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# Global Trends of Research Productivity in Natural Fibre Reinforced Composites: Comprehensive Scientometric Analysis

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**ABSTRACT**

The research on natural-fiber-reinforced composites (NFRC) has been evolving rapidly with many academic publications in recent decades for their potential applications in automotive, textiles, furniture, healthcare, biofuel sectors, and so on. Hence, an attempt is made to provide an overview of NFRC literature by employing novel scientometric and network analysis tools to examine 1143 articles extracted from Scopus database between 2010 and 2022. The novelty in the manuscript that is scientometric and network analysis of different disciplines and, tracking the latest developments would pull of great interest for plenty of much researcher and scholar because today's some scientific output just focuses on interest, effort, and attention of policy-makers. Results obtained through this work describe the real impact of the research published till date and its usage; it also gives directions for new researchers who wish to perform research on NFRC.

摘要

近几十年来, 由于天然纤维增强复合材料 (NFRC) 在汽车、纺织、家具、医疗保健和生物燃料等领域的潜在应用, 其研究进展迅速, 许多学术出版物也在发表. 因此, 我们试图通过使用新的科学计量学和网络分析工具, 对2010年至2022年间从Scopus数据库中提取的1143篇文章进行研究, 从而对NFRC文献进行概述. 由于今天的科学产出成为决策者关注的焦点, 手稿中的新颖之处, 即对不同学科进行科学计量和网络分析, 并跟踪其最新发展, 引起了大多数研究人员和学者的极大兴趣. 通过这项工作获得的结果描述了迄今为止发表的研究的实际影响及其使用情况, 也为希望对NFRC进行研究的新研究人员提供了方向.

**KEYWORDS**

Scientometric analyzing; network analyzing; citation; co-occurrence; natural fiber; reinforced composites

**关键词**

科学计量分析; 网络分析; 引用; 共现; 天然纤维; 增强复合材料

## Introduction

Strength of an engineering material plays key role in defining its usability, durability, and life cycle. Engineers primarily focus on enhancing the materials strength by incorporating an additive in any form such as powder, solid, liquid, and fiber (Andrzej et al. 2002; Laly et al. 2003; Zainuddin et al. 2013). Addition of fibers into engineering components, parts, and elements is being done to enhance specific engineering characteristics of the material to suit rigorous need and demand (Arun et al. 2020; Bejjam et al. 2020; Thangapandi et al. 2020). Fiber addition into engineering materials was being researched by bountiful researchers across the globe during the last few decades, and it has a lot of scope (Jaspert et al. 2021; Ramesh et al. Forthcoming) and potential (Gobinath et al. 2019; Palanisamy et al. 2020) to study (Misra et al. 2019). In these research works,

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numerous fibers both naturally available and manmade fibers were incorporated into various materials and their characters were studied. Numerous natural fibers were also studied for countless engineering applications that proved not only to be viable but also to be economical and sustainable. Also, abundant availability and accessibility of natural fibers were the major reasons for an emerging new interest in sustainable technology such as patents (Hobbs 1974; Vieth, Flachenecker, and Siejak 2014) and books on fiber-reinforced material (Schmiemann, Bledzki, and Ehrenstein 1990; Thomas, Harrats, and Groeninckx 2006). While focusing on the composite materials, few main points to be considered are environment friendliness and material weight, with high specific properties, as many products that are having high strength are proved to be unsustainable. To enhance sustainability, researchers are focusing on utilization of sustainable resources that will enhance strength and durability. Natural fibers have proven to be such kind of resource, which will be renewed by nature and human ingenuity for thousands of years (Ramesh, Palanikumar, and Reddy 2017). The natural-fiber-reinforced composites (NFRCs) are increasingly gaining impetus due to their important characters and properties such as recyclability (Adekomaya 2020; Boopathi, Sampath, and Mylsamy 2012; Ng et al. 2019), environmental friendliness (Mahmoudi and Hebbar 2012), lightweight (Awoyera, Adesina, and Gobinath 2019; Awoyera et al. 2020; Gobinath et al. 2019), biodegradability, and non-toxicity that allow them to gain their wide acceptance in industries (Awoyera et al. 2019a, 2019b). This century has witnessed remarkable achievements in enabling greener and sustainable technologies in the broad field of material science with the manufacturing of high-performance materials made of by-product.

Additionally, fibers used for engineering applications were classified into three types based on their origins: plant, mineral, and animal fibers. Animal fibers such as hair and silk and mineral fibers are not widely used as reinforcement fibers, but several plant fibers are being used widely in bio-composites with bountiful applications in the areas such as automotive, marine, and construction (Ramamoorthy, Skrifvars, and Persson 2015). During the last two decades, there have been tremendous interest and technological developments in the field of bio-composites primarily targeting engineering applications. Plant fibers can be derived from various natural agro-sources, with the preferred choice as a composite reinforcement often being driven by abundance, geographical location, and historical use (Bourmaud et al. 2018; Dungani et al. 2016). Plant fibers can be considered a reinforcing material to substitute the more expensive polymers and enhance the green credentials of the final composite. Due to better mechanical performance, unidirectional plantfiber-reinforced polymers are used for more applications than randomly oriented glass-fiber-reinforced polymers (GFRP) (Fortea-Verdejo et al. 2017). Considering one domain such as automobile industry, majority of the automobile manufacturing companies are now exploring the usage of recyclable or biodegradable materials for part replacement, making NFRC a material for the future (Adekomaya 2020).

However, this rising trend of using NFRCs has stimulated the continuous exploration of their mechanical properties. The usage of natural fiber cannot alone improve the properties of the composites, fiber orientation also plays a significant role in improving the mechanical properties of the FRP composites (Retnam, Sivapragash, and Pradeep 2014). Probably, the optimization of the interfacial bonding between the reinforcing plant fiber and polymer matrix is the important aspect with respect to the formulation of plant-fiber-reinforced composites (PFRCs) with superior mechanical properties. While the interface plays a key role in determining the mechanical properties, e.g., transferring the stress and distributing the bond, it is among the least understood components of the composite (Zhou, Mizi, and Lihui 2016). Since there is a significant supply of plant materials, an increasing interest is seen in their application in various composite manufacturing processes (Jones et al. 2017), and natural fiber, bamboo, flax, hemp, and coir, has different microstructure and chemical composition that are not present in cement-based material. Physico-mechanical properties of natural fiber are strongly related to the content of fiber. Fiber has had high stretching property toward failure as well as its high stress resistance and stiffness increaser properties. Based on the unique properties of

the fiber, it is expected from fiber to fill the gap areas mentioned previously and to provide new contribution in the cement-based materials developing for advance concrete construction applications.

