Research trends and shrimp farming adaptation to climate change: a bibliometric analysis

Mohammad Syaichudin[1,2*], *Abd Rasyid* Jalil[1], *Akhmad* Mustafa[2], and *Abdul* Gafur[2]

[1]Environmental Science Program, Postgraduate School, Hasanuddin University, Makassar, South Sulawesi 90245, Indonesia
[2]Research Centre for Fishery, National Research and Innovation Agency, Cibinong, Bogor,West Java 16912, Indonesia

Abstract. Climate change poses significant challenges to the global aquaculture industry, especially shrimp farming in developing countries, where shrimp farmers must adapt to ensure the sustainability of their businesses. Adaptation of aquaculture has been studied a lot, but less to shrimp farmers. This study aims to understand the pattern of the research directions. Based on bibliometric analysis, this paper presents research trends and future prospects 2009 to 2024, that used VOSviewer and Biblioshiny software to visualize the analyzed datasets from the Scopus database. Based from the results show that China leads the overall field, then following by United States, Vietnam, Bangladesh, UK, Australia, Thailand and Indonesia. Thematic map shows that very relevant topic are "decapoda", "shrimp farming", and "climate change", including the themes of mangroves and adaptive management. Meanwhile, the research themes, such as: "animals" and "adaptation", may be included in the research categories that are lesscentral and less developed compared to the highlighted themes. Research trends for the future research focuses on "eutrophication" and "shrimp farming", appear to have more consistent mentions, while the specific terms such as "decapoda", "climate change", and"bacteria" are likely to be of particular interest that indicate significant trends in their use over time.

* Corresponding author: mohammad.syaichudin@brin.go.id

1 Introduction

1.1 Background

The global aquaculture industry faces considerable challenges due to climate change, particularly shrimp farming, which is vulnerable to environmental fluctuations [1–3], and become a crucial economic activity in many developing countries [4]. Shrimp farmers must adapt to changing environmental conditions, including increased temperatures, rising sea levels, and severe weather events, to ensure the sustainability of their operations [5]. In Bangladesh, amajor shrimp-producing country, coastal communities heavily rely on aquatic resources for their livelihoods, which have been impacted by changes in climate patterns [6,7]. These climatic changes have had detrimental impacts on the survival, growth, and production of shrimp [7,8], without adaptation measures, climate change will lead to a swift decrease in production [9].

In response, shrimp farmers have adopted various adaptation strategies, including changes in farming practices and management techniques [7]. One potential adaptation strategy is the integration of mangrove ecosystems with shrimp farms, which can provide natural protection, improve water quality, and contribute to blue carbon sequestration [5], where the effective mangrove management is vital for climate adaptation [9]. Ecosystem-based adaptation (EbA) has emerged as a climate change adaptation strategy for coastal regions [10].

A more comprehensive understanding of the specific adaptation strategies shrimp farmers use to address climate change is still required. Current literature emphasizes the negative impacts of various climate factors, including coastal flooding, cyclones, rising sea levels, salt levels, dry spells, and ocean surface temperature, on shrimp culture and the overall socioeconomic conditions [8,11].

Greater focus on implementing polyculture shrimp farming is essential to enhance climate change adaptation and ensure the sustainability of this aquaculture practice [3]. Upgrading pond dikes and adding a settling pond have proven to boost shrimp farming productivity. Additionally, educating farm operators and farmers' awareness of climate change and its effects on shrimp farming play a key role in driving adoption behaviors [12]. Access to information is also crucial in adopting new practices and strategies, while attitudes toward innovation, investment levels, and social norms further influence the adoption of technological, organizational, and informational approaches [13].

Shrimp farmers employ several strategies to adapt to changes in climate variables, such as deepening ponds, using tidal water exchange, adding shade with aquatic plants, reinforcing earthen dikes, and installing nets or fencing around the dikes. Polyculture, or mixed cultivation with shrimp, remains the most popular shrimp farming method [3,14]. Adaptation programs often benefit only some people while harming others, so such adaptation strategiesproduce uneven impacts, so it is necessary to focus more on the impact of adaptation on poorand most vulnerable farmers to reduce the risk of negative impacts and help ensure more equitable outcomes from adaptation measures [15].

