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## GAMBARAN DAN TREN PENGETAHUAN MASA DEPAN *GREEN PORT* *GREEN PORT FUTURE KNOWLEDGE MAP AND TREND*

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### ABSTRAK

*Green port* atau pelabuhan berwawasan lingkungan, juga dikenal sebagai *ecoport*, merujuk pada pelabuhan yang dalam manajemen dan operasionalnya memperhatikan aspek-aspek sosial, ekonomi, dan lingkungan, bukan hanya profit bisnis semata. Penelitian ini bertujuan untuk melacak publikasi penelitian terkait *green port* dari waktu ke waktu dan menentukan peta pengetahuan serta tren topik penelitian *green port* di masa depan dengan menggunakan analisis bibliometrik peta tematik. Selain itu, penelitian ini memberikan gambaran umum tentang peneliti dan kontributor negara penelitian dalam penelitian *green port* secara global. Dalam kajian ini, ditemukan tiga fase dalam penelitian *green port* yaitu Fase Stagnasi Awal (1991-2006): Jumlah artikel masih terbatas, Fase Pertumbuhan Awal (2007-2015): Artikel mulai meningkat dan Fase Perluasan (2016-2022): Jumlah artikel meningkat pesat. Hasil penelitian menunjukkan bahwa China merupakan negara penyumbang penulis kontributor terbanyak dalam penelitian *green port*. Hal ini disebabkan oleh fakta bahwa China memiliki 10 pelabuhan peti kemas terbesar di dunia, dengan total pangsa pasar mencapai 70% secara global. Dari analisis tersebut, ditemukan bahwa peta pengetahuan dan arah topik masa depan terkait *green port* meliputi pembangunan berkelanjutan, pembangunan pelabuhan, operasional pelabuhan, emisi karbon dan sumber daya energi terbarukan pada pelabuhan. Selain itu, tren penelitian juga mencakup pelabuhan ramah lingkungan dan pelabuhan pintar. Sehingga dapat direkomendasikan kedepannya topik-topik tersebut sangat relevan untuk dikembangkan, tema-tema penelitian yang diperlukan meliputi strategi alternatif dalam *net zero emisi* (NZE) di pelabuhan dalam aspek operasional dan pengembangan pelabuhan. Penelitian ini menggunakan analisis bibliometrik R Studio Cloud dan paket *biblioshiny* dengan mengkaji 462 artikel yang diterbitkan pada tahun 1991-2023 di database Scopus.

**Kata Kunci:** bibliometrik, *green port*, *net zero emisi*, *ecoport*, *sustainable port*

### ABSTRACT

*Green ports*, also known as *ecoports*, prioritize social, economic, and environmental aspects in their management and operations, beyond mere business profits. This study aims to track research publications related to *green ports* over time and identify knowledge trends and future topics using bibliometric analysis. Examining 462 articles published from 1991-2023 on Scopus, the research identifies three phases in *green port* studies: initial stagnation (1991-2006), infant growth (2007-2015), and expansion (2016-2022) the number of articles increased quite rapidly in the third phase until now. This research also highlights related to authors, contributor countries and it was found that the country of China contributed the most contributor authors compared to other countries, this is because China is a country that places many container ports as the top 10 largest container ports in the world, with a total market share reaching 70% of the global. From this analysis, it is found that the knowledge map and the direction of future topics related to *green ports* are "sustainable development", "port development", "port operation", "carbon emissions" and "renewable energy resources", besides that it is also found that there is a direction of the current *green port* and "smart port" research trends. So, it can be recommended that in the future these topics will be very relevant to develop, the themes of research themes needed include alternative strategies in *net zero emission* (NZE) in ports in the operational and development aspects of the port.

**Keywords:** bibliometric, *green ports*, *net zero emission*, *ecoport*, *sustainable port*

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## 1. INTRODUCTION

Ports are part of regional and global supply chains and part of production networks. These supply chains move dynamically with changing patterns of global trade, consumer preferences and advances in supply chain management, digital technology, the environment, and sustainable development.

Seaports become the meeting point between various land modes (trucks and trains), waterways modes, so that ports become locations with facilities and infrastructure that provide storage, control, packing, sorting, customs inspection, immigration, surveying services, document issuance and distribution centers. The port functions as a logistics and distribution center (Jakomin, 2003).

Ports, shipping, global trade and production, and supply chains are now inseparable. The current world supply chain problems caused by Covid-19 have not ended and have been exacerbated by the conflict between Russia and Ukraine. The ban on Russian ships that will dock in the European Union and the UK has reduced the supply of energy and various commodities in Europe and triggered inflation.

Before the emergence of the Covid-19 situation and the geopolitical conflict between Ukraine and Russia, ports were focusing on improving related to environmental issues such as climate change, green ports, the use of renewable energy and other environmental issues. In addition to environmental issues, ports are also moving towards high-tech ports with the presence of digital technology and industry 4.0.

Green port or ecoport, is a term for ports that in their management and operations pay attention to social, economic, and environmental aspects, not just business profits (Ahmadi, 2016). There are at least nine groups of environmental aspects in port development including: (1) water quality, (2) coastal hydrology, (3) pollution, (4) marine and coastal ecology, (5) air quality, (6) noise and vibration, (7) waste management, (8) visual intrusion and (9) socio-cultural impacts such as community relocation (Notteboom et al., 2022). Furthermore, the International Energy Agency (IEA) has targeted net zero emissions by 2050, meaning that all economic activities must be directed towards this goal including ports, the port can play a role by implementing the green port concept in its management, operations, and development.

Thus, it is necessary to support research and fixed implementation methods to accelerate the implementation of green port globally. Greenport research must support the agenda of emission reduction and sustainable development, so it is necessary to do a good knowledge mapping of green port. A green port knowledge map will be useful and easy for researchers to conduct future research and make it easier for the government to take policy decisions.

This paper investigates and synthesizes green port literature published in English from 1991 to 2023 or the recent 32 years and shows the evolution of the research field to prove the role of green ports in sustainable development globally. This research utilizes a novel approach to investigate the literature-Bibliometrix R-package bibliometric method and Biblioshiny web-based graphical interface, and VOSviewer applied to the data imported from Scopus. Therefore, this study is a bibliometric analysis that has performed a quantitative evaluation of the word "green port" to assess the interest, evolution and trends, main sources, authors and papers, conceptual, intellectual, and social maps of this topic. This article aims to identify the most published authors, the most influential papers, and the most relevant journals for this topic. Another objective is to determine the main research themes and directions, to understand the current state of the green port research topic. Through R-package and VOSviewer Bibliometric tools and data collection from relevant databases.