On the other hand, outcome of any research will end up in dissemination through print or online research journals, books, and other sources that serves as platform where future authors source information for their research work. Hence, it is mandatory to analyze the number of such research papers published during last few decades that will show the progress of research in this domain. Several methods were employed to analyze such patterns, once such is bibliometric. It is a concept of using statistical methods to analyze various publication sources; this is used widely in various fields including library and information science. Among various techniques used in bibliometric analysis, citation analysis is widely adopted by several researchers that focuses on generating citation graph or a network graph or any other kind of suitable graphical representation informing citations between documents. It is a proven solution and numerous research fields use bibliometric analysis and its related fields to arrive at the impact of a particular research field or to obtain the impact of a specific research paper or to identify multiple works within a particular domain and to obtain the potential impact of certain researchers. Scientometrics, a sub-field of bibliometrics, is a scientific field that focuses on measuring and analyzing the impact of scientific literature published in academic journals. It helps in understanding the pattern of citations and the usage of the published articles among scientific fraternity focusing on policy making and management context. The outcome of scientometrics research always helps in several issues including policy decisions and in management context. But, majorly, the primary aim of those two studies is to analyze institute-level impact on research done in a particular field such as obtaining top authors, top papers, top journals, and so on. This paper mainly focuses on scientometric study of natural fibers, with more emphasis on plant fibers that are key parts of bio-composites reinforcements. The primary aim of this work is to provide sufficient information related to works done, top authors, top journals, top institutes, and top countries that did research related to FRC in the last few decades.

The aim of this designed research work is to provide information related to the NFRC-based research conducted across the globe by several researchers in a systematic way by using bibliometric database output. Future directions can be obtained by the researchers who wish to work on this domain with the information provided related to NFRC. Keywords in this work indicate all the keywords including author defined, indexed by Scopus, and keywords search algorithm uses. The objective of this work is to give an in-depth analysis of the contribution carried out on NFRCs over the past decade using bibliometric analysis. The study does so by examining the literature published in leading journals indexed in Scopus database. This analysis helps in identifying the most productive research in the field of natural fiber composites and citations used by researchers in their studies. As a result, the contributions made by authors identify and weigh up the linkages between the main articles, topics already covered, and contributors in this topic and consequently, provides directions for future research. This study also serves as a quantitatively supported starting point for a literature review in further studies of NFRCs and provides a basis for conducting meta-analysis.

## Classification, usage, and novelty of plant fibers

The plant fibers are grouped into different categories and can be classified according to their origin, derivations of the plant, which are shown in Figure 1 (Ramesh, Palanikumar, and Reddy 2017). There are six types of plant fibers, namely bast/stem fibers, leaf fibers, seed/fruit fibers, stalk fibers, grass/reed fibers, and wood fibers.

(i) *Bast fibers*: These fibers may be delineated as those separated from the outer cell layers of the stems of various plants. The examples of these plant fibers are abaca, banana, flax, hemp, jute, kenaf, ramie, and soyabean. Bast fibers are made up of a bundle of pipe-like cell walls. These fibers are extracted by retting process and are carried out by means of biological or chemical degradation of plant stems. These fibers are normally longer in length and characterized by higher mechanical

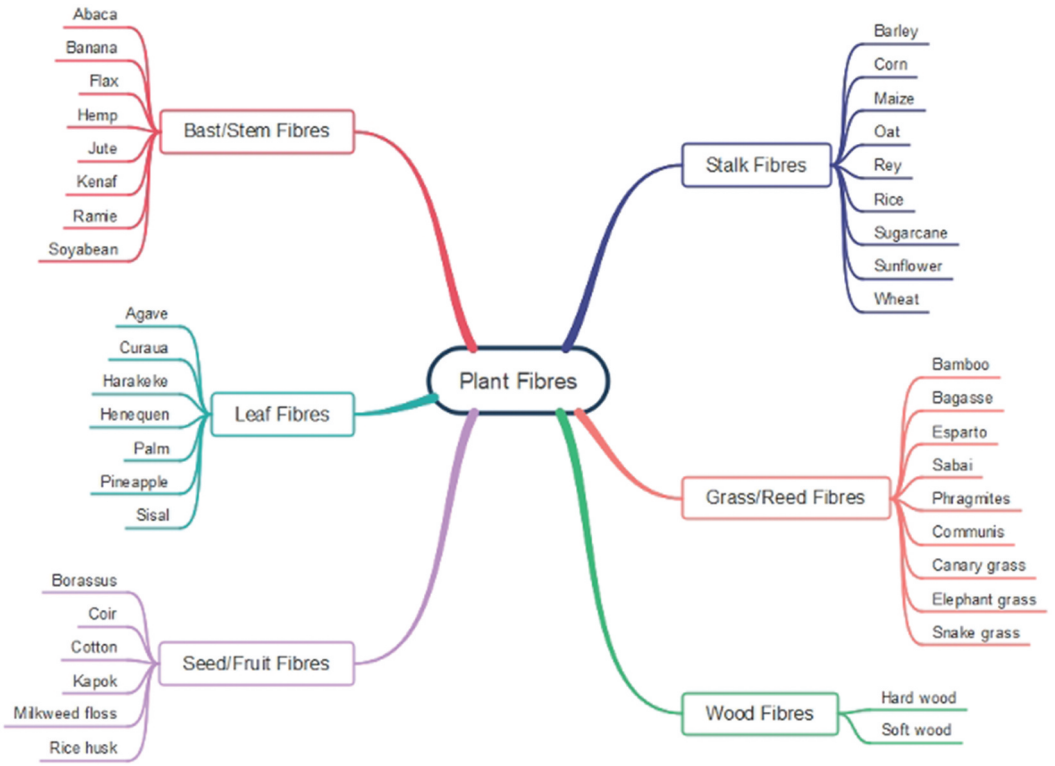


**Figure 1.** Classification of plant fibers through different categories according to their origin and derivations of the plant.