The application of ecological modernization theories highlights the necessity of integrating environmental, social, and political dimensions in adaptation strategies [16]. Implementing better management practices (BMPs) can enhance shrimp health, increase production, and mitigate climate change impacts, ensuring sustainability [17]. Shrimp farming has become a prominent diversification strategy, correlated with more stable income sources compared to traditional agricultural practices, impacted by increasing salinity and environmental hazards [18]. Shrimp farming has become a prominent diversification strategy, correlated with more stable income sources compared to traditional agricultural practices, impacted by increasing salinity and environmental hazards [19]. Gaining insights into shrimp farming concerning climate change impacts and vulnerabilities will provide valuable knowledge for future shrimp farm management, marketing, and adaptation strategies in the region [20].

The existing literature highlights the complex relationship between shrimp farming

and the surrounding ecosystems [21], while shrimp aquaculture has expanded rapidly to meet global demand, it has also had a detrimental impact on sensitive coastal environments, such as mangrove forests [22]. Excessive nutrient loading, water pollution, and habitat destruction can degrade the ecological integrity of these areas, jeopardizing the long-term viability of shrimp farming [23]. To address these challenges, researchers have explored various approaches to sustainable shrimp farming, including integrated mangrove-shrimp systems, organic aquaculture, and improved management practices [5].

1.2 Adaptation strategies of climate change in shrimp farming

The term climate change adaptation is an effort or process of adjusting practices, systems, and livelihoods in response to the effects of climate change [24]. Climate change adaptation is a strategy focused on minimizing vulnerability and strengthening resilience to the harmful effects of climate change, including rising temperatures, alterations in rainfall patterns, sea level rise, and extreme weather events [24,25]. Through this climate change adaptation strategy, shrimp farming operations can become better equipped to withstand the effects of climate change, thereby enhancing the sustainability and productivity of the fisheries sector [26]. By promoting innovative practices, fostering collaboration, and implementing science-based approaches, the aquaculture sector can effectively navigate the challenges posed by climate change [27,28]. Some of the strategies to enhance the resilience and sustainability of shrimp aquaculture in the face of global warming as shown in Figure

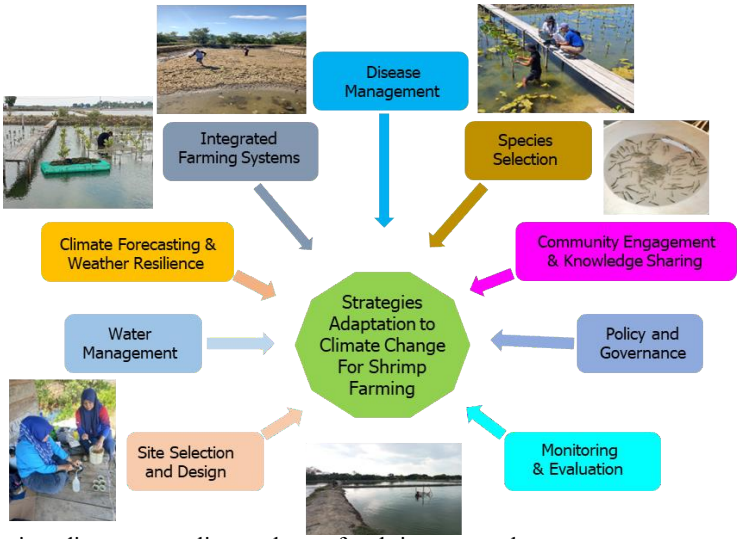

Fig. 1. Strategies adjustment to climate change for shrimp aquaculture

Based on the Figure 1 shows that adaptation strategies to enhance the resilience and sustainability of shrimp aquaculture in the face of global warming, include: a. Site selection and design [17,29], where the site is selected and uses innovative pond designs to improve water management and reduce vulnerability to climate impacts, ; b. Water conservancy [26,30], with monitoring and control of salinity and temperature in ponds using techniques such as water filtration and shading structures; c. Species selection [31], selection of

species and making investments in breeding programs for traits such as disease resistance and heat tolerance; d. Integrated agricultural systems [32–34], by implementing diverse aquaculture practices, such as polyculture with other species and plants, to improve ecosystem stability and resilience; e. Disease management [35,36], through the enforcement of biosecurity protocols and the use of probiotics to strengthen shrimp health and reduce disease risk; f. Climate forecasting and weather resilience [37,38], by utilizing technology for real-time monitoring of environmental conditions and developing emergency preparedness plans for extreme weather events; g. Community engagement and knowledge sharing [39,40], which promotes training programs and collaborations with research institutes to share best practices among cultivators; h. Policy and governance [27,41], where advocating for supporting regulations and incentives that encourage sustainable aquaculture practices; and monitoring and evaluation [42,43], by building a system to assess the effectiveness of adaptation measures and implement adaptive management for continuous improvement.