Knowledge mapping can be done by viewing, analyzing, and assessing research activities on green port. Given that green ports are a scientific topic involving a wide range of science disciplines, this research conducts knowledge mapping based on bibliometric data to enable researchers to create structured visualization and analysis results to support knowledge mapping. This in turn can provide structured strategic planning for next innovation of green ports.

## 2. METHODS

The bibliometric method involves quantitative data processing, mainly through bibliometric data in the form of scientific publications (Donthu, 2021). The author chose to use R software, especially the biblioshiny package because it can produce better knowledge mapping tables and graphs and topic trends than other software.

The first step in developing the literature review is to develop a problem of statement, decide on the research issue that need to be address in future, search strategy (keywords, databases, inclusion, and exclusion criteria, etc.), and methodology. The study was based on a wide range of existing scientific literature in the world. Strict inclusion and exclusion criteria were used and well-defined to ensure that the review consisted only of papers that were related to the topic of green ports and therefore worthy of consideration for inclusion in the data to be analyzed. Articles addressing issues related to green ports published between 1990 and mid-2023 were considered for selection. A bibliometric approach was taken by applying quantitative techniques to describe the bibliometric data, mainly retrieved from the Scopus metadata database (Figure 1).

The second step in this literature study is to determine the database that will be used to retrieve relevant documents. In this study, we used the Scopus database, because Scopus has more than 23,000 indexed journals in all scientific fields (Falagas, 2008). In addition, it is easy to export metadata from Scopus to other programs. Scopus also offers easy search methods, namely with basic search or with advanced search where it can execute complex and lengthy search queries according to the objectives of interest and has high validity. In addition, Scopus also allows searches using terms in the title or title/abstract or journal name or author name or affiliation.

The third stage is to choose the appropriate search terms with the required boundaries. For this study, the term "green port" was used, along with terms that share similarities with it, such as "green port\*" OR "greenport\*" OR "eco port\*" OR "ecoport\*" OR "sustainable port\*." In addition to keyword constraints, language restrictions are also present in published documents and publications; in this study, only English-language documents and articles are used as the basis for analysis. The author did not place limitations on the year of publication because the purpose of this was to be able to determine when articles on green ports first started to appear as well as to learn about the most recent study up until this research was conducted.

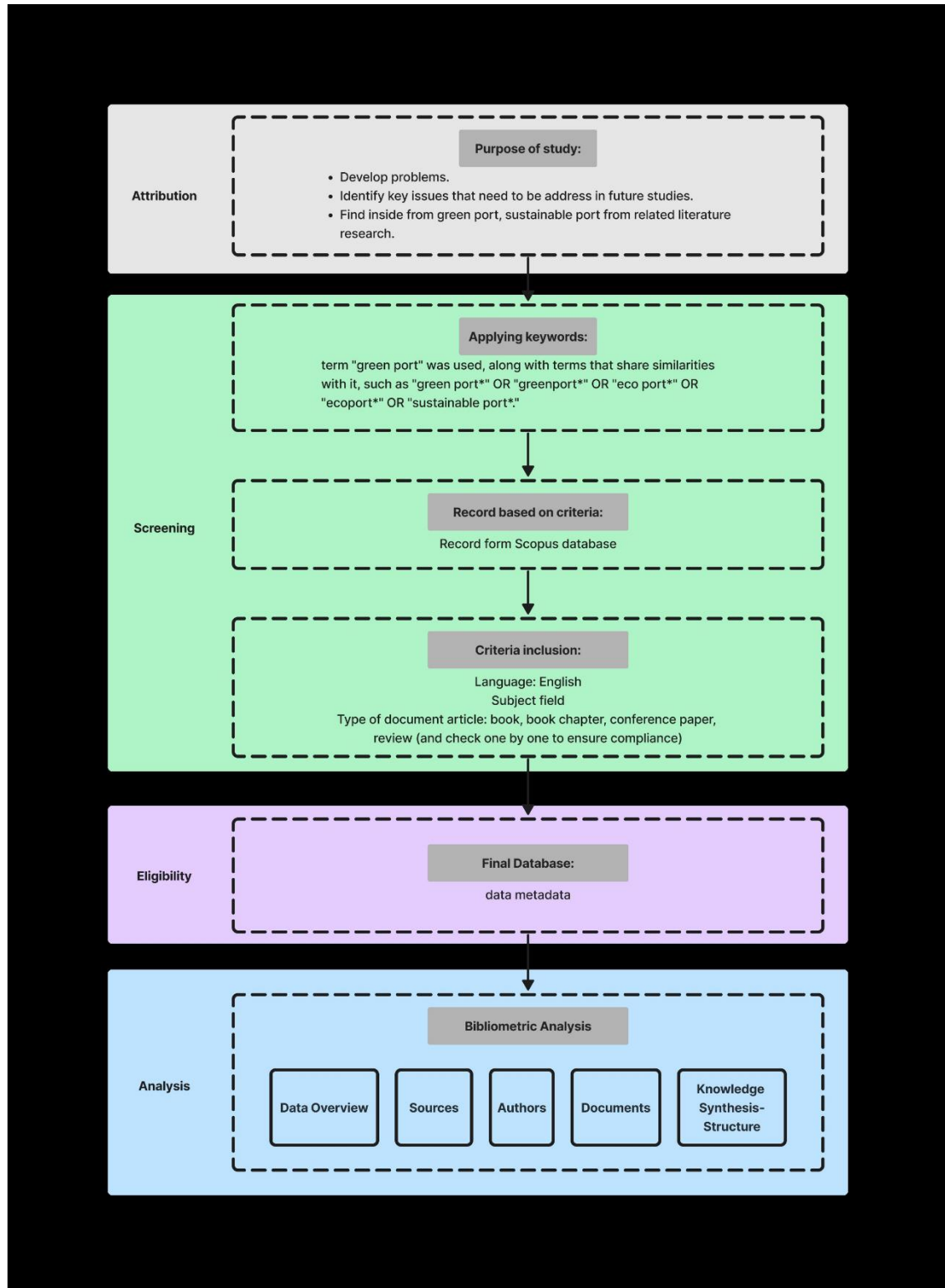
The fourth step is to conduct screening of the data that has been taken, by checking one by one on each of the existing metadata attributes such as title, keywords and abstract, whether the documents are related to the theme of green ports or not, if there is no relation at all to the theme, then the metadata of the document is removed, so that from 498 documents it finally becomes 462 documents.

## 3. RESULT AND DISCUSSION

Based on the search results with the keywords "green port" or "sustainable port" on the Scopus database, 498 documents were found. The next step is to screen data that has the keywords "green port" or "sustainable port" but these documents have nothing to do

with the theme of green ports, from the results of this screening obtained as many as 462 documents that are ready for analysis, from 235 publisher sources and 1,109 Authors, as can be seen in Table 1 below.

