
Paper	**DOI**	**Total Citations**	**TC per Year**
Bond tc, 2013, j. Geophys. Res. Atmos.	10.1002/jgrd.50171	4477	373.08
Mohan d, 2014, bioresour. Technol.	10.1016/j.biortech.2014.01.120	1841	167.36
Thakur vk, 2014, acs sustain. Chem. Eng.	10.1021/sc500087z	1127	102.45
Dhyani v, 2018, renew. Energy	10.1016/j.renene.2017.04.035	1056	150.86
Parihar p, 2015, environ. Sci. Pollut. Res.	10.1007/s11356-014-3739-1	937	93.70
Akhtar ms, 2013, acs sustain. Chem. Eng.	10.1021/sc300118u	713	59.42
Van den hoogen j, 2019, nature	10.1038/s41586-019-1418-6	677	112.83
Vet r, 2014, atmos. Environ.	10.1016/j.atmosenv.2013.10.060	615	55.91
Raliya r, 2013, agric. Res.	10.1007/s40003-012-0049-z	577	48.08
Mishra rk, 2018, bioresour. Technol.	10.1016/j.biortech.2017.12.029	574	82.00

Table 2 indicate the most globally cited documents in biomass research from India highlight the significant impact and influence of Indian researchers in this field. Leading the list is the 2013 study by Bond et al., published in Journal of Geophysical Research: Atmospheres, which has garnered 4,477 citations and an impressive 373.08 citations per year, reflecting its critical contribution to understanding atmospheric impacts related to biomass. Following this is Mohan et al.'s 2014 publication in Bioresource Technology, cited 1,841 times with 167.36 citations per year, focusing on advanced biotechnological methods for biomass conversion. Thakur et al.'s 2014 paper in ACS Sustainable Chemistry & Engineering has also made a substantial impact with 1,127 citations and 102.45 citations per year, contributing to the development of sustainable chemical processes. Dhyani et al.'s 2018 work in Renewable Energy has been highly influential, with 1,056 citations and a notable 150.86 citations per year, emphasizing renewable energy innovations from

biomass. The 2015 study by Parihar et al. in Environmental Science and Pollution Research has accumulated 937 citations, contributing to the understanding of environmental impacts of biomass. Other significant contributions include Akhtar et al. (2013) in ACS Sustainable Chemistry & Engineering with 713 citations, and Van den Hoogen et al. (2019) in Nature, with 677 citations, underscoring interdisciplinary research.

Most Relevant Affiliations in biomass research from India

Table 3 Most Relevant Affiliations in biomass research from India

Affiliation	Articles
Banaras Hindu University	1063
Indian Institute of Technology	1006
Indian Institute of Technology Guwahati	956
ICAR-Indian Agricultural Research Institute	945
Punjab Agricultural University	745
National Institute of Technology	729
Indian Institute of Technology Delhi	691
Indian Agricultural Research Institute	567
Anna University	537
King Saud University	458

Table 3 shown that, In biomass research from India, several institutions stand out for their significant contributions. Banaras Hindu University leads with 1,063 articles, followed closely by the Indian Institute of Technology (IIT), which collectively accounts for substantial research output, with IIT Guwahati contributing 956 articles. The ICAR-Indian Agricultural Research Institute also plays a key role, with 945 publications. Other prominent contributors include Punjab Agricultural University (745 articles), National Institute of Technology (729 articles), and Anna University (537 articles). Additionally, King Saud University, despite being an international institution, is notably involved in collaborative research with Indian entities, contributing 458 articles.