strength. Thus, they are traditionally employed in making fancy bags, curtains, yarn, cloth, rope, and so on (Ramesh, Palanikumar, and Reddy 2017). (ii) *Leaf fibers*: These are primarily stiffer and coarser structure than bast fibers and hence have limited industrial applications. By mechanically scraping the non-fibrous material, leaf fibers are produced (Sfiligoj Smole et al. 2013). The relatively high strength of leaf fiber finds its applications in making of woven ropes, fabrics, carpets, mats, and so on. The typical leaf fibers are agave, curau, harakeke, henequen, palm, pineapple, sisal, and so on. (iii) *Seed/Fruit Fibers*: These fibers are in general derived from the outer husk of the various fruits. The coir fiber is a best example for fruit fiber, which is extracted from the coconut husk. These fibers are strong and light in weight, mainly used in making ropes, mats, sacks, brushes, geo-textile, and so on. Other types of seed fiber is produced from the pod or boll of plant seeds. The examples of such fibers are borassus, coir, cotton, kapok, milkweed floss, and rice husk. (iv) *Stalk fibers*: These fibers are obtained from stalks/straws of plants and crops such as barley, corn, oat, rey, rice, sugarcane, sunflower, wheat, and so on. The pulp derived from some of the stalk fibers has applications in paper making industries. (v) *Grass/Reed fibers*: These fibers were extracted from the tall grasses and fibrous crop residues such as bamboo, bagasse, esparto, sabai, phragmites, communis, canary grass, elephant grass, and snake grass. Fiber reinforcements in cement-based composites use fibrous crop residues. (vi) *Wood fibers*: The fibers obtained from various trees can be classified into two types, such as softwood and hardwood. Softwood fibers are normally longer than hardwood fibers. These fibers are treated through industrial processes to enhance bonding. Due to this controlled processing, these fibers ensure better dimensional stability and mechanical properties compared with the unprocessed plant-based fibers.

It is noted from the literature that fibers that undergo chemical treatment (Sridhar, Gobinath, and Kırgız Forthcoming) and physical modifications exhibit enhanced fiber-matrix interfacial adhesion in the composite (Cichosz and Masek 2019; Del Masto et al. 2019; Salasinska and Joanna 2014; Zhang

et al. 2014) and improve mechanical properties of the composite (Adekomaya 2020; Ahmad, Hamid, and Osman 2019; El Oudiani et al. 2009). Furthermore, studies on the more recent developments in the analysis of the major chemical constituents, such as cellulose, hemicellulose, and lignin of plant fibers (Hamawand et al. 2020), also consider the methods for improving properties of plant fibers via chemical treatments (Jones et al. 2017). There is a lot of scope for future research on chemical treatment and physical modifications of plant fibers that find more applications of PFRCs (Ahmad, Hamid, and Osman 2019). Table 1 summarizes the variations in chemical composition of select plant fibers.

## Possible practices of fiber

The latest technological developments on manufacturing of fiber provided attractive performance and sustainability for materials containing fiber. Till now, these materials were used mostly in vehicle products and some construction applications, with the advantages. If these fiber-filled materials are to be induced in other sectors of industry, as for instance goods of household, there are fundamental properties that they need to accomplish: durability, resilience, functionality, usability, and reliability. This argument depends on a major area of influence: properties of mechanic (Peças et al. 2018).

### *Properties of mechanic*

Recently, fiber-filled-material-related technology was developed to enable better mechanical characteristics in various components. With the broad effort, it is possible for fiber-filled materials to universalize in other fields of application. As it will be understood from the study, the information of the materials, manufacturing steps, and design stages must make a greater level of reliability. Nowadays, grand effort is being made to make fiber-filled material overcome mechanic issue in construction. In fact, some cellular plates and beams were built as structural frame in the construction industry, which was made from hemp, jute, and flax fibers in polyester resin. The results of experimentally tested structural frame containing fiber showed that the force-carrying-material-filled fiber developed the mechanical properties at desired level. The practices depend on additional developments of fiber in other sectors of industry. However, as we will understand from the literature works, natural composite containing fiber is a cost-effective solution compared to other material, and, although a limitless recyclable solution is needed, this effort of review and scientometric analysis also opens further interest (Peças et al. 2018).

## Methodology

This paper presents a hybrid approach to systematically review research on NFRCs by integrating bibliometric and complex network analyses. A description of the research process and integration of analytical tools is shown in Figure 2.

The collection of data from the existing literature was critical to this research, particularly for the conclusion drawn from the scientometric analysis. Scopus was chosen as the database for this study due to its comprehensive coverage of journals and knowledge domains in comparison to other databases such as Web of Science, Google Scholar, or PubMed. A two-level search string is applied on Scopus database focusing on NFRCs for the period 2010–2022. It is observed that nearly 76% of the total articles were published only during the last decade. Figure 2 presents the search process wherein query sets related to natural fiber and composites are applied. As a result, the following search string was custom made for this research. TITLE-ABS-KEY (“plant fib*” OR “natural fib*”) AND ((“Reinforced composite*”) OR (“Reinforced polymer*”)). Thus, the set of these keywords identify the possible combination research topics studied on NFRC. The search process excludes articles in press and sources other than journals and conference proceedings. Figure 3 shows number of publications and their corresponding citations in the field of NFRCs during last decade and