**Figure 1. Flowchart of the study.**



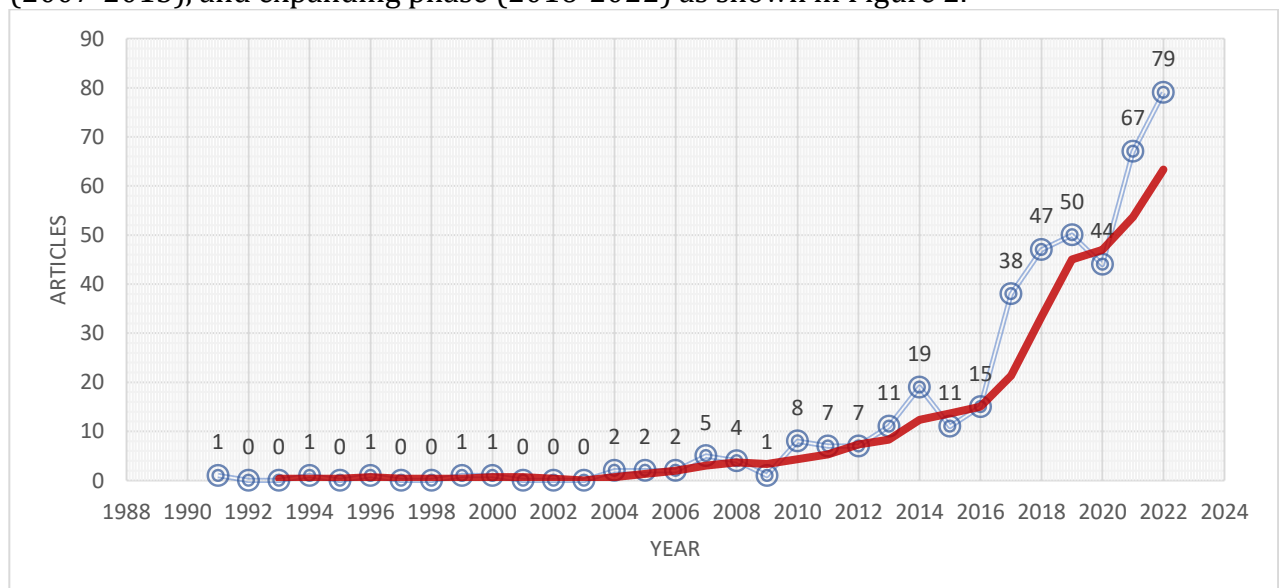
**Table 1.** Main information

Description	Results	Description	Results
<b>MAIN INFORMATION ABOUT DATA</b>			
Timespan	1991:2023	<b>AUTHORS</b>	
Sources (Journals, Books, etc.)	235	Authors	1109
Documents	462	Authors of single-authored docs	54
Annual Growth Rate %	12.04	<b>AUTHORS COLLABORATION</b>	
Document Average Age	4.64	Single-authored docs	58
Average citations per doc	13.66	Co-Authors per Doc	3.21
References	16753	International co-authorships %	28.14
<b>DOCUMENT CONTENTS</b>			
Keywords Plus (ID)	2374	<b>DOCUMENT TYPES</b>	
Author's Keywords (DE)	1323	article	280
		book	5
		book chapter	32
		conference paper	126
		review	19

## Historical Development of Green Port Research

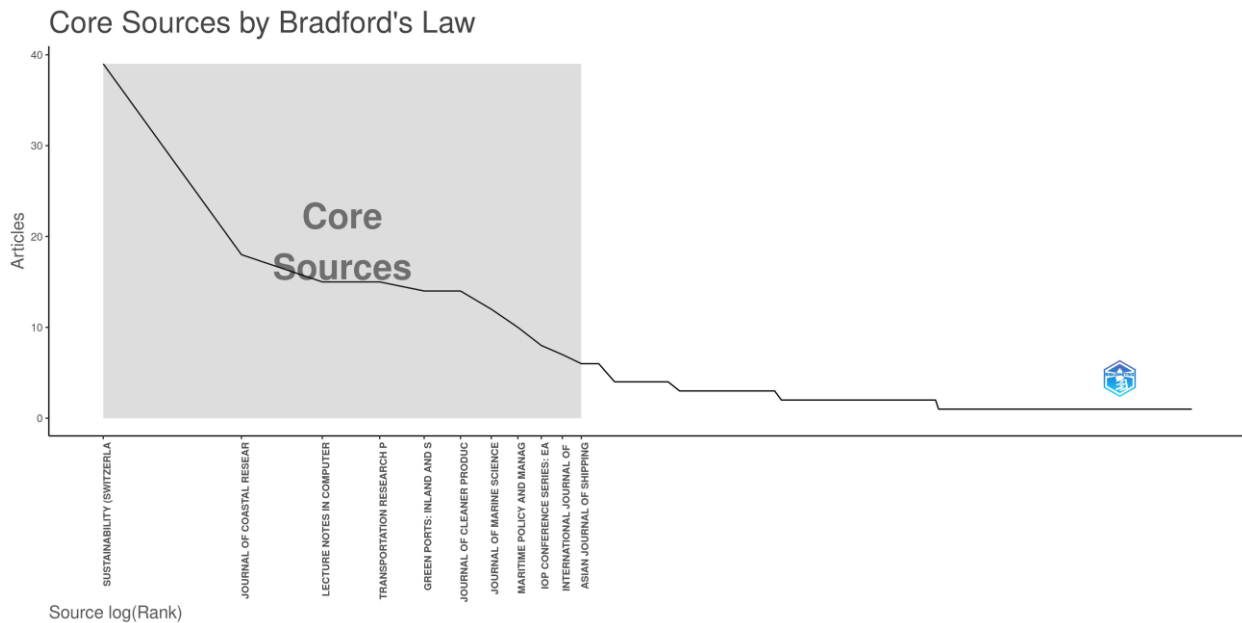
### Scientific Production

Based on Figure 2, the term green port first appeared in Scopus indexed scientific publications in 1991 in a book entitled *A green port: an engineer's view* by Burdall A.C and Williamson H.J. The development phase of research related to the topic of green ports can be divided into three parts: initial stagnation phase (1991-2006), infant growth (2007-2015), and expanding phase (2016-2022) as shown in Figure 2.

**Figure 2.** Annual Scientific Production

In phase 1, namely early stagnation, starting from 1991 to 2006, there were no frequent publications every year, however, at the end of the period, which was 2004 to 2006, there are two articles published annually. The number of publications increased during the second phase (infant growth), starting with five articles in 2007 and ending with 11 articles in 2015, however, before the end of this phase, in 2014, the number of articles published was 19 articles, which was higher than at the end of the period.