Most Relevant Sources in biomass research from India

Fig.1: Most Relevant Sources in biomass research from India

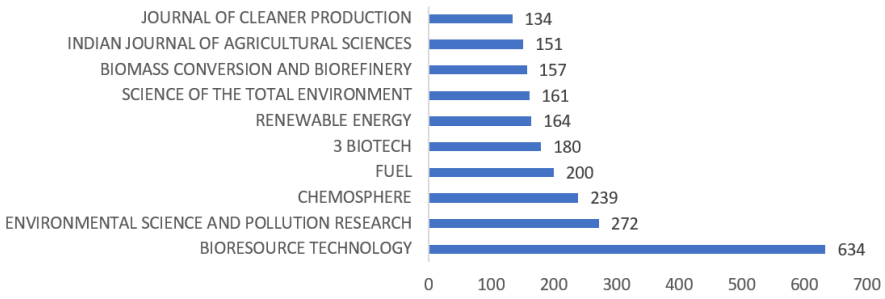

Figure 1 indicate that, in biomass research from India, certain academic journals are particularly influential. Bioresource Technology is the leading source, publishing 634 articles, reflecting its central role in disseminating research on biomass conversion and bioenergy. Environmental Science and Pollution Research follows with 272 articles, focusing on the environmental impacts of biomass. Chemosphere and Fuel contribute significantly, with 239 and 200 articles, respectively, addressing the chemical and fuel aspects of biomass research. Other key journals include Biotech (180 articles), Renewable Energy (164), and Science of the Total Environment (161), highlighting the multidisciplinary nature of biomass studies. Biomass Conversion and Biorefinery and the Indian Journal of Agricultural Sciences also play crucial roles, along with the Journal of Cleaner Production (134 articles), emphasizing sustainability and cleaner production technologies.

Conceptual Structure Map

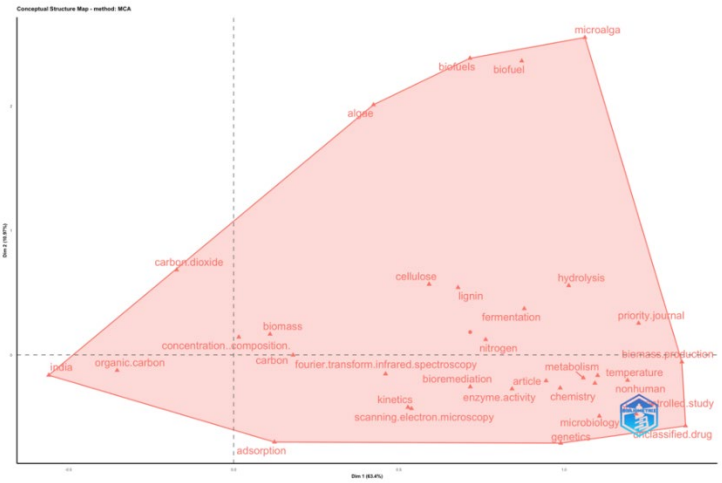

Figure 2 Conceptual Structure Map

Figure 2 shows an MCA-generated Conceptual Structure Map. In biomass study in India, this strategy is used to examine the correlations between ideas or variables in a dataset.

The map shows Dimension 1 (63.4%) and Dimension 2 (10.9%). These dimensions indicate the dataset's key variation or differentiation axes. These dimensions plot concept-phrase relationships. Cluster placement indicates the research field's conceptual framework. In the upper-right section of the image, "biofuels," "biofuel," "microalga," and "algae" are grouped together, indicating a close relationship between the two fields. The location of "carbon dioxide," "organic carbon," and "adsorption" further apart shows that they belong in a different conceptual realm within biomass study. Bigger nodes represent bigger ideas. Size and colour intensity of terms (nodes) represent their frequency or relevance in the dataset. The coloured zone connects related concepts by showing their conceptual limits.

Network visualisation of the co-occurrence of keywords in Indian biomass research

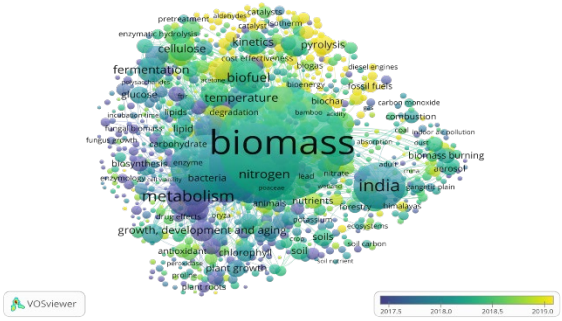

Figure 3 Network visualisation of the co-occurrence of keywords in Indian biomass research

Figure 3, Using VOSviewer, a network visualisation of the co-occurrence of keywords in Indian biomass research was produced. The size of the nodes, which each represent a keyword, shows how frequently the keyword appears in the research publications. The keyword appears in the dataset more frequently the larger the node. The co-occurrence relationships between keywords are displayed by the connections or links between nodes; this indicates that certain terms frequently occur together in the same articles.