1.3 Objective

This bibliometric analysis aims to examine the current research trends and adaptation strategies related to shrimp farming and climate change. The analysis will synthesize existing literature to identify the key research themes, geographic focus, and methodological approaches, as well as the adaptive measures adopted by shrimp farmers to address the challenges posed by climate change. The study will employ a comprehensive search of relevant databases Scopus, to identify peer-reviewed journal articles, conference proceedings, and other relevant publications. The analysis will focus on quantitative and qualitative synthesis of the collected literature, with a particular emphasis on identifying the most influential studies, emerging research topics, and the adaptation strategies utilized by shrimp farmers to address climate change. By integrating the existing knowledge, this research will enhance the understanding of the current landscape of studies on shrimp farming and climate change adaptation, and provide insights to inform future research and policy interventions in this critical area.

2 Methodology

In order to examine research trends and adjustment of shrimp aquaculture to global warming, this study uses bibliometric analysis, which follows the previous study method conducted by [44–46], where all use bibliometric methodologies in the framework of a systematic literature review with quantitative data derived from numerous journal articles sourced from various databases. This bibliometric review was performed using the bibliometrix package in R-Studio (version 4.4.1). This method enables the mapping and examination of sub-themes related to climate change adaptation that are vital for the sustainability of shrimp farming, along with strategies for adaptation and adaptive management. Specifically, bibliometric reviews provide a quicker and more efficient means of analyzing extensive literature compared to conventional manual review methods. [47–49]. Figure 2 illustrates the research methods, processes, and tools employed in this study.

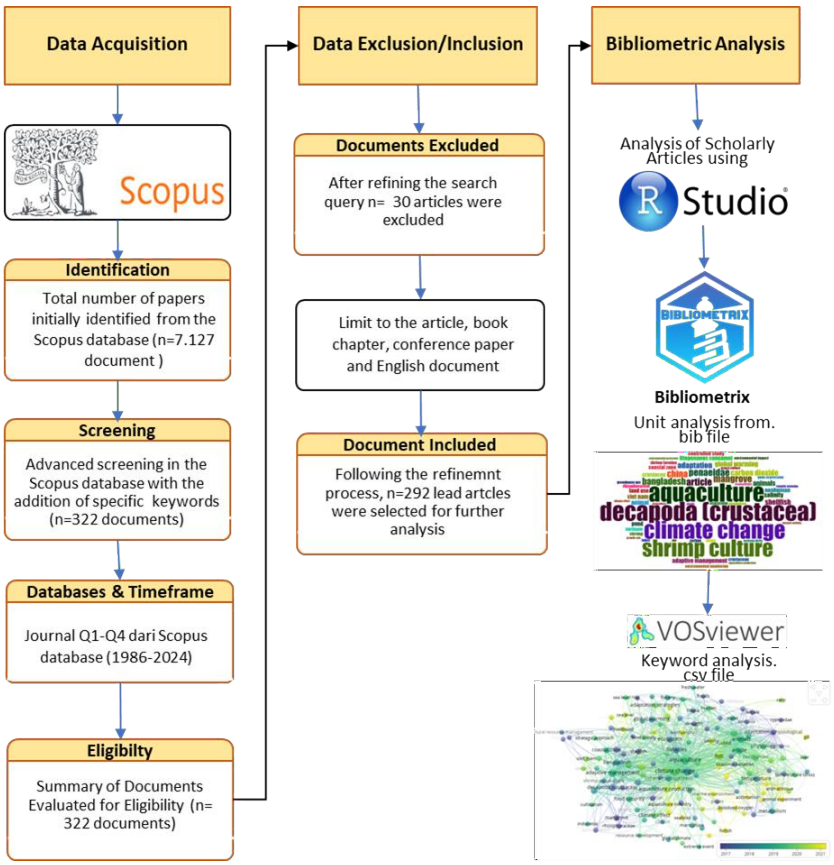

Fig. 2. Research process, methods, and instrument.

2.1 Data Collection and Data Preparation

The study uses the sophisticated bibliometric software tool of the he 'Bibliometrix' R package to provide functionality, and the 'Biblioshiny' interface, to perform bibliometric analysis. This study takes meta data for bibliographic analysis taken from the Scopus database, because it has a very wide collection of journals and publications from various disciplines, which allows researchers to conduct comprehensive analysis, in addition to the quality of the data is known for its strict selection process for indexed journals, thus ensuring that the metadata taken comes from high-quality publications and provides more validity in the analysis bibliometrics. Researchers have extensively utilized the Scopus database in earlier review studies [50,51].