The topic of green ports entered an expansion phase in 2016, starting with 15 published articles and reaching 79 articles by 2022. This was due to a greater emphasis on news, information, social media, the global political agenda, and the publication of articles related to the UN Sustainable Development Goals (SDGs), causing a significant increase of interest in topics related to sustainable development around 2015.



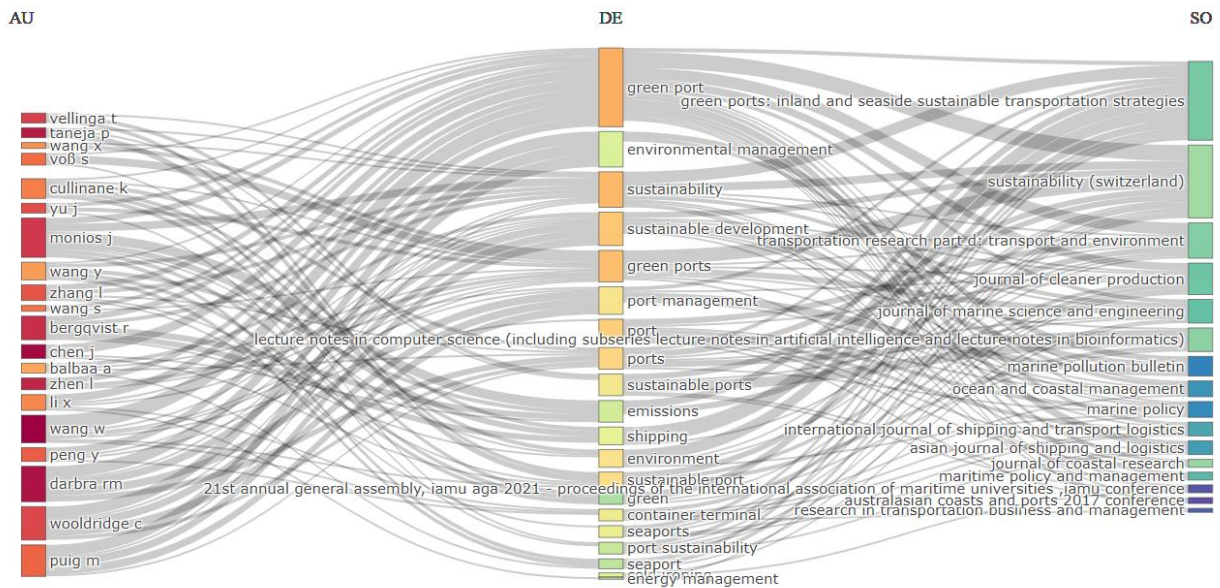
**Figure 3.** Core Sources by Bradford's Law

Figure 3 shows Bradford's Law, which illustrates the statistical distribution of scientific or technical knowledge in a region. Where a small group of journals will have the most publications on a subject/theme, while a wider group will have fewer on the subject/theme in question. The Bradford distribution is evenly divided into 3 zones, the first zone will come from a small "core" group of journals. The second zone will require more journals to achieve the same number of citations, and the third zone is exponentially more numerous than the second zone. Figure 3 depicts a graphical representation of Bradford's law. Based on this, it was found that Sustainability Switzerland is the highest reputable journal in the green port theme with several frequencies of 39, followed by Journal of Coastal Research with several frequencies of 18.

The relationship between authors, authors' keywords, and sources can be seen using the Three-Plane Plot, that illustrates which concepts (as keywords) are explored and which sources are most frequently published by authors. This is a diagram with different colors and sizes of rectangles-the more relationships one element has, the taller the rectangle representing it.

Figure 4 illustrates that there are four authors (Monios J., Darbra M., Wooldridge C. and Pluig M) and two publication sources (Sustainable Transportation Strategies and Sustainability Switzerland,) which have strong relationships with the main topics of green port.





**Figure 4.** Three-Fields Plot: authors-authors’ keywords-sources

In Figure 5 a different graphical representation of the text data (as a Word Cloud), by selecting keyword plus and word occurrence frequency as graphical parameters, the following ten keywords are most frequently used: port; sustainable development, green port; ship; port development; port operation; sustainability; emission control; environment management; and economic.



**Figure 5.** World Cloud top keyword plus using biblioshiny

There are differences in keyword occurrence based on author keywords and plus keywords, overall, plus keywords and author keywords reveal similar research trends. Both types of terms characterize the same research population and terms. There are some terms that are not present in author keywords but are present in keyword plus and vice versa, these terms include sustainable ports, port management, container terminals, seaports, shipping, ships, port development, port operations, emission control, environmental management, and economics, as can be seen in Table 2. Between keywords plus and author keywords complement each other and enrich the terms related to green ports in various research that has been done so far.

**Table 2.** Most Frequent Words using author keyword and keyword plus

Authors Keyword		Keyword Plus	
Terms	Frequency	Terms	Frequency
green port	122	port	116
sustainability	42	sustainable development	107
port	40	green port	80
sustainable port	32	ship	57
sustainable development	27	port development	48
environment	13	port operation	44
port management	13	sustainability	43
container terminal	11	emission control	42
seaports	10	environmental management	40
shipping	10	economics	37

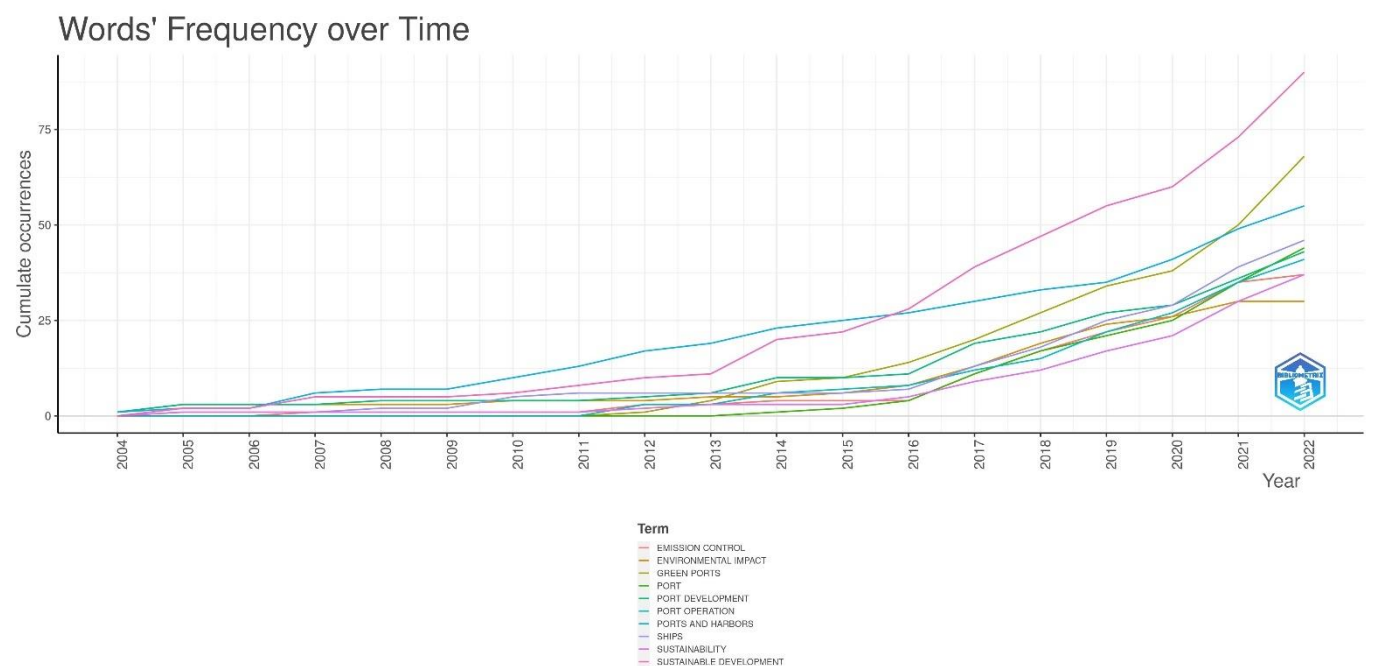
**Figure 6.** Words' Most Frequency over time