**Table 1.** The variations in chemical composition of plant fibers selected.

| Fiber | Cellulose (wt %) | Hemicellulose (wt%) | Lignin (wt%) | Wax (wt%) | References |
|---|---|---|---|---|---|
| Bast/Stem Fibers | | | | | |
| Abaca | 62.5 | 21.0 | 12.0 | 3.0 | (Ramesh, Palanikumar, and Reddy 2017; Liu and Li 2017) |
| Banana | 62.5 | 12.5 | 7.5 | - | |
| Flax | 72.5 | 14.5 | 2.5 | - | |
| Hemp | 81.0 | 20 | 4.0 | 0.8 | |
| Jute | 67.0 | 16.0 | 9.0 | 0.5 | |
| Kenaf | 53.5 | 21.0 | 17.0 | - | |
| Ramie | 72.0 | 14.0 | 0.8 | - | |
| Soyabean | 29.0–51.0 | 10–25 | 1–4 | - | |
| Leaf Fibers | | | | | |
| Agave | 59.0 | 38.4 | 2.5 | - | (Ramesh, Palanikumar, and Reddy 2017; El Oudiani et al. 2009; Efendy and Pickering 2014; Zhang et al. 2015) |
| Curaua | 73.6 | 5.0 | 7.5 | - | |
| Harakeke | 60.9 ± 4.4 | 27.3 ± 4.1 | 7.8 ± 1.3 | | |
| Henequen | 60.0 | 28.0 | 8.0 | 0.5 | |
| Palm | 28.16 | 20.6 | 44.07 | - | |
| Pineapple | 80.5 | 17.5 | 8.3 | - | |
| Sisal | 60.0 | 11.5 | 8.0 | - | |
| Seed/Fruit Fibers | | | | | |
| Borassus | 68.94 | 14.03 | 5.37 | 0.64 | (Ramesh, Palanikumar, and Reddy 2017; Boopathi, Sampath, and Mylsamy 2012; Sfiligoj Smole et al. 2013; Clément et al. 2018) |
| Coir | 456.0 | 0.3 | 45 | - | |
| Cotton | 89.0 | 4.0 | 0.75 | 0.6 | |
| Kapok | 35–50 | 22–45 | 15–22 | 2-3 | |
| Milkweed floss | 40–45 | 35–40 | 15.0 | 3.0 | |
| Rice husk | 28–36 | 23–28 | 12–14 | 14-20 | |
| Stalk Fibers | | | | | |
| Barley | 31–45 | 27–38 | 14–19 | 2–7 | (Ramesh, Palanikumar, and Reddy 2017; Dungani et al. 2016; Jones et al. 2017; Salasinska and Joanna 2014) |
| Corn | 38–40 | 28 | 7–21 | 3.6–7 | |
| Oat | 32.0–37.3 | 31.0–36.4 | 2.3–9.8 | 2.6– | |
| Rey | 26.0 | 16.0 | 13.0 | 7.0 | |
| Rice | 30.4–44.0 | 20.1–32.3 | 8.6–19.0 | 34.0 | |
| Sugarcane | 55.6–57.4 | 23.9–24.5 | 24.35– | - | |
| Sunflower | 37.3 | 35.0 | 26.3 | - | |
| Wheat | 33–38 | 26–32 | 22.9 | - | |
| Grass/Reed Fibers | | | 17–19 | 6.8 | |
| Bamboo | 34.5 | 20.5 | 26.0 | - | (Ramesh, Palanikumar, and Reddy 2017; Jones et al. 2017; Guna et al. 2019; Oleszek et al. 2014; Brant et al. 2017; Sathishkumar 2015) |
| Bagasse | 37.0 | 21.0 | 22.0 | - | |
| Esparto | 33–38 | 27–32 | 17–19 | - | |
| Sabai | 67.7 ± 0.5 | 12.9 ± 0.2 | 14.3 ± 1.3 | - | |
| Phragmites | 44–46 | 20.0 | 22–24 | - | |
| Communis | 44–46 | 20.0 | 22–24 | - | |
| Canary grass | 29.76 ± 0.30 | 25.80 ± 0.84 | 8.04 ± 0.02 | - | |
| Elephant grass | 35.17 | 26.12 | 9.01 | - | |
| Snake grass | 80.0 | 11.25 | 7.8 | - | |
| Wood Fibers | | | | | |
| Softwood | 40–50 | 6–10 | 27–30 | - | (Saka 1993) |
| Hardwood | 45–50 | 15–20 | 20–25 | - | |

classification of publications based on the type of documents. One thousand nine hundred and forty (n = 1940) academic papers were identified in the initial search. Among these 55.7% were journal articles, 28.5% were conference proceedings papers, 7.5% were book chapters, and 8.3% were classified as 'other.' We screened the initial selection to include English papers only (n = 1917). Further


**Figure 2.** The flowchart for generating dataset – a description of the research process and integration of analytical tools.

screening included top 10 contributing countries in the field, papers in the final stage of publication, journals and conference proceedings as sources, document type as articles, and conference papers. After refinement, the final study database comprised 1143 research publications.

This study uses the network analytical tool VOSviewer (version 1.6.15) that is an open-source platform well suited to visualize large datasets and relationships. A network is used to represent research papers, keywords, countries, and authors as nodes to understand contributions and relationships among them. VOSviewer creates maps using bibliographic data and evaluates co-authorship, keyword co-occurrence, citation, bibliographic coupling, or co-citations of documents drawn from a data source viz., Web of Science, Scopus, PubMed, and so on.

## Results and discussions

### *Interface interactions among fiber and cement-based material*

Since fiber stack is properly dispersed with no accumulation in the cement-based system, there will be no crack through material. Cracking control capacity of fiber relies on the mechanic characteristic properties of fiber: tensile strength, flexural strength, compressive strength, as well as the bonding capacity between fiber and cement, also known interface. The concept of interface is considered from the literature referring to a basic adhesion that is from a molecular level to a microstructural level. Fiber coating, a softened interfacial bond, and developed fiber–matrix compatibility could help the interface formation and performance modification. Since the interface of fiber–cement matrix is a formation which is for cracking, its withdrawing strength sets fiber efficiency at early age. The length of fiber was defined as a lower significant part of strength

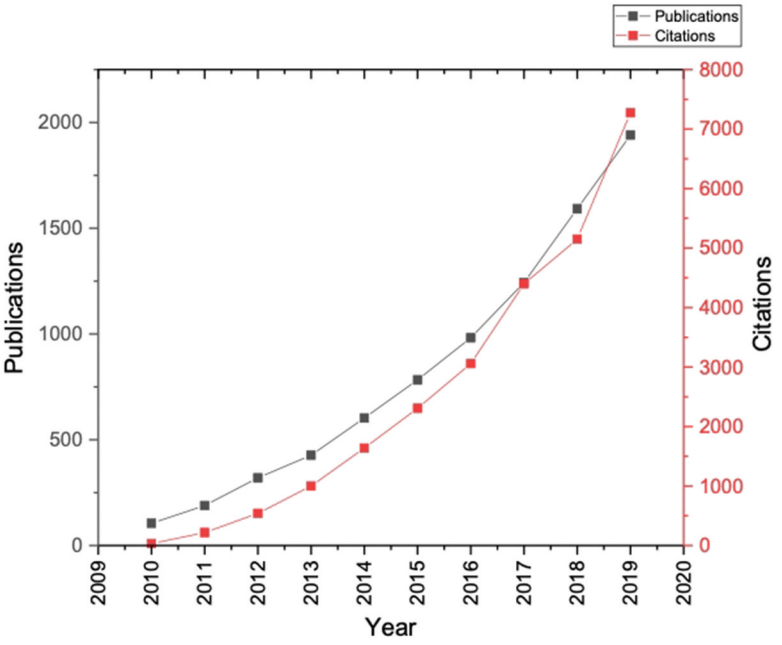


**Figure 3.** Number of publications and their corresponding citations in the field of NFRCs during last decade, and classification of publications based on the type of documents.

of interface since the strength does not escalate importantly over 1 mm interfacial length. Furthermore, fiber length was described to significantly decrease the toughness of fiber–matrix, as lengthy fiber failures occur majorly due to fiber fracture, which uses less fracture energy than that of short fiber (Peças et al. 2018).

