

## **A BIBLIOMETRIC REVIEW OF RESEARCH TRENDS IN WOOD ANATOMY AND CHEMISTRY**

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### **Abstract:**

*Those who work with wood should have a basic knowledge of wood anatomy and chemistry so they can understand how different anatomical and chemical features influence wood properties and, in turn, how these properties contribute to different treatments and final wood utilization. However, little attempt has been made to map global research trends in wood anatomy and chemistry. This paper presents a bibliometric review of research trends in wood anatomy and chemistry to determine research trends and gaps in these research areas. A total of 183 publications on wood anatomy and chemistry from 1974 to 2023 were reviewed. The analysis was done with the VOSviewer software (version 1.6.13). The analysis focused on the bibliographic coupling of countries, co-authorship of authors, citation of documents, and co-occurrence of keywords, which were presented as network visualization maps. The findings revealed that the wood anatomy and chemistry publication trends, although not completely gradient, have been upwards since 2000. Countries including Germany, the United States, Switzerland, the United Kingdom, Brazil, the Netherlands, China, Italy, Mexico, Spain, the Czech Republic, Canada, Australia, Chile, Finland, France, Sweden, and Japan had a great impact on this research area. It also became evident that African countries lag in this area of research. Only one data source - Scopus - was used. It has a wide coverage of publications from diverse areas and provides researchers with information on the most important academic literature in any specific scientific domain.*

*Therefore, the representation of publications presented in this study is limited to only the Scopus data source.*

**Key words:** wood anatomy; chemistry; overlay visualization; VOSviewer.

### **INTRODUCTION**

Wood is a complex plant tissue composed of several distinct types of cells. The selection of a particular tree species for various end uses is, in most cases, based on the physical, anatomical, mechanical, and chemical properties of the wood. Though used worldwide, wood has disadvantages, such as being susceptible to damage by radiation, chemical, and biological agents. The macroscopic structure of wood, the arrangement of wood cells, and the shapes of the cells need to be investigated well for effective and efficient use. Wood anatomy is concerned with the study of wood's microscopic and macroscopic structure. The synthesis of structural components and the anatomy of wood are both impacted by biotic and abiotic growth conditions simultaneously, highlighting the connection between the two characteristics.

It also investigates the relationship between different cells and their structure which may eventually lead to the identification of woods and their classes (Brian 2010).

Tropical deforestation is of global concern towards sustainable timber and non-timber forest products as well as biodiversity conservation. The high international demand for timber, processing (legal and illegal) activities, fuelwood collection, charcoal production, human settlements, and overexploitation beyond annual allowable cut (AAC) are the major drivers of deforestation, particularly in Africa (Damnyag 2012; Kissinger et al. 2012). Timber species and non-timber forest resources such as bamboo and rattan offer several benefits and therefore underscore the need for more research on their properties about their final utilization.

Although studies on wood anatomy and chemistry in general abound, there is no evidence of studies that identified the research trends in wood science studies. Evidence of bibliometric reviews in this area of

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study is lacking. This paper presents a bibliometric review of research trends in wood anatomy and chemistry studies. The output of publications, key authors, and the collaborations among authors and countries, as well as the network of keywords, were explored with the aid of network visualization maps to identify research trends in this area of study. The first 9 sources include a wider scientific area than wood anatomy this can help wood scientists and technologists to become familiar with the current research trends that could promote effective research in the wood and wood-based resources.

## METHODOLOGY

The Scopus database was selected as the data source for this study. Hosseini et al. (2018) believe that the Scopus database has a wide coverage of publications from diverse areas.

Moreover, scientific research databases, such as Scopus, provide researchers with information on the most important academic literature in any specific scientific domain (Chadegani et al. 2013). This makes Scopus a credible database. This study focused specifically on global research trends in wood anatomy and chemistry. Consequently, the specific keywords used for the search were: “wood anatomy” and “wood chemistry”. The search was limited to documents published from 1974 to 2023. This helped to demonstrate how research on wood anatomy and chemistry has evolved. The first search resulted in a total of 487 documents. The search was further refined to include only articles including literature reviews, conference papers, and book chapters published in the scientific areas of wood anatomy, wood chemistry, plant biology, dendrochronology, and wood physics. This resulted in a reduction from 487 to 413 documents. The search was further limited to only documents published in English resulting in a reduction from 413 to 397 documents.