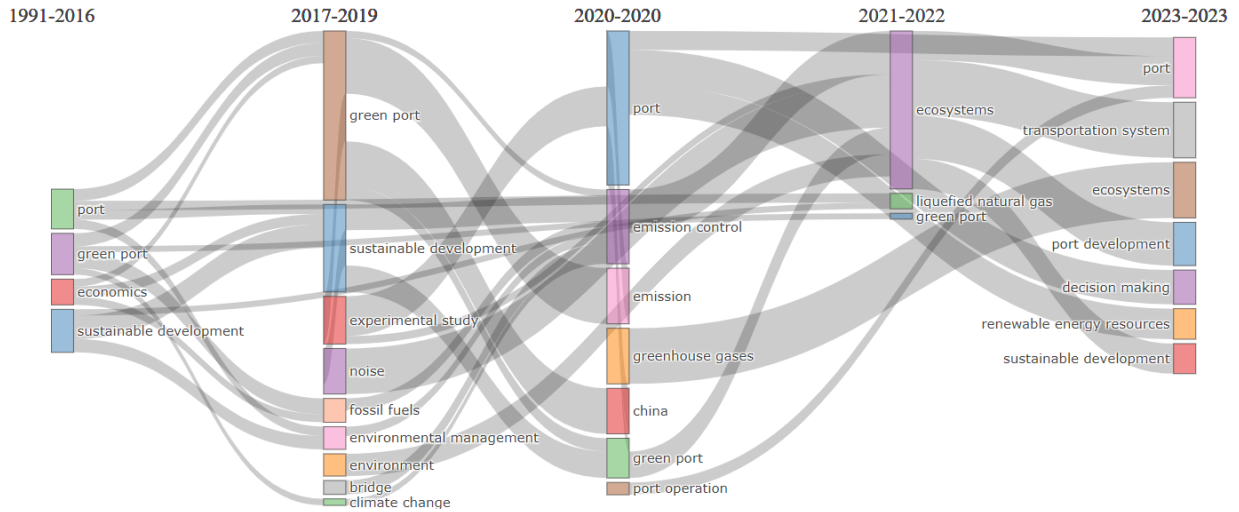
Figure 6 shows the number of words that often appear throughout green port research, where in the first order topics related to sustainable development become words that often appear in every green port research.

Longitudinal analysis of the thematic maps revealed the development of the research themes over time. Figure 7 shows the thematic evolution, bringing a historical perspective on the green port literature since it was first published in journals on the Scopus database, the author divides the thematic evolution in 5 periods (by setting the keyword plus as a field and 4 cut-off points - in 2016, 2019, 2020 and 2022), it can be seen that from 1991 to 2016 the issues of ports, green ports, economics and sustainable development appeared.

Then in the period 2017 to 2019, the term green port became the main issue followed by sustainable development, noise, fossil fuels, climate change. Then in the 2020 period the main terms that appeared included port, emission control, emission, greenhouse gases, China, green port and finally related to port operations. In the span of 2021 to 2022



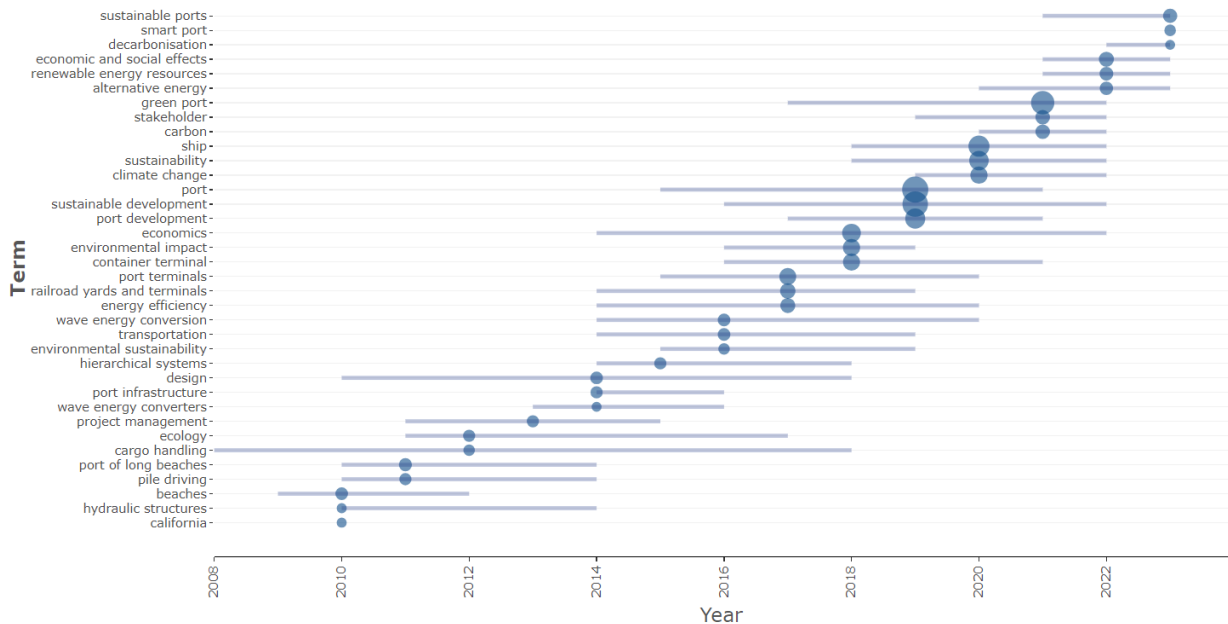
the term ecosystems became the main issue in green ports, and in the span of 2023 recently the terms port, transportation system and ecosystem, port development have the same issue strength followed by issues related to renewable energy and sustainable development. Throughout the period, sustainable development has become the main issue in green ports.