## *Performance of journals*

The 1143 articles considered in our analysis were published in 314 different journals and conference proceedings. The top 10 journals publishing articles related to NFRCs (listed in Figure 4) account for 28.4% of total publications. Among these sources, Materials Today Proceedings (ISSN: 2214-7853) has the most publications addressing NFRCs (89 articles), followed by IOP Conference Series Materials Science and Engineering (42 articles), Composites Part B Engineering (32 articles), and Journal of Reinforced Plastics and Composites (29 articles). The subject matter descriptions of the top 10 journals include natural fibers, plant fibers, and/or reinforced composites.

Figure 5 indicates the bibliography coupling between the documents that indicates the probability of two documents citing one or more documents in common. For this analysis, out of 1143 documents available, 53 documents that meet thresholds of minimum 50 citations are considered. The first 20 documents with highest number of citations are considered for computing the total strength of the bibliographic coupling links with other documents, and the link strengths are shown in Figure 5. Though the article published by Ku et al. has the highest number of citations (Ku et al. 2011), the bibliographic coupling link strength is high for the articles (Kabir et al. 2012; Sanjay, Arpitha, and Yogesha 2015) published.

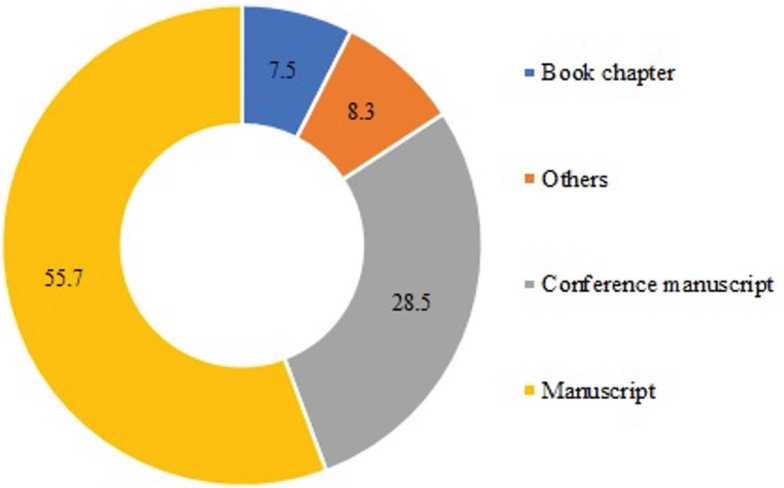


**Figure 4.** The top 10 journals publishing articles related to NFRCs.

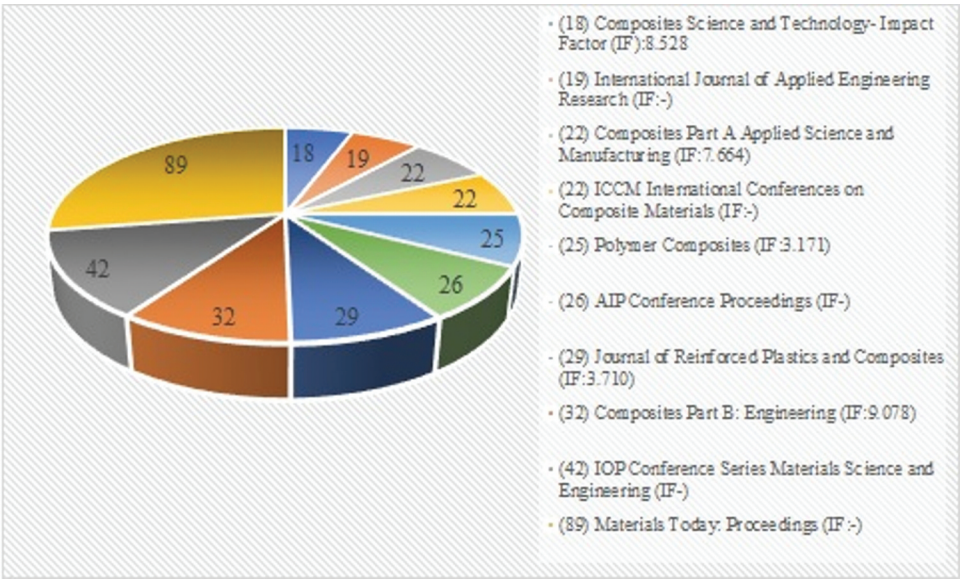


**Figure 5.** Top 10 contributing journals publishing articles in the field of NFRC.

## *Co-occurrence analysis*

To analyze the most-used words in the article titles, abstracts, and keywords, the data were extracted from Scopus data file. The authors of the research articles in our sample used 5955 different keywords to classify their studies. Table 2 and Figure 6 show the top 20 keywords with more than 50 occurrences in the articles. Figure 6 generated by VOSviewer represents overlay visualization in which keyword occurrences are shown with different colors. The color of a keyword is determined by the score of it, and the colors range from blue (lowest score) to green to yellow (highest score). The top 20 keywords with the greatest total strength of the co-occurrence links with other keywords are shown in Figure 6. It is observed from the color coding that 'mechanical properties' has the highest co-occurrence score followed by 'polymer matrix composites' and 'natural fiber reinforced.' These keywords have a strong

**Table 2.** Top 20 keyword search results.

| Keyword | Frequency | Keyword | Frequency |
|---|---|---|---|
| Natural Fiber* | 584 | Polymer Matrix Composites | 121 |
| Reinforcement | 467 | Yarn | 118 |
| Fiber Reinforced Plastics | 458 | Polymers | 117 |
| Mechanical Properties | 385 | Hemp | 116 |
| Fibers | 344 | Flax | 112 |
| Composites | 240 | Natural Fiber Reinforced Composites | 110 |
| Reinforced Plastics | 230 | Linen | 108 |
| Tensile Strength | 220 | Water Absorption | 97 |
| Composite Materials | 192 | Polypropylenes | 91 |
| Scanning Electron Microscopy | 157 | Natural Fiber Reinforced | 77 |