The second stage was the screening; the titles and abstracts of the 397 documents were further screened to eliminate papers that did not align with the research title or theme. This was done by analyzing the content of the titles and abstracts. After the screening, a total of 183 documents were deemed appropriate for the study. The list of publications downloaded on 28<sup>th</sup> December 2023. The filtering and screening of the titles and abstracts were completed within a week.

A bibliometric review was then conducted in the third stage to analyze the 183 documents obtained in the second stage. The bibliometric review was done with the VOSviewer software version 1.6.13). (<https://www.vosviewer.com/>). Bibliometric review is a quantitative technique involving the visual and logical analysis of articles by assessing, mapping, and identifying structural patterns in a research domain using mathematical models, visualization clusters, and algorithms (Olawumi and Chan 2018). Van Eck and Waltman (2014) clarified that the VOSviewer software, a bibliometric analysis tool, can help to display large visualization networks such that they become easily interpretable. Therefore, for this study, data was imported from the Scopus database into the VOSviewer software to create a network and overlay visualization maps. Four visualization maps are presented in this study. The visualization maps used for the study are the bibliographic coupling of countries and sources, citation of documents and authors, and co-occurrence of keywords. The network visualization map represents items by their labels in a circle. Three factors – size, color, and link – influence the analysis of the network visualization map (Van Eck and Waltman 2019). First, the size of the label and the size of the circle of an item have a relation to the weight of the item; thus, bigger labels/circles represent higher weight. Secondly, all related items in a cluster network are presented in the same color.

Finally, items are linked with lines; thus, the distance between two items indicates their relatedness. For example, the closer two items are to each other, the stronger their relatedness (Van Eck and Waltman 2019). Moreover, the methodology used captured only the top 14 journal sources which are among the Q1 journal category. Fig. 1 shows the steps adopted in this study.