Initially, our search of the Scopus database identified 7,127 publication documents. Where to collect the articles published In this study, a thorough search process was conducted using the term "OR" to incorporate synonyms for both phrases from the database and the term "AND"to combine similar sets of word types for the two main search topics. In this initial search, we used the following keywords: TS=("shrimp culture*" OR "prawn culture*" OR "shrimp farming" OR "prawn farming" OR "shrimp pond*" OR "prawn pond*"). Then the search continued with the addition of a keyword field with the term DAN for: TS=("climate change" OR "climate effect" OR "temperature rise*" OR "global warming" OR adaptation* OR "adaptation strategies" OR "adaptive management") so that publication documents were obtained that narrowed down to 322 documents found, with the range of publication years:

1986-2024. After a search refinement, these 322 articles were selected for additional analysis on August 08, 2024.

The search conducted in the Scopus database adhered to established exclusion criteria, with the aim of thoroughly gathering relevant literature within a specified time period. To ensure the focus and quality of our research, we excluded a total of 30 articles. Specifically, 25 articles were filtered out to retain only publication documents, including articles, book chapters, and conference papers. Additionally, 5 non-English articles were excluded to guarantee consistent understanding and analysis. By applying these exclusion criteria, the researchers identified 292 relevant and high-quality articles that aligned with the study's focus.

2.2 Analytical Tools

2.2.1. VOSviewer

VOSviewer is a robust software application intended for constructing and visualizing intricate bibliometric networks involving a range of entities, such as authors, researchers, institutions, collaborating countries, regions, and continents [49,52]. The app has been widely used to analyze scientific literature and has several key features and functions, which allow the use of different methods for analyzing research collaboration and networks, including descripton, source network, analysis of the co-occurrence of all keywords, analysis of the author, analysis of thr country, thematic map and tren topic. In summary, VOSviewer is a versatile tool that provides a powerful platform for conducting bibliometric analysis to effectively visualize and interpret relationships in the scientific literature. To assess the significance of the research domain, we employed "keyword analysis" in this research.

2.2.1. Biblioshiny

Biblioshiny is an R-based web application that is part of the Bibliometrix package, which is specifically designed to make bibliometric analysis accessible and user-friendly. Onthe app It offers an interactive interface for researchers to conduct comprehensive bibliometric studies. as evidenced by the widespread use of this application in some previous researches to examine scientific texts [44,45]. This software can retrieve bibliographic data from multiple sources, including Scopus, Web of Science, and Dimensions. Consequently, Biblioshiny, which is developed on the Bibliometrix R package, offers access to a variety of analytics, such as annual scientific outputs, the most cited articles, key sources, prominent authors and affiliations, geographical data, and the creation of keyword clouds. Biblioshiny provides a comprehensive platform for conducting robust bibliometric analyses, making it easier for researchers to derive meaningful insights from bibliographic data.

3 Results

3.1 Descriptive Statistics

By using the keyword search described before, this bibliometric analysis give some importance information about research trends and adaptation of shrimp aquaculture to global warming. The topic of climate change adaptation research for shrimp farming has been studied

first for several Southeast Asian regions that are vulnerable and at risk of climate change, seperti Bangladesh, Vietnam, Philippines and Sri Lanka [16,17,20,53]. The total number of papers used for this bibliometric analysis is 292 documents, which includes all documents in the form of journal articles, book chapters and conference papers. The publication trend from 1986-2002 tends to be constant, then increases slightly in 2003-2012, then the trend increases sharply from 2013-2024. This can reveal insights and provide clues about the development of the field and growing research interests. As for the total number of authors representing the cumulative number of individuals who have contributed to the publication, there are 1,137 authors. This data provides an overview of the extent of participation in the field of research. Statistics from the top 15 authors with the number of publications per author ranged from 4-12 articles and had an impact measure H of 4-9.

Based on the analysis of documents provided in the Scopus database, seen at Figure 3 the largest documents appear in two subject areas, namely: environmental science (29.1%) and agricultural and biological science (28.6%), followed by social science (9.5%), earth and planetary science (8.0%) and engineering (3.7%).