* The frequency includes the terms, natural fiber/fiber

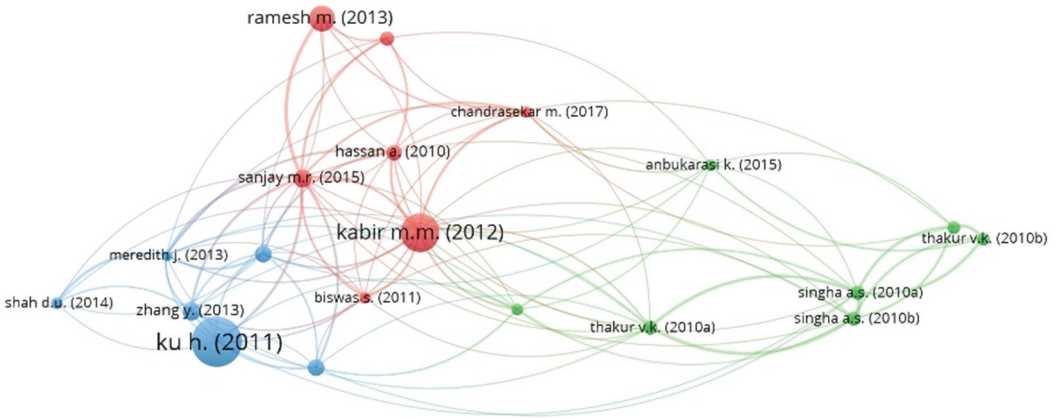


**Figure 6.** The top 20 keywords with the greatest total strength of the co-occurrence links with other keywords.

co-occurrence with other top keywords shown in Figure 6. It indicates that most of the researchers are interested to study mechanical properties of various types of NFRCs. Furthermore, many researchers were also interested to study about 'polymer matrix composites' and 'natural fiber reinforced' material in combination with other keywords shown in the network. It is always recommended to use the most-cited keywords because most cited means many of the researchers are interested to read (Mukhlif et al. 2019). The size of the nodes in the map indicates the weight of each keyword analyzed. The closeness of keywords, as well as lines, indicates the strength of their relationship. The first two keywords, "natural fibers" and "reinforcement," in the rank list give the expected results since they were among the selection criteria.

## *Performance of authors, institutions, and countries*

### *Performance of authors*

Bountiful research works being published in recent days in all research domains put thrust on understanding the real impact of those research works among scientific community. Understanding the impact of all those published articles, research works, books, and other materials is of utmost importance to the success and furthering the development of scientific dialog. Also, without having a clear understanding about the impact of published research article, it will be tough to derive a specific research direction (Hicks and Sylvan 2011). Although many metrics were developed (Bollen et al. 2009), to support understanding about the real impact of a published work, historically, number of citations an article may receive stands tall concerned with the acceptance level among research

fraternity (Gross and Gross 1927). While modern tools are developed to find the impact of a research, recent days scientometric research gives several parameters to check authors' performance. However, nothing dethrones citations from being a yardstick (Garfield 2006). It has been proven time and again that citations are widely considered as an index parameter and used as an indicator of a published works significance; yet, there are issues surrounding the usage of it (Baccini, Giuseppe De, and Eugenio 2019; Loannidis et al. 2019). It appears popular, particularly among science administrators, to use citations and various citation measures for ranking scientists, as if such exercises would reflect the scientific potential of the persons considered (Randić 2009). Hence, in this work, to arrive authors' performance, we had used citations as a measuring tool that is universally accepted parameter. Table 3 presents the top 10 natural fibers used for the composites and some mechanical properties and types of polymer binders.

Through this study, it is found that authors from multiple countries have contributed to the growth of research in PFRCs. Figure 7 shows top 20 keywords from papers published and citations received, respectively, based on information on the Scopus database. However, some other renowned authors in the field who have published their research for decades do not appear as the period considered for the current analysis is only between 2010 and 2022.

**Table 3.** The listing the top 10 natural fibers used for the composites and their mechanical properties and types of polymer binder.

| | Mechanical properties | | | | |
|---|---|---|---|---|---|
| Types of fiber | Tensile strength (MPa) | Young's modulus (GPa) | Flexural strength (modulus of rupture) (MPa) | Poisson's ratio | Types of polymer binder |
| Coir | 130–180 | 4–9 | 135–250 | 0.38–0.39 | Resin |
| Silk | 600–610 | 9–15 | NA* | 0.25–0.3 | Epoxy |
| Sisal | 60–515 | 9–25 | | 0.35–0.37 | Cement |
| Hemp | 285–600 | 65–75 | | 0.25–0.3 | Tar |
| Kenaf | 250–950 | 15–55 | | 0.34–0.36 | Bitumen |
| Flax | 350–1500 | 25–100 | | 0.25–0.3 | Gypsum |
| Ramie | 400–950 | 60–130 | | 0.34–0.35 | Lime |
| Cotton | 300–600 | 5–30 | | 0.25–0.3 | |

*The NA stands for the Not Available.

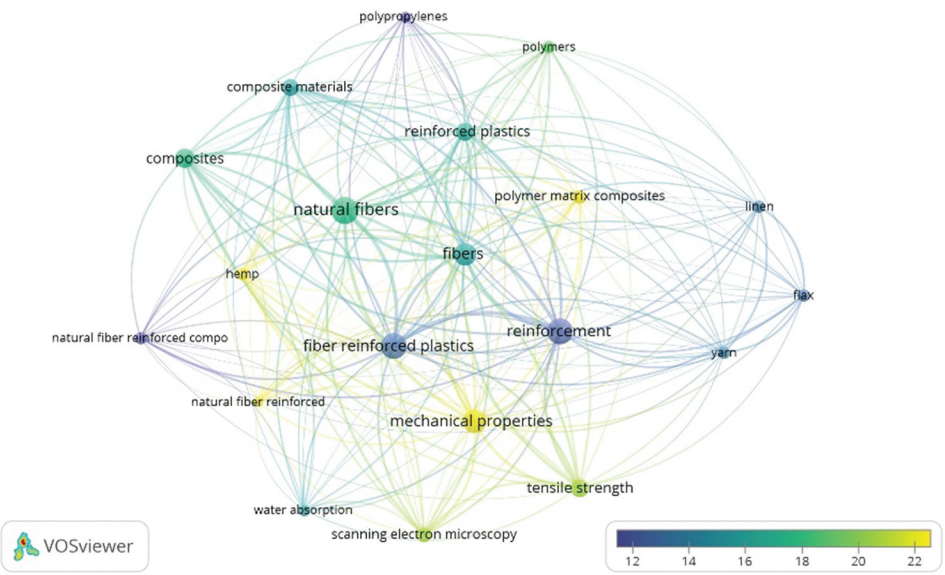


**Figure 7.** Providing top 20 keywords from papers published and citations received, respectively, based on information on the Scopus database.