**Figure 7.** Thematic Evolution Map using keyword plus

**Tren Topics**

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**Figure 8.** The Most Frequent Terms with Respect to Time

Figure 8 depicts the results of the analysis of key terms over time providing a more detailed view of current trends by year. Bubbles and lines represent trending terms or keywords that were extensively studied between 2008 and 2023. The larger the size of the bubble, the more frequently the term appears in publications during a given period. In addition, the length of the line indicates how much time was spent on a particular topic. The term "green port" appeared frequently from 2017 to 2022. Then the terms "port" and "sustainable development" appeared frequently in 2015-2022 and had the largest bubble size and became popular in those years. The direction of academic interest and the topics

that have received the most attention over the past few years can be determined by looking at the trending topics between 2021 and 2023. In that year, the three most frequently used terms by authors were "sustainable port", "smart port", and "decarbonization". In 2023, green port will be associated with issues of digitalization, sustainable development, and climate change, especially the issue of reducing greenhouse gas emissions in ports.

## Relevant Authors, Sources of Document

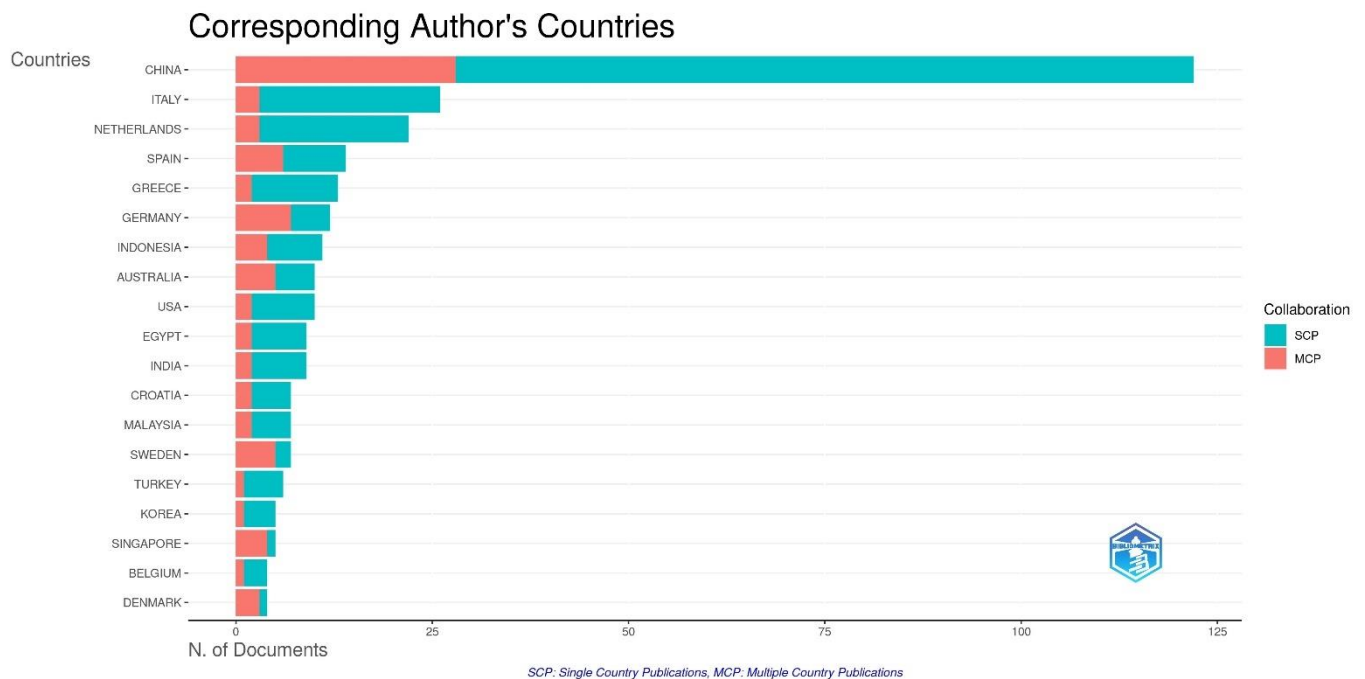
### Country of Authors

The Corresponding Author Country analysis lists the country of origin of the correspondence author, the country and collaboration network of the correspondence author will likely improve our understanding of which researchers are most committed to green ports.

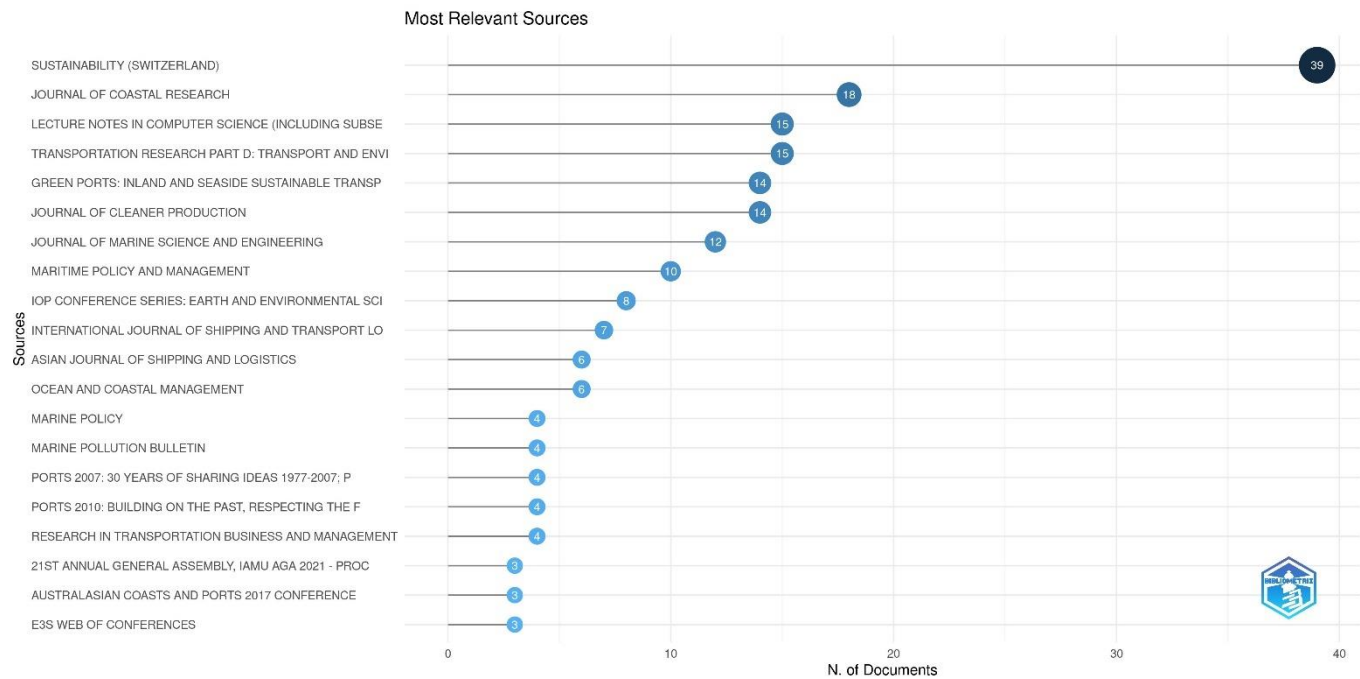
Figure 9 shows the 19 countries of origin of correspondence authors and indicates whether the research was conducted in collaboration with researchers from the same country (single country publication/SCP) or with researchers from other countries (multi country publication/MCP). China, one of the most productive countries in the world in green port publications, has the most researchers collaborating with other countries.