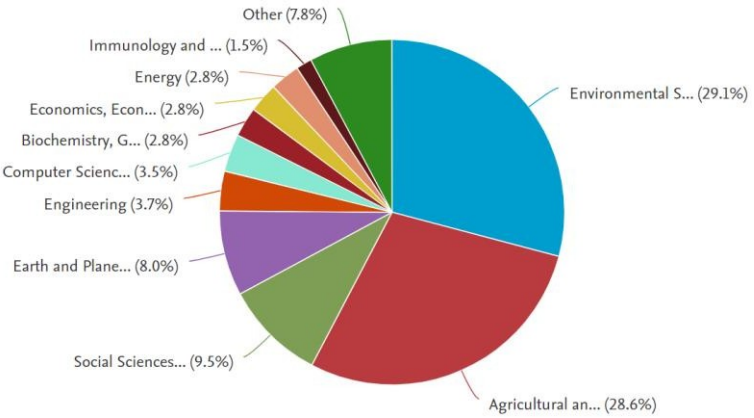

Fig. 3. Total document based on subject area (source: analyze result Scopus)

The largest author affiliation is from Fujian Normal University with 36 articles, followed by Can Tho University (15), Mahidol University (11) and The Chinese University of Hong Kong (9). Then for the total of journals included in the bibliometric analysis data of 174 which shows the variety of journals in which publications have appeared. Various journals can indicate interdisciplinary research, while concentration in specific journals indicates a focused area of research. Based on the data of the top 15 journals, it can be seen that the journal Aquaculture has the largest number of documents, namely 26 articles, followed by Aquaculture Research (9), IOP Series: Earth and Environment Science (7), Marine Policy (6) and Sustainability (6), that have Impact Measure H 2-12.

3.2 Bibliometric Indicators

3.2.1 Source network

Knowledge and understanding of the latest developments and advances of a specific area of research of interest is a necessity for scientific visualization of the most prolific and highly cited document sources is essential. In Figure 4 the research article network of shrimp culture adaptation to climate change is generated from the visualization of 292 articles using the VOSviewer tool. Setting a threshold with a minimum requirement of 4 documents and citations ranging from 3 to 25 for each document. Out of 177 journal sources, 17 satisfied the criteria. The largest node is displayed in Figure 4 indicates the highest number of published documents. Aquaculture has the largest node compared to other sources, with a

total of 26 articles in the shrimp culture adaptation to climate change research, followed by Aquaculture Research (9), Marine Policy (6), Sustainability (Switzerland) (6), Ambio (4), Science of The Total Environment (4). Meanwhile, Aquaculture received the highest number of citations, totaling 634 from 22 documents. Additional details can be found in Table 1. The journal's impact factor (JIF) was obtained from its official website, accessed on September 25, 2023.

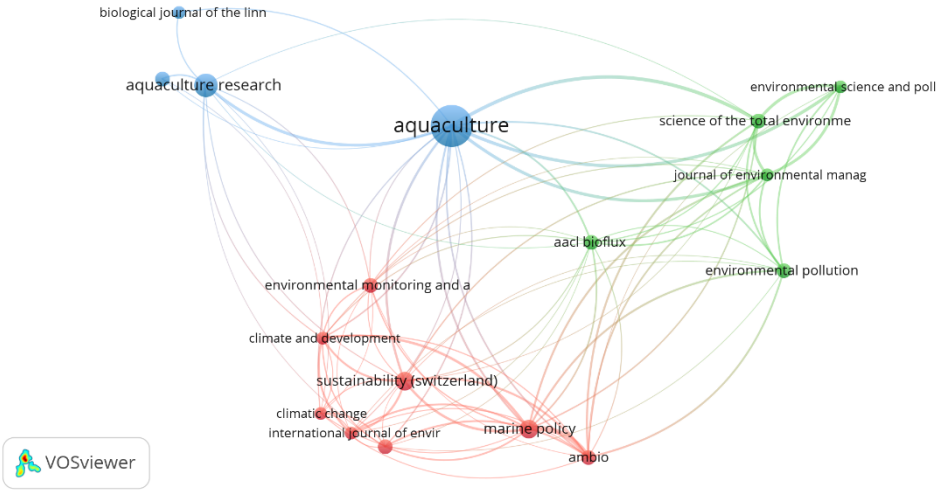

Fig. 4. Research article network of shrimp culture adaptation to climate change

From Figure 5 that produced by Biblioshiny displays the H-index of the journal, where the Aquaculture is the top source in shrimp culture adaptation to climate change with 12 H- index, followed by Marine Policy (6), Aquaculture Research (5), Ambio (4), Environment Development and Sustainability (4), AACL Bioflux (3), Climate and Development (3), Climate Change (3), Sustainability (Switzerland) (3), Advances in Global Change Research (2), Agricultural Systems (2), Aquaculture Economic and Management (2), Aquaculture International (2), Biological Journal of The Linnean Society (2), and Environmental Earth Sciences (2).