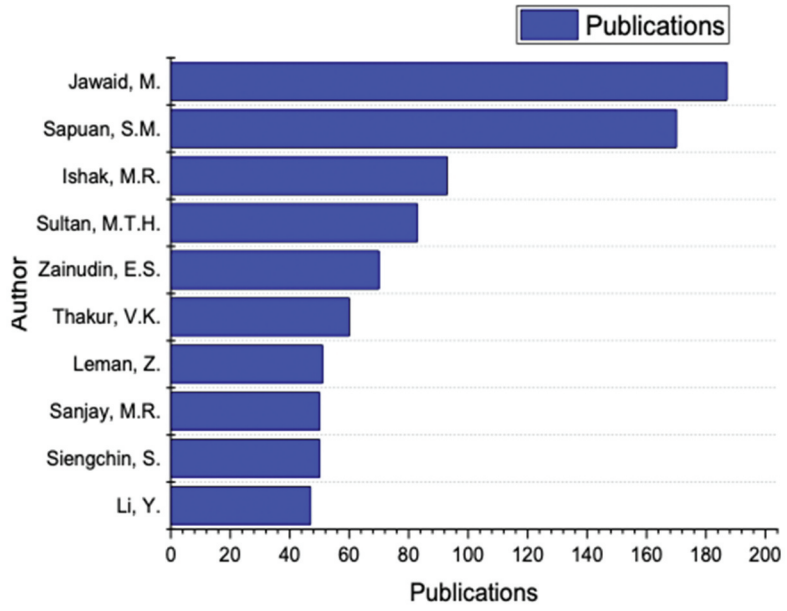


**Figure 8.** Providing top 10 contributors in terms of the number of papers published based on information on the Scopus database.

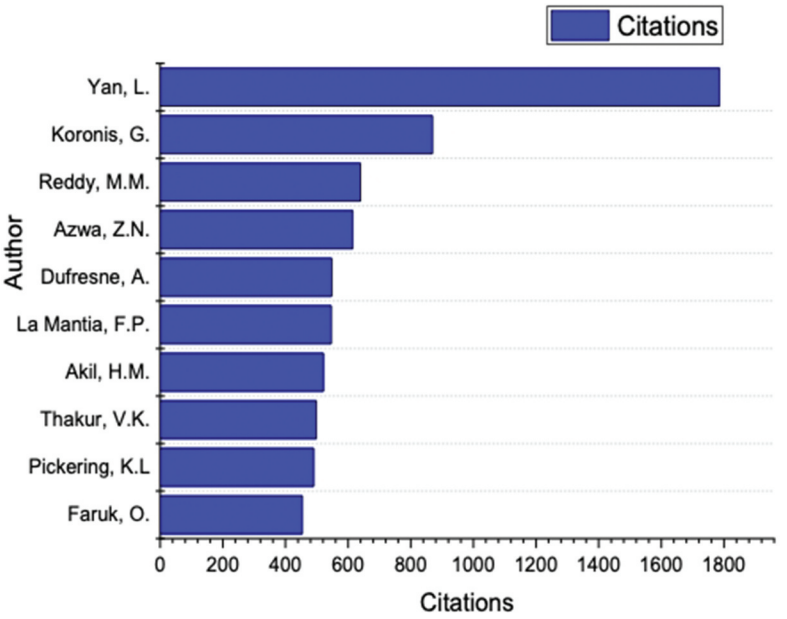


**Figure 9.** Providing top 10 contributors in terms of the received citations based on information on the Scopus database.

Figure 8 shows top 10 contributors in terms of the number of papers published based on information on the Scopus database. Top ten contributors are shown in the Figure 9, in terms of the received citations based on information on the Scopus database.

It is clear from the comparison between Figures 8 and 9 that there is a difference between the authors who has the highest number of publication and those who has the highest number of citations. Thus, it is evident from the data that quantity does not reflect the quality of the authors, the highest number of citations reflect it, or it may be attributed to several other factors including journal visibility and its impact factor that are not analyzed in this work. Thus, it is possible to identify the most influential authors in this field through this study whose contribution is well received. We had adopted only citation as analyzing tool, yet there are other tools available that is beyond the scope of this article. Hence, it is allowing the reader to identify key authors in the field. Furthermore, co-citation analysis of authors with minimum 100 citations is performed. Of the 30,653 authors contributed to the subject area, 52 met the threshold. For each of the 52 authors, the total strength of the co-citation links with other authors is calculated.

### *Performance of institutions*

Figure 10 shows that 160 institutions conducted research in this domain on fiber-reinforced composites between the years 2010 and 2022.

Researchers from Universiti Putra Malaysia published maximum number of papers (59 articles), followed by Tongji University (46 articles) Anna University, India (31 articles), Under Ministry of Education China affiliation (22 articles), Indian Institute of Technology Roorkee, India (21 articles), and Sathyabama Institute of Science and Technology, India (20 articles), and these are the leading institutions with minimum 20 articles. It is observed that six institutions from India are in the top 10 contributing institutions in this field of study.

### *Performance of countries*

Figure 11 shows 10 countries with highest number of publications and citations in the field of PFRCs, namely India (532, 4538), Malaysia (173, 2143), China (140, 1833), USA (93, 1475), Germany (65, 811), France (59, 878), United Kingdom (55, 959), Canada (44, 394), Australia (36, 2200), and Brazil (36, 536). Figure 12 shows the highest number of publications and citations in the field of PFRCs in terms of country.

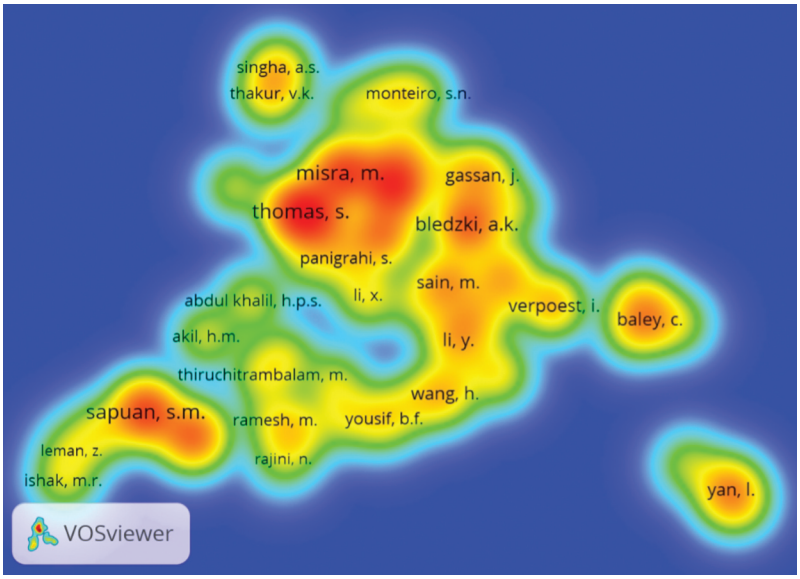


**Figure 10.** Figure shows that 160 institutions conducted research in this particular domain on fiber-reinforced composites between the years 2010 and 2019.