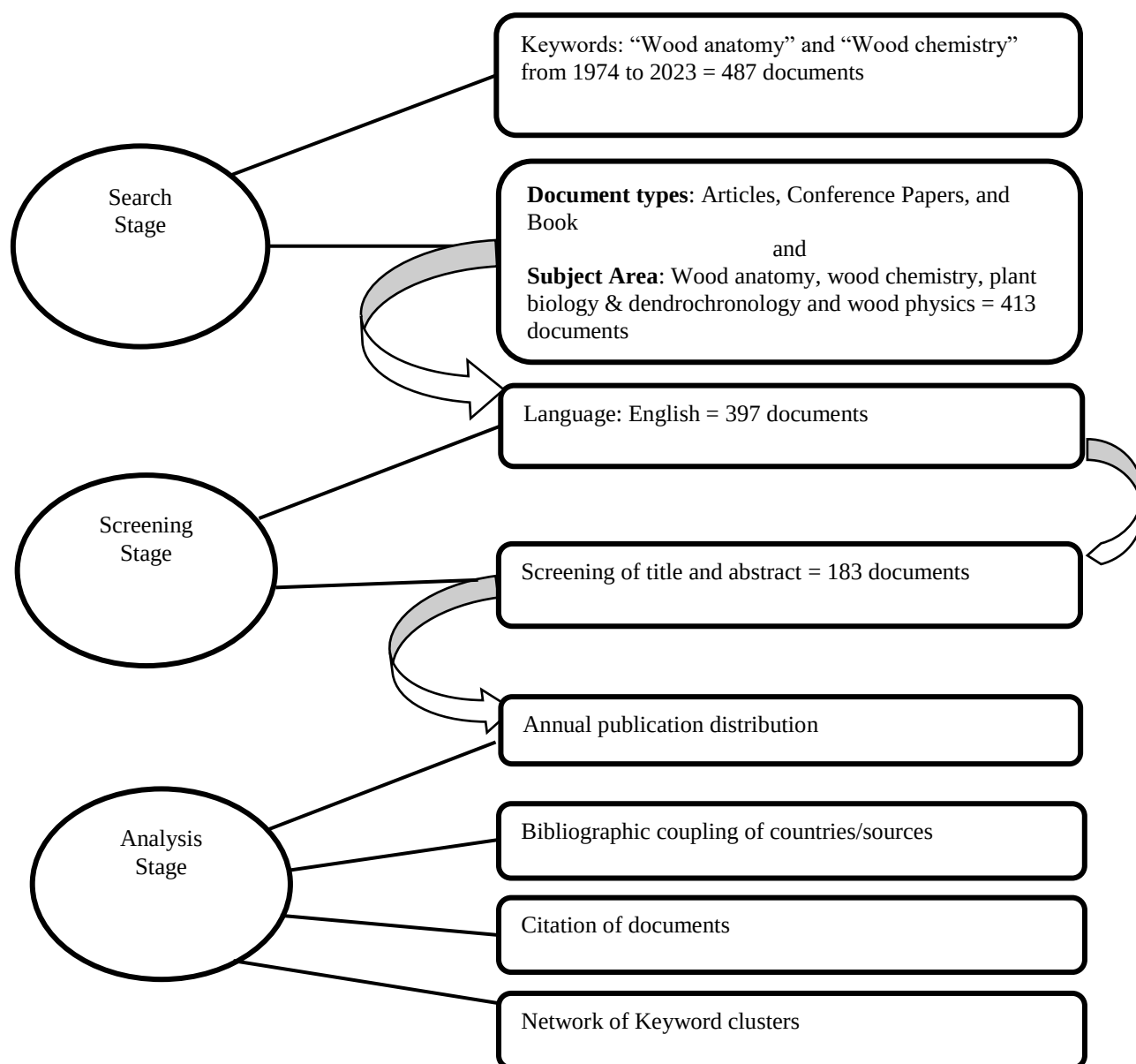


**Fig. 1.**  
*Graphical visualization of the steps followed in the methodology.*

## ANALYSIS AND DISCUSSION

### ANNUAL PUBLICATION DISTRIBUTION

The number of publications from 1974 to 2023 is demonstrated in Fig. 2. It is evident that no or low publication number was recorded between 1974 to 1999. A low publication average of 3 a year was recorded between 2000 to 2002. The number of publications increased from 9 in 2013, 21 in 2021 to 25 in 2022 and 31 in 2023; but, declined gradually from 2014, and 2017. A decrease was recorded in 2019 with 8 publications, whilst a gradual increase was recorded in 2020 with 18 publications. The highest increase was recorded in 2023 followed by 202 and 2021 with the number of publications 31, 25, and 21 respectively. This is probably due to a lot of conferences organized such as the International Youth Forum for Wood Anatomy and the 9th IAWA meeting held in Guangzhou China and the Summer meeting of the Anatomical Society held in Dublin with a specific focus on wood anatomy and chemistry. Although the trend has not been smooth, the general trend of publications has been upward.

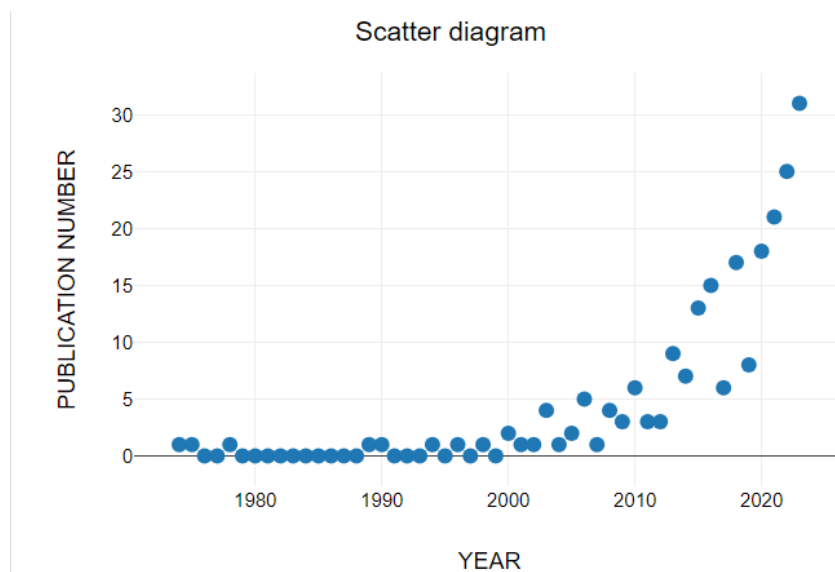


**Fig. 2.**  
*Annual publication research trend.*

#### BIBLIOGRAPHIC COUPLING OF COUNTRIES

A bibliographic coupling analysis of countries was done to first determine the number of publications recorded by each country, and secondly to evaluate the level of collaboration between the countries. The minimum number of documents of a country was set at 5, whilst the minimum number of citations of a country was set at 30. Out of the 56 countries, only 19 met the threshold. For each of the 19 countries, the total strength of the co-authorship links with other countries was calculated. The 19 countries with the greatest total link strength were selected. The United States had the highest number of documents, i.e., 33 with 1480 citations whereas Germany recorded the highest total link strength of 4377 with only 18 documents and the second highest number of citations, i.e. 1055. Similar to the Netherlands, Canada recorded a remarkable 373 citations with 7 documents. Switzerland, the United Kingdom, Brazil, China, Italy, Mexico, Spain, the Czech Republic, Canada, and Australia recorded the second-highest number of documents ranging from 5 to 14. It is worth noting that the contribution of African countries was small and did not meet the threshold of 5 documents and 30 citations. This demonstrates that Africa lags in this area of research.