China currently plays an important role in the global port network where the ten largest container ports in the world are in China with a market share of 70% of the global. Furthermore, in the European region, Italy is the second most author country with a lower MCP value than China.

Figure 10 shows the most relevant sources that can be used for researchers who want to find relevant sources related to the topic of green ports, or for researchers who want to publish their work related to the topic of green ports. The journal Sustainability Switzerland is the journal that publishes the most articles related to green ports, followed by the Journal of Coastal Research.



**Figure 9.** Corresponding Author's Countries



**Figure 10. Most Relevant Sources**  
**Knowledge Map Recommendation for Future Research**

### Thematic Map

To discuss recommendations for future research topics, we must analyze the position of the sub-topics on the thematic map related to green ports. A thematic map, or strategic map, represents keyword plus and groups them into four quadrants, with an x-axis and a y-axis, where the x-axis indicates the significance or centrality of the research topic, while the y-axis indicates the density of development degree, which measures the development of the theme.

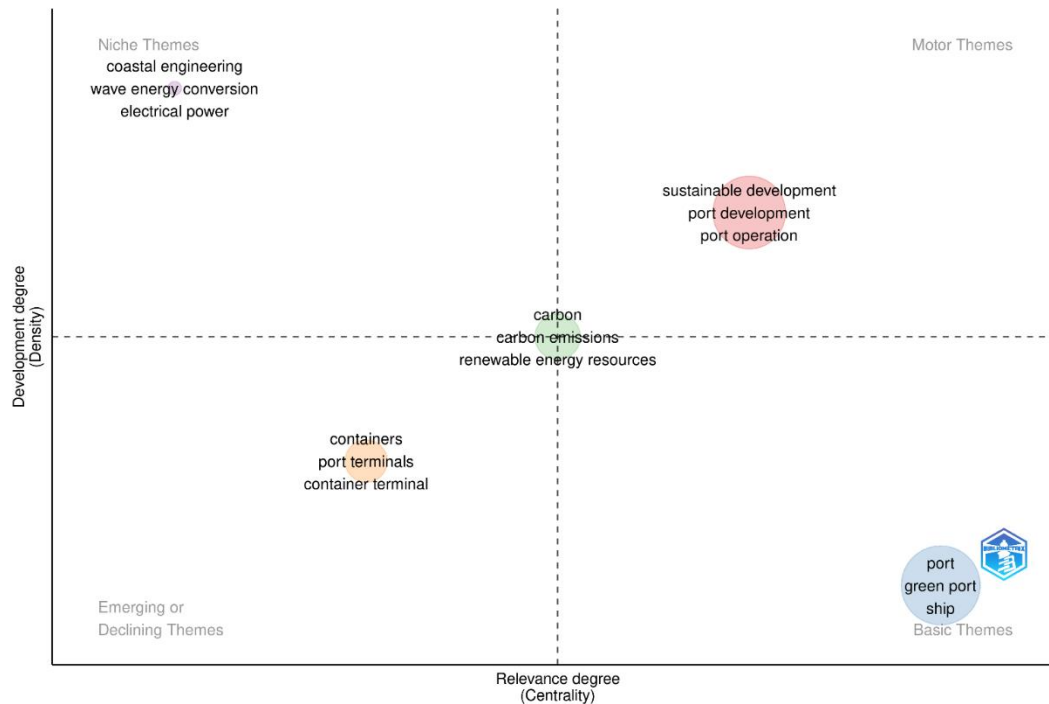
Figure 11 illustrates a thematic map with four quadrants: the first quadrant on the top right is called the motor themes quadrant; the second quadrant on the top left is called the niche themes quadrant; the third quadrant on the bottom right is called the basic themes quadrant; and finally, the fourth quadrant on the bottom left is the emerging or declining themes quadrant.

In the first quadrant on the top right are motor themes that have a high level of relevance and research development compared to the other quadrants. In this quadrant the research themes are well developed and significant for the knowledge domain. The green port motor themes in the first quadrant include “sustainable development”, “port development”, and “port operation”. Many studies are looking for the relationship between the development and implementation of the green port concept and sustainable development, as well as green port research related to port development and operation in ports, as well as research that connects environmental management in ports to implement green ports.

The second quadrant is the upper left quadrant, which is also known as the niche themes with high density but low centrality or limited significance to the field in question. In this quadrant, there is only one group with a small frequency of discussion, as indicated by the small size of the circle in this quadrant compared to the size of the circles in the other quadrants, where the topics are such as “coastal engineering”, “wave energy

conversion”, and “electrical power”. Research with these topics seems to be rarely done in relation to green ports.

The third quadrant on the bottom left, also known as the emerging or declining themes quadrant, contains study topics with low centrality and density, indicating that development of the topic is limited which indicates emerging or declining topics. Topics included in this cluster include issues on “containers”, “ports and terminals”, and “container terminals”.



**Figure 11.** Thematic Map from keyword plus

The fourth quadrant on the lower right is the basic themes quadrant, which involves research topics with a high level of relevance but a low level of development, indicating that they are important to the field of study and include topics common across the various research areas of “port”, “green port”, and “ships”.

From Figure 11, there are interesting things, namely the existence of topics in the center of the quadrant, namely the topics of "carbon", "carbon emission", and "renewable energy resources", so it can be interpreted that these topics are included in all quadrants and could be important topics in research related to green ports. Based on this, green port research related to carbon will develop considering that the issue of carbon emission related to climate change is currently developing as well, so green port research related to carbon emission needs to be better developed and encouraged.