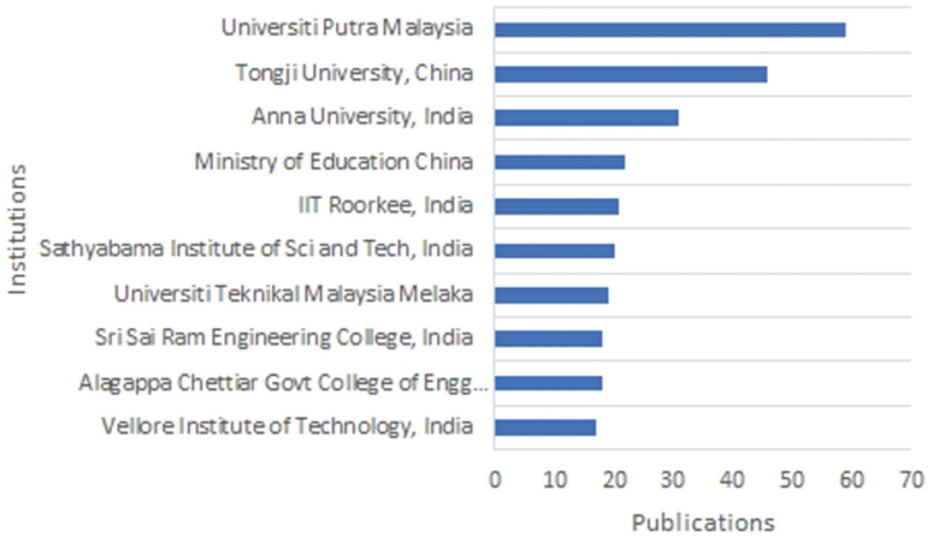


**Figure 11.** Ten countries with highest number of publications and citations in the field of plant-fiber-reinforced composites.

As seen in Figures 11 and 12, India tops the list with maximum number of publications and citations; it exceeds Malaysia and China in double and triple folds, respectively, w.r.t citations and publications. However, Figure 11 indicates Australia to be more productive in terms of citations, i.e., 2200 citations by just 36 articles, and as citations figure out to be the prominent quality indicator, we can conclude that their articles were read and used by many researchers.

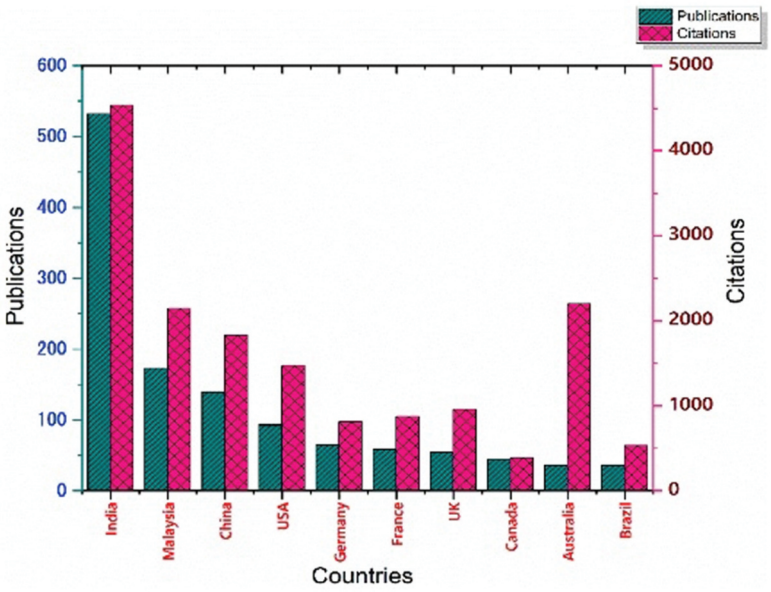


**Figure 12.** The highest number of publications and citations in the field of plant-fiber-reinforced composites in terms of country.

## Conclusions

A comprehensive review of the scientific literature on NFRCs using scientometric and network analysis tools is presented. The manuscript obtained the following conclusion.

- The results indicate a significant increase in number of publications, number of authors, average citations per year per manuscript, and the total numbers of countries conducting research during the last decade, i.e., between the years 2010 and 2022, which may be attributed to several factors including material availability, dissemination of information, and funding.
- The authors from various countries are leading in publishing several articles in the field of NFRC. It is observed that six institutions from India are in the top 10 contributing institutions in this field of study during the last decade. Though India tops in number of citations, Australia was found to be more productive and was able to create much impact on research community of NFRC with just 36 articles. Universiti Putra Malaysia is the leading institution in NFRC research followed by Tongji University, China. The leading sources that published articles in NFRC are Material Today Proceedings and IOP Conference Series Materials Science and Engineering that indicates many research works related to NFRC are being published via conferences. Even though authors had attempted to explain the research works being conducted, still there are limitations of this research that include the following: (i) the findings of the contributions were calculated only during last decade and (ii) limited keywords were searched using an abstract–title–keyword search on Scopus database.
- Furthermore, the use of natural fibers is likely to expand beyond a single application in near future and may find several applications in the fields of textiles, furniture, healthcare, biofuels, and so on. However, there is a need to identify most-suitable NFRC for a specific application. There is no point in using expensive fibers to make reinforced composites without much gain in terms of mechanical properties compared to non-expensive fibers. Thus, the future researchers can focus on decision-making process that maps various NFRCs to specific applications through bibliometric studies that will help the researchers working in this domain.

## Highlights

(1) Several manuscripts on natural-fiber-reinforced composite are evaluated.
(2) Classification, usage, and novelty of natural fiber are summarized.
(3) Preparation of natural-fiber-reinforced composite is presented.
(4) The article reported such factor as co-occurrence analysis.
(5) It is shown that there is a significance on natural fiber publication.

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## Ethical approval

We confirm that all the research meets ethical guidelines and adheres to the legal requirements of the study country. The research does not involve any human or animal-welfare-related issues.

## Data availability

The datasets generated during the current study are available from the corresponding author on request.

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