The network's thicker lines indicate stronger co-occurrence correlations, highlighting a close association between research field themes. The blue-to-yellow gradient reflects the average publishing year for each keyword, with yellow indicating recent years (around 2019) and blue representing earlier years (approximately 2017.5). This color-coding illustrates the progression of Indian biomass research topics. At the core of the network, "biomass" emerges as the most frequently occurring keyword, underscoring its central importance. Other key terms like "metabolism," "nitrogen," "biofuel," "temperature," and "India" emphasize the study's main focus areas.

Overlay visualisation of the co-authorship of organisations in Indian biomass research

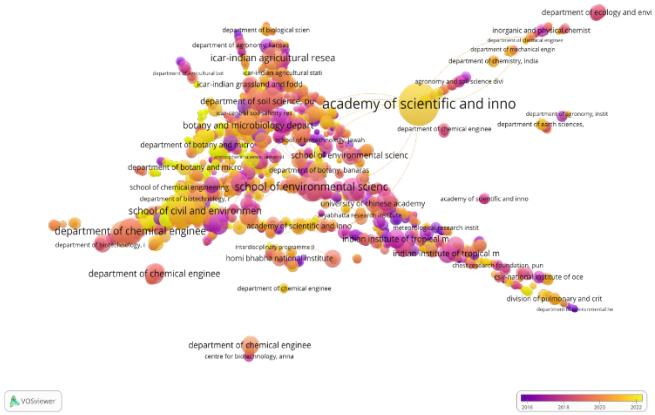

Figure 4 Overlay visualisation of the co-authorship of organisations in Indian biomass research

Figure 4 showcases an overlay visualization of co-authorship among organizations, likely linked to a specific study, created using VOSviewer, a widely-used bibliometric network mapping tool. In this network, each node represents an organization, with its size reflecting the organization's prominence or number of co-authored publications. Thicker lines between nodes indicate stronger or more frequent collaborative partnerships. The color gradient from yellow to purple suggests the timeline of publications, with purple representing more recent years (up to 2022) and yellow denoting earlier years (around 2016). Larger, central nodes indicate prominent institutions within the co-authorship network, while smaller, peripheral nodes represent lesser-known collaborations. This visualization highlights the evolution of collaboration among organizations, revealing key players, research networks, and potential emerging trends in the field.

Overlay visualisation of the co-authorship of countries in Indian biomass research

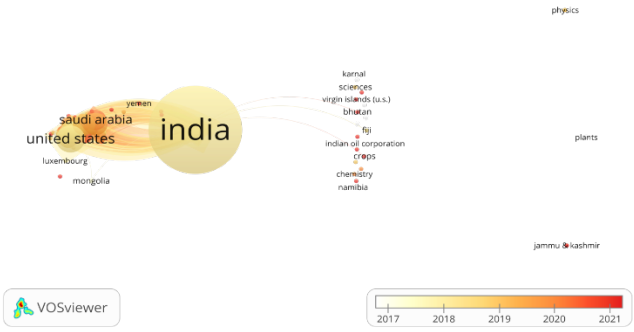

Figure 5 Overlay visualisation of the co-authorship of countries in Indian biomass research

Figure 5, Using VOSviewer, this overlay visualisation highlights India-led research cooperation while displaying the co-authorship of other nations. The number of publications linked to each nation is represented by the size of the circles (nodes), and the co-authorship relationships between them are shown by the links (lines). With the largest circle, India is the most active participant and is involved in many partnerships, especially with Saudi Arabia and the United States, which are both represented as having important ties. The colour gradient represents the average year of publishing; the yellow tones imply older collaborations (about 2017), and the redder colours indicate more recent collaborations (about 2021). The diversity of subjects related to India, including "chemistry," "plants," and "physics," demonstrates the breadth of research fields. In worldwide research collaborations, the visualisation aids in identifying important collaborators and new trends.