Table 1

| <i>Bibliographic coupling of countries</i> |                |           |           |                     |
|--------------------------------------------|----------------|-----------|-----------|---------------------|
| No.                                        | Author         | Documents | Citations | Total link strength |
| 1                                          | Germany        | 18        | 1055      | 4377                |
| 2                                          | United States  | 33        | 1480      | 3878                |
| 3                                          | Switzerland    | 14        | 602       | 3065                |
| 4                                          | United Kingdom | 9         | 509       | 2589                |
| 5                                          | Brazil         | 12        | 128       | 1873                |
| 6                                          | Netherlands    | 7         | 373       | 1723                |
| 7                                          | China          | 21        | 446       | 1688                |
| 8                                          | Italy          | 13        | 314       | 1652                |
| 9                                          | Mexico         | 10        | 181       | 1645                |
| 10                                         | Spain          | 10        | 337       | 1406                |
| 11                                         | Czech Republic | 5         | 72        | 1278                |
| 12                                         | Canada         | 7         | 336       | 1181                |
| 13                                         | Australia      | 6         | 703       | 1010                |
| 14                                         | Chile          | 5         | 42        | 917                 |
| 15                                         | Finland        | 11        | 221       | 824                 |
| 16                                         | France         | 9         | 212       | 797                 |
| 17                                         | Sweden         | 12        | 180       | 709                 |
| 18                                         | Japan          | 6         | 83        | 410                 |
| 19                                         | India          | 5         | 181       | 168                 |

Regarding the link among the countries, VOSviewer software calculates it automatically. Germany had the strongest link i.e. 4377 whilst India had the weakest link i.e. 168. The United States, Switzerland, the United Kingdom, Brazil, Netherlands, China, Italy, Mexico, Spain, the Czech Republic, Canada, and Australia had the second highest link strength ranging from 3878 to 1010. Chile, Finland, France, Sweden, and Japan followed with a total link strength ranging from 917 to 410. However, all countries had links with each other demonstrating a satisfactory level of research links among the countries. The network visualization map also reveals 4 clusters: cluster 1 has 6 items (China, Czech Republic, Finland, India, Sweden, and Switzerland) Cluster 2 has 5 items (Australia, Canada, Germany, Netherlands, and the United Kingdom); cluster 3 has 5 items (Brazil, Chile, Mexico, Spain and United States (Finland, and Italy); Cluster 4 has 3 items (France, Italy, and Japan) (see Fig. 3).