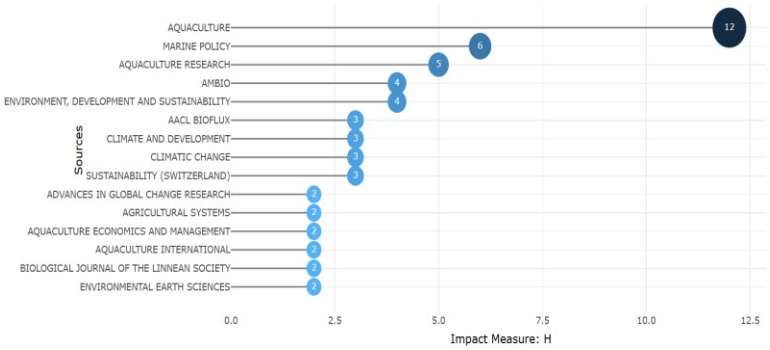

Fig. 5. Sources H-index in shrimp farming adaptation research.

Table 1. Top 15 research publications based on the Scopus meta data for shrimp culture adaptation

No	Sources	Articles	Citations	Average Citation	Total Link Strength	SJR
1	Aquaculture	26	634	24	172	1.059
2	Aquaculture Research	9	132	15	41	0.529
3	Iop Conference Series: Earth And Environmental Science	7	21	3	33	0.199
4	Marine Policy	6	265	44	173	1.036
5	Sustainability (Switzerland)	6	52	9	76	0.672
6	Aacl Bioflux	4	81	20	38	0.236
7	Ambio	4	141	35	143	1.786
8	Aquaculture Economics And Management	4	22	6	124	1.029
9	Aquaculture International	4	6	2	104	0.585
10	Environment, Development And Sustainability	4	97	24	34	0.889
11	Environmental Monitoring And Assessment	4	151	38	21	0.643
12	Environmental Pollution	4	105	26	55	2.132
13	Journal Of Experimental Marine Biology And Ecology	4	32	8	7	0.630
14	Science Of The Total Environment	4	100	25	107	1.998
15	Aquacultural Engineering	3	8	3	19	0.735

3.2.2 Analysis of Keyword Co-occurrence

Scientific evaluating keywords can help the process of meticulousness in retrieving important sources of information that are relevant and efficient enough to be used to meet various research objectives. From a total of 292 articles as seen in Figure 6 which were generated from data visualization using VOSviewer. Of the 2935 keywords using VOSviewer, using a total of 73 keywords that can meet the threshold, and using the minimum number of keyword occurrences is 10. The collection of a number of terms from each cluster will show the collectivity of a number of researchers globally in the field of shrimp farming adaptation to climate change, so that special themes need to be considered that are particularly interesting that need to be improved in the future.

The four topic from the primary clusters can be classified in this study are red clusters, greenclusters, blue clusters, and yellow clusters. The red network cluster consists of adaptive management, agriculture, aquaculture, aquaculture production, Bangladesh, climate effect, climate change, coastal zone, crustacean, decapoda (crustacea), environmental impact, farming system, life cycle assessment, livelihood, Mekong delta, remote sensing, sea level, shrimp aquaculture, shrimp culture, shrimp farming, sustainability, sustainability development, Vietnam, and vulnerability, which represents the efforts of adaptive management of the shrimp farming to climate change effect.

The green network cluster consists of adaptation, animal, article, controlled study, crustacea, enzyme activity, fisheries, gene expression, genetics, growth rate, litopenaeus vannamei, metabolism, nonhuman, penaeidae, physiology, prawn culture, priority journal, and survival, which represents the theme of adaptation mechanism of crustacea to climate change effect. The blue network group, which signifies the theme of climate change impact to shrimp

farming, consists of carbon dioxide, china, concentration, environmental monitoring, global warming, greenhouse gas, lake, methane, pond, salinity, temperature, and water.

The last cluster is the yellow cluster, which includes the theme of ecosystem role to protect shrimp ponds, which consists of blue carbon, carbon, carbon emission, ecosystems, environmental protection, land use, land use change, mangroves, rhizophoraceae, and shrimp ponds. Table 2 gives the details information of the four topic from the main network clusters based from the author's keywords, where the coocurrence rates of the red network cluster, green network cluster, blue network cluster, and yellow network cluster respectively had the highest incidence for 795 (46,5%), 439 (25,7%), 303 (17,7%), and 174 (10,2%).