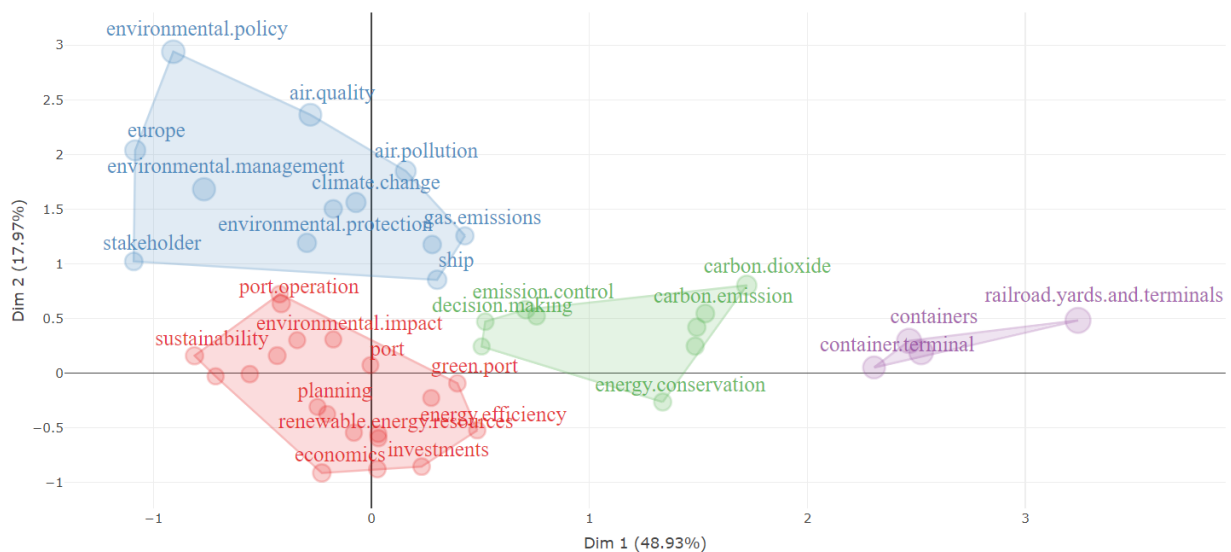
### Factorial Analysis Approach to drawing the conceptual map

To see the subfields of the research area, we chose to draw a conceptual map of keyword plus, by selecting Multiple Correspondence Analysis (MCA) and 50 terms. The selected keywords were keyword plus and then plotted on a two-dimensional map showing a closer representation for words with the same distribution. The results can be seen in Figure 12 where four clusters can be observed (1-blue, 2-red, 3-green, and 4-purple).

The starting point of the map is the center of the research field and represents the average position of all articles. The keywords "port", "planning", "green port" and

"environmental impact" are closest to the center, which means that many articles cover these topics. The two dimensions of the map can be explained as follows: The horizontal dimension separates keywords reflecting sustainability, stakeholders, and environmental impact (on the left) from keywords analyzing terminals and containers (on the right); the vertical dimension separates keywords studying environmental policy and pollution (at the top) from keywords focusing on economics and investment (at the bottom).

The first cluster in blue is more about environmental, stakeholder and ship. The second cluster in red, discusses a lot related to sustainability, energy, port, port operation, economics, and investment. Furthermore, the third cluster in green is mainly related to emission, carbon, and energy conservation to reduce carbon emission. And the last cluster, the fourth purple cluster, focuses on green ports in relation to terminals and containers.



**Figure 12.** Conceptual map and keyword plus clusters.

### Future Green Port Knowledge Map Research Agenda

From the existing thematic map we can take important things, namely the themes in the emerging themes and niche themes quadrant can be further developed and the emergence of topics that are relevant at any time shown in the position of the center of the quadrant. Aspects of green port research related to sustainable development at the port are the main driving issues in future research, as well as aspects of port operations that are more environmentally friendly, such as the use of port facilities that are low in carbon emissions and port operations that use renewable energy will also be the topics of current and future green port research.

Carbon emission reduction continues to grow in relation to the increasingly incessant issue of climate change and net zero emission (NZE) targets in the industry in the future, especially in the port sector. So that various strategic steps in order to achieve NZE in the port need to be developed through research that is closely related to the existing green port steps, NZE needs to be made one of the important indicators in various green port determinants. The emergence of the topic of renewable energy resources in green port research is one of the efforts to achieve NZE at the port, then other strategies need to be found in addition to efforts to use renewable energy in port operations, so that the NZE target will be easier to achieve.

In the framework of this, several important topics that arise such as investment and environmental policies to support the development and operation of ports that are more environmentally friendly are also needed, such as investment incentives in ports that implement green ports need to be researched more deeply to find innovative investment incentives in the development and environmentally friendly port facilities. It is also necessary to support research related to interesting environmental policies to facilitate the application of green ports in ports globally. The results of the bibliometric analysis show that most of the research related to green ports examines sustainable development, port operations, emission control, environmental management and economics and the relationship with ships and shipping. Further research is needed to determine strategies and policies that support the reduction of carbon emissions in port operations and the reduction of environmental impacts on port development.

Based on the topics mentioned above, the prospects for future green port research that can be recommended are as follows:

- 1) Studies related to sustainable development goals that can be done by ports.
- 2) Studies related to reducing environmental impacts in ports due to port operations and development.
- 3) Studies related to the strategy of using renewable energy at the port.
- 4) Studies on alternative NZE strategies in the operational aspects of the port within the framework of climate change issues
- 5) Strategies for investment innovation and environmental policies that support the acceleration of green ports globally.

#### **4. CONCLUSION**

The findings of the bibliometric analysis of green port research in this paper can be summarized as follows:

- 1) The historical evolution of green port research can be divided into three phases: initial stagnation phase, infant growth and expanding phase. The number of green port publications has increased over the past few years, especially in the expanding phase, namely in 2016-2023, which was influenced by global issues in the form of SDGs, climate change and NZC.
- 2) Based on the analysis of correspondence countries, the most publications come from China, this is because China is one of the countries that has the largest port market share in the world which controls 70% of the global container port market share.
- 3) Based on the analysis of thematic themes and the latest research trends, the topics of sustainable development, port development, port operation are still the driving force of green port research, besides that there are topics that are also still relevant, namely carbon emissions and renewable energy resources for green ports, then it is also found that technological innovation with smart ports is also closely related to green ports.

The findings of this paper show the knowledge map and directions for future research on green ports supporting sustainable development, climate change issues and NZE targets, this paper provides insights into the development and trends of green port research, identifies authors, author countries, author collaborations and emphasizes the direction of topics that will develop in the future.



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