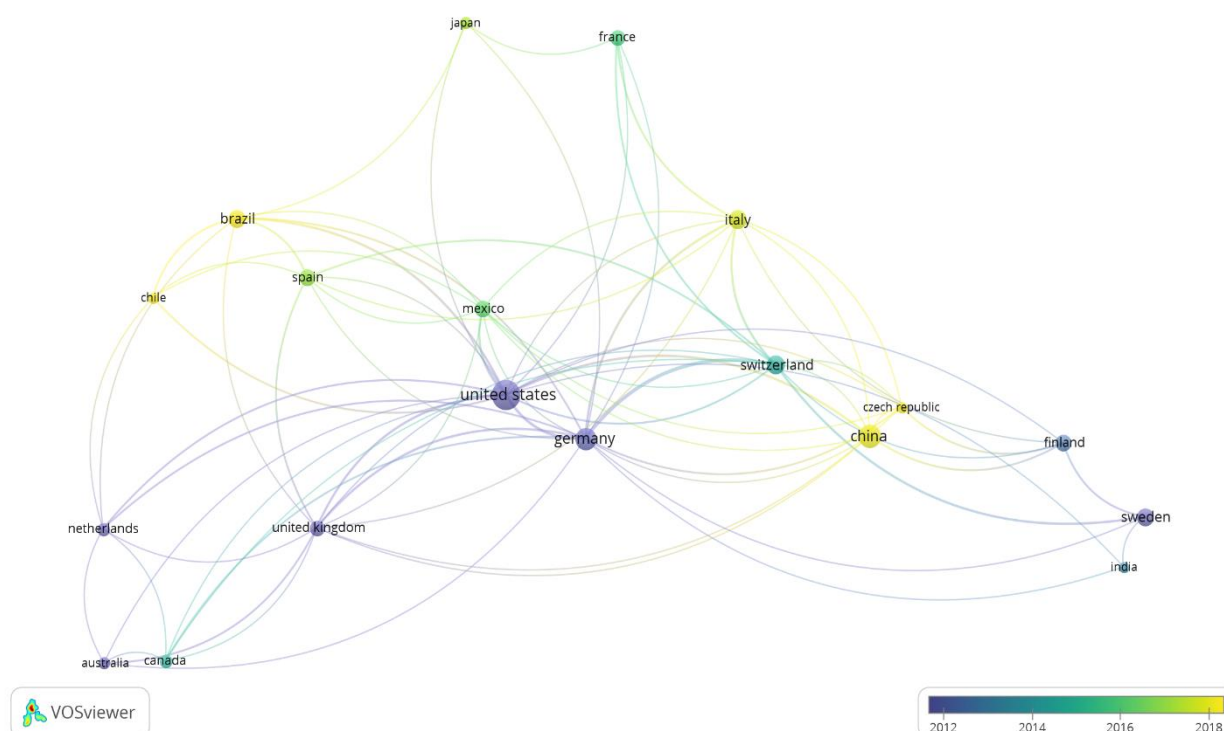


**Fig. 3.**  
**Country network visualization map.**

## BIBLIOGRAPHIC COUPLING OF SOURCES

According to the bibliographic records, a total of 100 sources (Journals) had publications in this area of study. Using the VOSviewer software, a minimum number of documents was set at 3 and the minimum citations were set at 10. Out of the total of 100 sources, only 14 met this threshold. These, without a doubt, are the sources that have contributed to this area of research. It is quite revealing that all these 14 sources have either an element of wood anatomy or chemistry in the title. Table 2 further reveals that Tree Physiology had the highest number of documents followed by New Phytologist. However, in terms of citations, Tree Physiology, Global Change Biology and American Journal of Botany had the highest citations far ahead of all the journals. Thus, it could be argued that Tree Physiology, Global Change Biology, and the American Journal of Botany are the sources that have had the greatest impact in this area of research. Apart from Bioresource Technology and Carbohydrate Polymers, it appears all the other sources have a good link (see Fig. 4).

Table 2

| Top 14 sources |                                     |           |           |                     |
|----------------|-------------------------------------|-----------|-----------|---------------------|
| No.            | Sources                             | Documents | Citations | Total link strength |
| 1              | Tree physiology                     | 13        | 375       | 156                 |
| 2              | Plant cell and environment          | 3         | 113       | 119                 |
| 3              | New phytologist                     | 6         | 255       | 99                  |
| 4              | Global change biology               | 3         | 362       | 58                  |
| 5              | Science of the total environment    | 5         | 51        | 58                  |
| 6              | American journal of botany          | 3         | 360       | 52                  |
| 7              | Annals of botany                    | 3         | 87        | 43                  |
| 8              | Canadian journal of forest research | 3         | 72        | 40                  |
| 9              | Environmental pollution             | 3         | 58        | 29                  |
| 10             | Plos one                            | 5         | 222       | 29                  |
| 11             | Scientific reports                  | 3         | 17        | 20                  |
| 12             | IAWA journal                        | 4         | 76        | 12                  |
| 13             | Bioresource technology              | 3         | 90        | 3                   |
| 14             | Carbohydrate polymers               | 3         | 31        | 0                   |