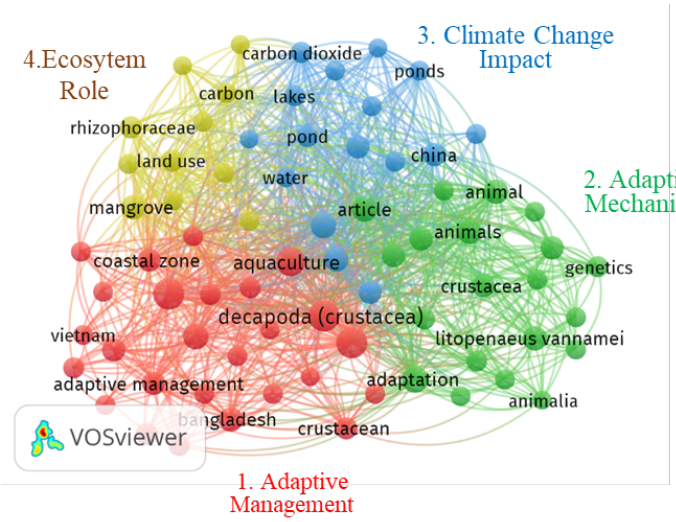

Fig. 6. Co-occurrence of network from the common keywords that used in this study

Table 2. Displays the specifics of the four primary clusters based on author keywords.

Cluster	Keywords	Theme	Occurences
Red	Adaptive management, agriculture, aquaculture, aquaculture production, Bangladesh, climate change, climate effect, Coastal zone, costal zones, crustacean, decapoda (crustacea), environmental impact, farming system, life cycle assessment, livelihood, mekong delta, remote sensing, sea level, shrimp aquaculture, shrimp culture, shrimp farming, sustainability, sustainability development, vietnam, viet nam, vulnerability	Adaptive management of shrimp farming to climate change	795 (46,5%)
Blue	Carbon dioxide, china, concentration, environmental monitoring, global warming, greenhouse gas, greenhouse gases, lakes, methane, pond, salinity, temperature, shrimp, water	Climate change impact to shrimp farming	303 (17,7%)
Green	Adaptation, animal, animals, animalia, article, controlled study, crustacea, enzyme activity, fisheries, gene expression, genetics, growth rate, litopenaeus vannamei, metabolism, nonhuman, penaeidae, physiology, prawn culture, priority journal, survival	Adaptation mechanism of crustacea to climate change	439 (25,7%)
Yellow	Blue carbon, carbon, carbon emission, ecosystems, ecosystem, environmental protection, land use, land use change, mangrove, rhizophoraceae, shrimp ponds	Ecosystem role to protect shrimp ponds	174 (10,2%)

In the red network cluster, where some interconnection of important keywords such as adaptive management, aquaculture, climate change, aquaculture production, climate effect, coastal zone, crustacean, decapoda (crustacea), environmental impact,

farming system, life cycle assessment, shrimp aquaculture, shrimp culture, shrimp farming, sustainability, sustainability development, and vulnerability, which represents the efforts of adaptive management of shrimp culture to climate change effect.

Our research performed [54] suggests that the limitations of the implementation of small-scale shrimp farmer adaptation practices are often caused by budget limitations, so there is a risk of potential damage. The recurrent adverse impacts caused by the pressure of the negative impacts of climate change that continue to recur greatly affect the livelihood of the community, and have formed a special perception regarding the negative risks of climate change at the lowest community level, so that farmers need to make an adaptation effort in carrying out appropriate aquaculture practices [55]. Contributions that can be made as an adaptation to climate change by combining shrimp agroecosystems and diverse rice farming systems can also increase production from marginal land [56]. The results of the identification and inventory carried out by [57] on the adaptation efforts of the climate change process include: changes in water replacement and exchange schedules, changes in feeding schedules and dispersal density levels, water treatment, water conservation reserves, and harvesting at an earlier time, while being the main factor that affects the choice of actions taken by cultivators in the adaptation process, namely a perception that has been built in cultivators against extreme drought conditions and erratic weather. In addition, in understanding the level of interconnectedness of climate change and the need for enlightenment on the level of gender equality, this is very useful in assisting an important long-term planning on any issue of climate change adaptation initiatives [58] [58].