Three-field plot illustrates the relationships between universities, authors, and their connected nations

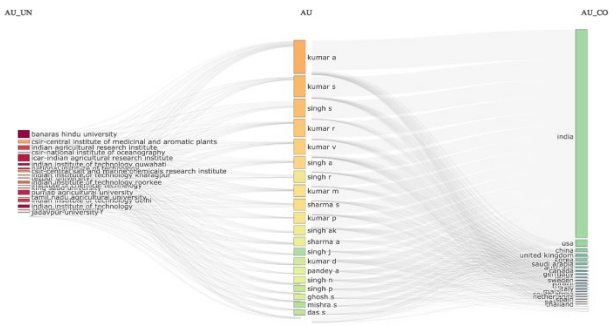

Figure 6 Three-field plot illustrates the relationships between universities, authors, and their connected nations

Figure 6, In the context of Indian biomass research, this three-field plot illustrates the relationships between universities, authors, and their connected nations between 2013 and 2022. The universities that participated in this research are listed in the left column; notable establishments that have strong affiliations to many authors include the Indian Institutes of Technology, Banaras Hindu University, and several agricultural research institutes. Key contributions to the field, such as those with the surnames "Kumar" and "Singh," are listed in the middle column along with the most prolific writers. The nations linked to these writers are displayed in the right column, with India leading the way in terms of research output. Still, there exist partnerships with nations such as the United States, China, and the United Kingdom. The narrative successfully draws attention to the extensive web of partnerships that support pearl millet research both internationally and within India.

Thematic Map

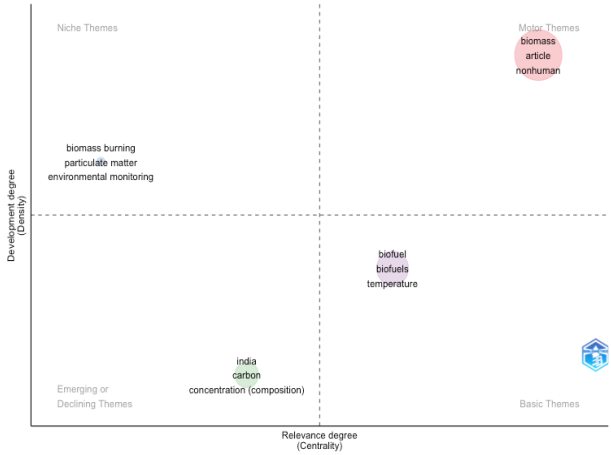

Figure 7 Thematic Map

Figure 7 visually represents themes associated with biomass research in India from 2013 to 2022 through a thematic map, divided into four quadrants based on the themes' degree of development (density) and relevance (centrality). The upper right quadrant, representing motor themes, includes highly significant and well-developed topics such as "biomass," "article," and "nonhuman," indicating their central role and strong connections with other research areas. The upper left quadrant contains specialized or isolated themes like "biomass burning," "particulate matter," and "environmental monitoring," which, while well-established, are more niche within the broader context of biomass research. The lower right quadrant features basic themes, including "biofuel," "biofuels," and "temperature," which are fundamental yet less developed, suggesting the need for more focused research despite their importance. The lower left quadrant represents either emerging or waning themes, such as "India," "carbon," and "concentration (composition)," which are less developed and less central, indicating they may be new areas of interest or declining in relevance. The size of each bubble reflects the significance of these themes, with larger bubbles indicating greater research emphasis or output.

Impact of Authors Work in Biomass Research in India

Table 4 Impact of Authors' Work in Biomass Research in India

Author	h_index	g_index	m_index	Total Citation	No. Publication	Publication Year Start
Kumar A	49	72	4.083	11359	506	2013
Kumar S	47	71	3.917	8553	349	2013
Kumar V	46	67	3.833	6975	252	2013
Singh S	46	79	3.833	8719	292	2013
Singh R	45	76	3.75	6973	189	2013
Kumar R	43	64	3.583	6741	265	2013
Pandey A	43	71	3.583	5666	126	2013
Sharma S	42	62	3.5	5605	215	2013
Kumar M	41	61	3.417	5330	195	2013
Ahmad P	39	65	3.9	5411	65	2015

Table 4 highlights the significant contributions of leading Indian biomass researchers through key bibliometric indicators. Kumar A stands out with an h-index of 49, signifying that 49 of his papers have garnered at least 49 citations, alongside a g-index of 72, indicating substantial citation impact, and an m-index of 4.083, reflecting consistent influence since 2013. With 11,359 total citations from 506 publications, he is a prominent figure in this field. Kumar S and Singh S also demonstrate strong influence with h-indices of 47 and 46, respectively. Kumar S has accumulated 8,553 citations from 349 publications with a g-index of 71, while Singh S has a g-index of 79 and 8,719 citations from 292 articles. Both researchers exhibit strong m-indices of 3.917 and 3.833, signifying sustained impact over time.