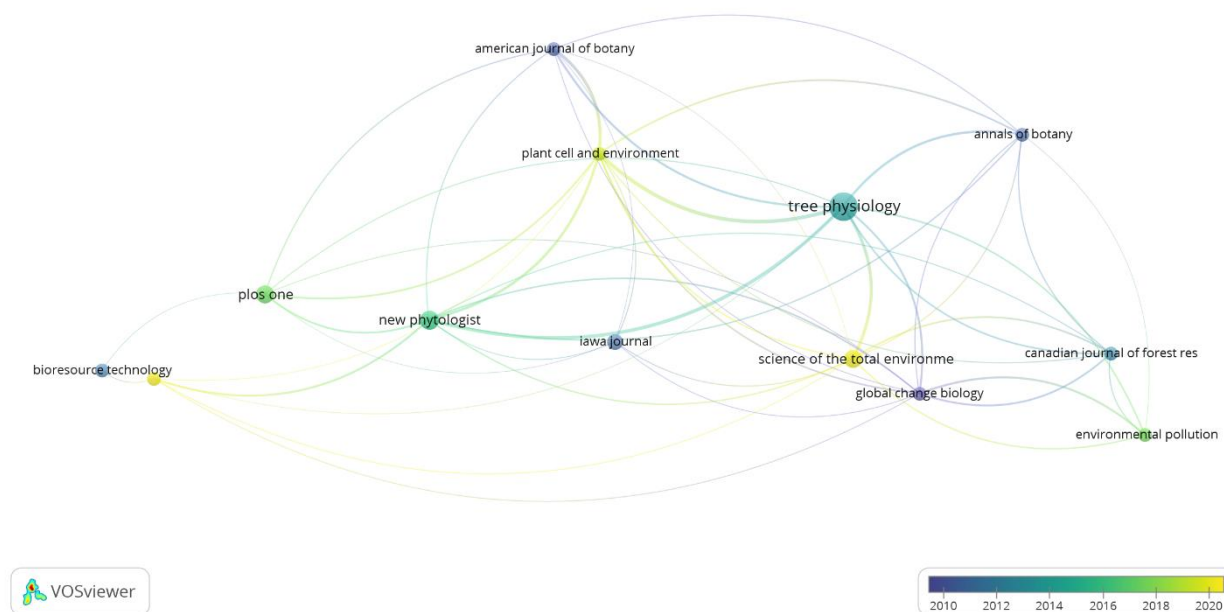


**Fig. 4.**  
**Sources network visualization map.**

## CITATION OF DOCUMENTS

A citation analysis of documents was done to determine the level of citations of the specific documents. The minimum number of citations of a document was set at 20. Out of the 183 documents, 57 met the threshold generating 53 clusters. Only three clusters had more than one item. Cluster 1 was made up of 3 documents whereas both clusters 2 and 3 were made up of two documents. Clusters 4 to 53 are single authors who did individual research work without any collaboration. It is worth mentioning that the focus of all three clusters was studies related to wood chemistry, plant biology, wood anatomy, tree-ring anatomy, and carbon isotope. A review of the remaining clusters' topics reveals a similar trend of research. However, other trends noticeable in the topics are plant traits, wood fates, wood decomposition rate, conductivity and embolism in the root, self-adhesive silk fibroin, and carboxymethyl cellulose nanofibrils and lignin-containing nanofibers. It can be inferred from the document analysis that there is less collaboration between/among authors.

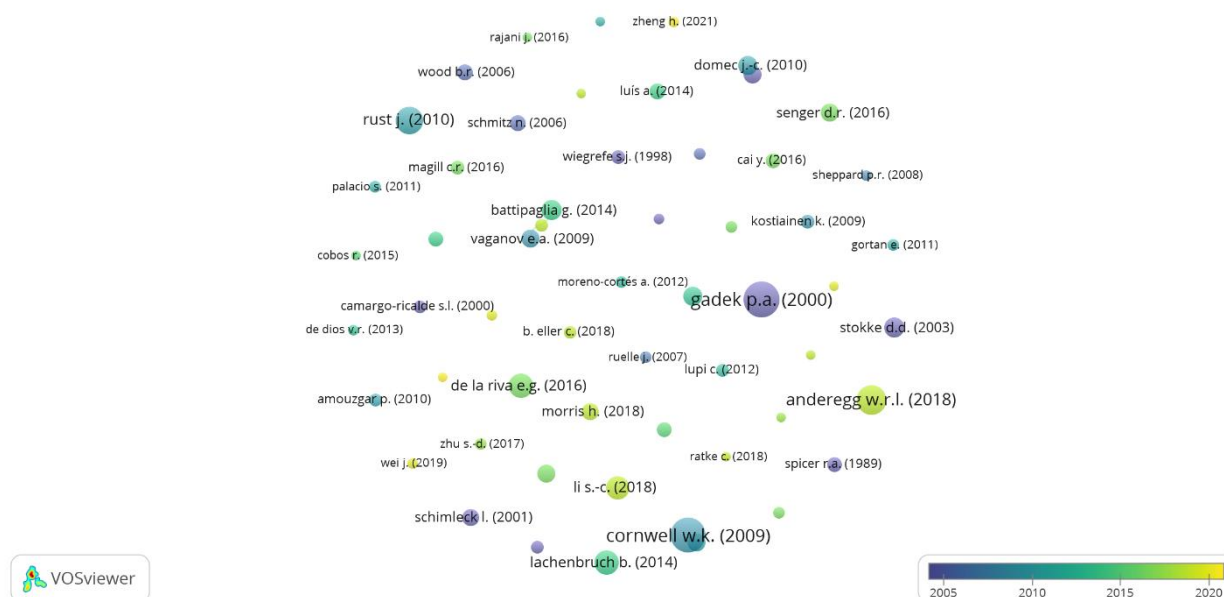


**Fig. 5.**  
**Documents citation network visualization map.**

## NETWORK OF KEYWORD CLUSTERS

A keyword co-occurrence analysis was conducted to determine the trends and evolution of research in wood anatomy and chemistry. Hu et al. (2019) revealed that clustering analysis helps to identify patterns by grouping sources that share similar words and attribute values. The scope of any research study is determined by the keywords. A network of keyword clusters was derived from a total of 2570 keywords. A minimum number of 5 co-occurrence of keywords was set and 129 keywords co-occurred. To ensure that only relevant keywords were captured in the network, some words such as article, nonhuman, human, control study, priority journal, soil, forest, forests, drought, season, seasons, animal, animals' concentration, procedures climate, histology, pine, pinus, Brazil, time, water, climate change, biomass, seasonal variation, analysis, drought stress, classification, pinus Sylvestre, and male were taken out.

Ninety-seven relevant keywords remained. Five clusters emerged from the analysis. Cluster 1 had 29 keywords; some of the keywords related to wood anatomy and chemistry in this cluster are chemical analysis, cells, chemical composition, dendrochemistry, lignin physical chemistry, tree ring, wood anatomy, wood fibers, and wood vessels. Cluster 2 had 22 keywords; notable keywords in this cluster are anatomy and histology, carbohydrates, leaf area, plant leaf, plant root, plant stem and branch, and starch. Cluster 3 had 19 keywords; some of the noticeable keywords in this cluster are cell wall, fibers, genetics, phenols, plant proteins, xylem, and phytochemistry. Cluster 4 had 16 keywords including anatomy, adaptation, biomechanics, cellulose nanofibrils, microbiology, morphology, nanocellulose, surface chemistry, and ultrastructure. Cluster 5 had 11 keywords; notable keywords in this cluster are carbon, chemistry, density, oxygen, stable isotope, physiology, and woody plant.

To allow for an informed discussion, the clusters are presented in different colors to demonstrate the timeframe where such words dominated (see the visualization map in Fig. 6). It can be inferred from Fig. 6 that keywords in Cluster 2 are represented in yellow which dominated in 2018 to 2023. The keywords in cluster 1 are represented in green; these keywords dominated from 2016 to 2017. Keywords in clusters 5, 4, and 3, represented in purple-blue and green, dominated from 2013 to 2016 as shown in Table 3.

Table 3

| <i>Keywords in Different Periods</i> |                                                                                                                                      |
|--------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|
| <b>Periods</b>                       | <b>Keywords</b>                                                                                                                      |
| Yellow<br>(2018 - 2023)              | Tree Composition, Tree Rings, Plant Leaves, Stable Isotopes, Cellulose Nanofibrils, Plant Proteins, Chemical Analysis, Nanocellulose |
| Green<br>(2016 - 2017)               | Wood Chemistry, Wood Anatomy, Physiology, Tree, Carbohydrates, Metabolism                                                            |
| Purple-Blue<br>(2013 - 2016)         | Wood Structure, Wood Tissue, Plant Stem, Dendrochronology, Seasons, Dicotyledon                                                      |