5. FINDINGS

Based on the Scientometric analysis of biomass research in India from 2013 to 2022, several key findings have emerged:

Significant Increase in Biomass Research Output: Over the previous ten years, there has been a steady and notable rise in the quantity of research publications pertaining to biomass in India, according to the data. The amount of publications published every year increased from 1,106 in 2013 to 2,696 in 2022, indicating increased funding and interest in this area. This expansion highlights the growing significance of biomass research in the larger framework of sustainability and renewable energy.

Core Themes of Research and Conceptual Structure: Key study themes within the biomass research domain were discovered using the conceptual structure map created using Multiple Correspondence Analysis (MCA). Terms pertaining to microalgae and biofuels are prominently clustered together, suggesting a high emphasis on the investigation of algal biomass and the development of alternative fuels. Other important themes, such organic carbon and carbon dioxide, point to the need for continued study into the environmental effects of biomass utilisation as well as carbon capture and sequestration.

Research Productivity and Author Impact: The examination of author impact showed that a number of Indian scholars, including A. Kumar, S. Kumar, and S. Singh, had made important contributions to the field of biomass research. These authors' strong h-index and g-index scores demonstrate how frequently cited and prolific their work is. Their work has significantly advanced the discipline and influenced later investigations.

Institutional Contributions: The Indian Institutes of Technology (IITs) and the India Agricultural Research Institute (ICAR) were found to be the top three institutions in terms of research production, with Banaras Hindu University (BHU) coming in second. These establishments are leading the way in biomass research in India and have made substantial contributions to the growth and exchange of information in this area. These institutions' impressive production demonstrates how important a role they play in developing biomass research.

Highly cited Publications: Bond et al.'s (2013) study on the radiative forcing of climate due to aerosols is one of the most referenced papers from India in biomass research worldwide, with 4,477 citations. Other highly cited papers in the field of biomass indicate that Indian academics are making important contributions to high-impact fields, such as bioresource technology, sustainable chemistry, and renewable energy.

Collaborative Networks and International Partnerships: The examination of co-authorship revealed a robust network of cooperation between Indian establishments and foreign associates. Co-authorship patterns show that India has developed significant research connections with Saudi Arabia and the United States. These partnerships are critical to the global growth of biomass research and the sharing of information.

Emerging and Declining Research Themes: The thematic map identified fundamental topics like "biofuels" and "nonhuman," as well as developing themes like "environmental monitoring" and "biomass burning." Topics such as "carbon concentration" seem less central, but they might reflect new areas of interest or waning importance, providing hints for future research routes.

Journal Contributions: "Bioresource Technology" was found to be the most pertinent source for Indian biomass research papers, followed by "Environmental Science and Pollution Research" and "Chemosphere." These journals serve as essential venues for sharing research results and expanding understanding in the subject of biomass.

6. CONCLUSION

Scientometric analysis of biomass research in India from 2013 to 2022 covers its progress, significant contributors, and upcoming trends. Research output has increased significantly, reflecting biomass's growing importance as a sustainable energy source and its relevance to environmental issues. Top universities and research institutes like Banaras Hindu University and the Indian Institutes of Technology contribute to this expansion. Research themes show that biofuels, microalgae, and carbon management dominate biomass research in India. The study of relevant sources shows that magazines like "Bioresource Technology" spread research and advance the discipline. These journals are crucial for disseminating new findings and advancing biomass as a sustainable resource. In the end, a solid research infrastructure, institutional contributions, and effective collaboration networks have helped biomass research in India advance over the past decade. The field now prioritises biofuels, carbon management, and novel themes. This Scientometric study guides biomass research in India and contributes to global sustainable energy efforts.

CONFLICT OF INTERESTS

None.

ACKNOWLEDGMENTS

None.

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