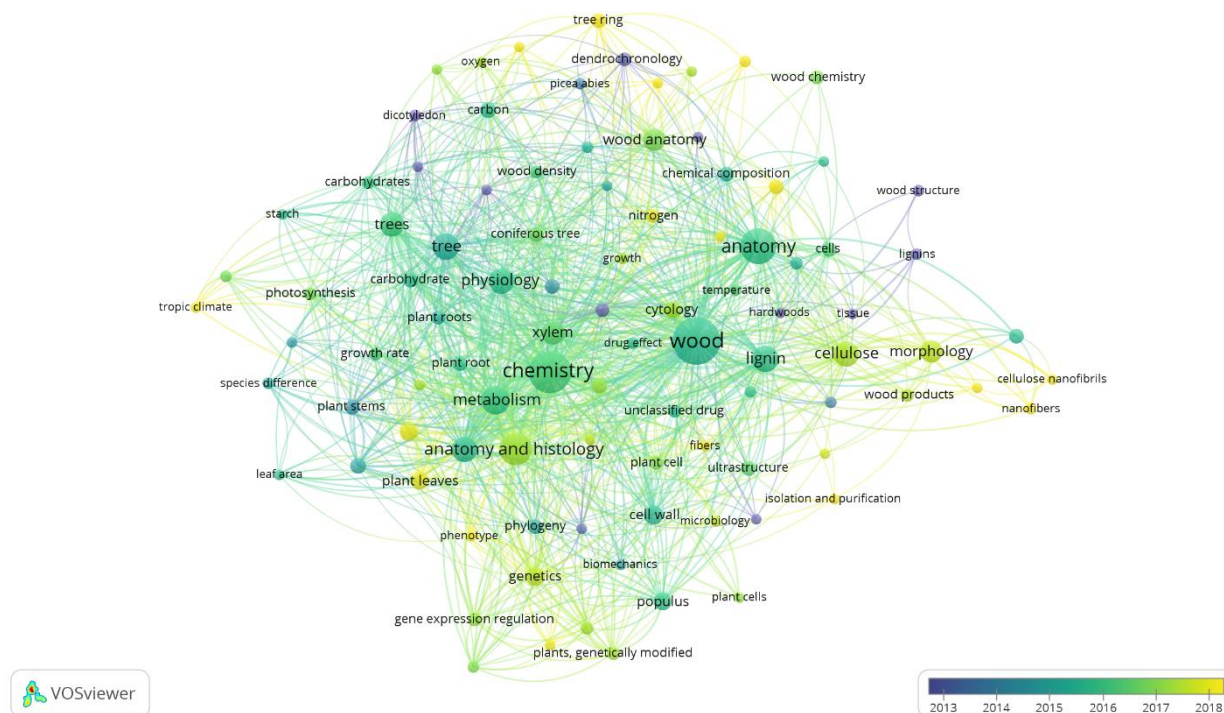


**Fig. 6.**  
**Overlay visualization map of co-occurring keywords.**

## DISCUSSIONS

It is evident that the general trend in publications on wood anatomy and chemistry, although not completely gradient, has been upward since 2000 due to conferences and scientific journals focusing on the research area.

It also became evident from the country analysis that whereas countries in Asia (i.e., China, India, Japan), the Americas (i.e., United States, Brazil, Chile, Mexico) Europe (i.e., United Kingdom, Germany, Netherlands, Finland, France, Spain, and Italy), and Australia (Australia) and Canada have had great impact in this research area, no country in Africa was found to have had a significant contribution in this research area. This finding correlates with those of Akram et al. (2019) and Akinlolu et al. (2020) which revealed that countries in Asia, the Americas, and Europe have a greater research focus on the application of digital technologies in the construction industry compared to those in the other continents. This is not particularly surprising because the general uptake and application of technologies used to research wood anatomy and chemistry in most of the countries on the African continent are low. Studies suggest that countries in the Americas, Europe, Australia, and Asia are the most digitally innovative in the world (Martinez-Aires et al. 2018, Institute of Management 2018). This demonstrates a gap in this area of research in Africa and indicates the need for the continent to focus more attention on these studies. This creates an opportunity for researchers on the continent to focus more attention on this research domain to help address the gap in this research area. This also opens up an opportunity for research collaboration and partnership with other countries outside the continent. There is also the need for organizations and research institutions to provide support to promote this research agenda.

## CONCLUSION

This study presented a bibliometric review of the research trends in wood anatomy and chemistry using publications from the Scopus database. A total of 183 relevant publications were used for the analysis focusing on the number of publications annually, the publication distribution across countries and continents, bibliographic coupling of sources, citation of documents, and co-occurrence of keywords. On the one hand, it has been found that studies on the research trends in wood anatomy and chemistry have significantly increased over the years from 1974 to 2023. On the other hand, it became evident that this area of research is under-represented on the African continent. Both the keywords and the document citation analysis were done to provide researchers with a trend of existing literature on wood anatomy and chemistry. The representation of publications presented in this study is somewhat limited since the data set used for the analysis was limited to the Scopus database. Also, only documents published in English were considered, excluding other possibly relevant documents published in other languages. Therefore, the study recommends further studies be conducted using more than one database. Moreover, Africans lag in this area of research. It is, therefore, highly recommended that researchers on the continent focus more attention on this research domain to help address the gap in this research area.

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