In the topic of green cluster networks, attention is drawn to the mechanism of adaptation of crustacea to climate change represented by several keywords such as adaptation, animal, article, controlled study, crustacea, enzyme activity, fisheries, gene expression, genetics, growth rate, litopenaeus vannamei, metabolism, nonhuman, penaeidae, physiology, prawn culture, priority journal, and survival, which represents the theme of adaptation mechanism of crustacea to climate change. The blue cluster represents the theme of climate change impact to shrimp farming that consists of carbon dioxide, china, concentration, environmental monitoring, global warming, greenhouse gas, lake, methane, pond, salinity, temperature, and water. Here are some differences in farmers' views on the level of vulnerability, although there are some clear relationships between the characteristics of shrimp farmers, the consequences of each cultivation system, reduced shrimp income, and shrimp farmers' views on income vulnerability.

In terms of income, farmers who use intensive shrimp farming systems appear to be less affected by the impacts of climate change that have occurred or are expected, when compared to farmers who adopt mixed production systems or those that have low density [59]. Research conducted [60] shows that the main risks faced include disease outbreaks, lack of tidal water supply, salinization, extreme temperatures, rainfall uncertainty, and price fluctuations. In addition, agronomic management, such as production system adjustment, agricultural operation adaptation, input application, and dike building, are the main adaptation strategies used, along with financial mechanisms such as market renewal, livestock sales, and input credits. Water management, excavation, dike construction, and water management are also part of the strategy. Adaptation efforts undertaken to reduce vulnerability to climate stress show the dynamics of community livelihoods and how they cope with current circumstances [61]. With the problem of weather shocks, cultivators are making efforts to polyculture tilapia to improve welfare, so that there is also an increase in adaptive capacity with the adoption of tilapia polyculture intervention [62].

The last cluster is the yellow cluster, which includes the theme of ecosystem role to protect shrimp ponds, which consists of blue carbon, carbon, carbon emission, ecosystems, environmental protection, land use, land use change, mangroves, rhizophoraceae, and shrimp ponds. One way to minimise the effect of global warming is to implement integrated mangrove-shrimp farming, which plays a role in sequestering blue carbon through mangrove restoration [53,63]. In addition, another adaptation strategy to address the effect

of climate change on land based aquaculture vulnerability is "Integrated Multi-Trophic Aquaculture (IMTA)", which is considered an ecosystem-based approach in adapting to global warming, while providing benefits for both the environment and the economy [64]. The shrinkage of shrimp pond areas will also provide direct benefits for mangrove restoration and support effective hydrological restoration [65].

Based on the Picture 7 appears to be a word cloud related to shrimp culture and aquaculture, highlighting various themes and concepts associated with shrimp farming adaptation to climate change. There are some key terms include: aquaculture (the farming of aquatic organisms, particularly shrimp); decapoda (crustacea), a classification of crustaceans that includes shrimp; climate cange (an important factor affecting aquatic ecosystems and shrimp farming); salinity (a critical environmental factor in shrimp culture); ecosystem (refers to the interconnected system of organisms and their environment); Bangladesh, China, Vietnam, they are some countries likely involved in shrimp farming; mangrove (coastal ecosystems that may play a role in shrimp habitats); and carbon dioxide (a greenhouse gas that impacts climate and aquatic environments). Overall, the word cloud emphasizes the interconnectedness of shrimp farming with environmental factors, geographical locations, and ecological considerations.

Fig. 7. WordCloud emphasizes the interconnectedness of shrimp farming

3.2.3 Authors analysis

In analyzing the most active authors as well as the network of collaboration among researchers focused on the adjustment of shrimp farming to global warming, the VOSviewer software with certain criteria was used. On VOSviewer, a threshold is defined where each author must have a minimum of 2 publications and 50 citations. Of the 1,204 authors, 33 met the threshold, based on verify selected authors, the Top 5 best citations were obtained, namely: Kauffman, J.B. published 5 documents with 456 citations, Ahmed Nesar (7 documents with 415 citations), Tong Chuan (12 documents with 320 citations), Yang Ping (12 documents with 320 citations), and Lai Qiuming (2 documents with 302 citations. Figure 8 generated by Biblioshiny shows the production of documents by the author in a specific period of time. The size of the blue node reflects the number of articles published in the year. The first researchers to address the adjustment of shrimp culturer to global warming were Gaxiola G. and Cuzon G., who published their work in 2003. Then followed by Diana JS. and Ahmed N. who published a paper 8-9 years later. Meanwhile, the most prolific authors in this field until 2023 are: Tong C., Yang P., Lai DYF., and Yang H.

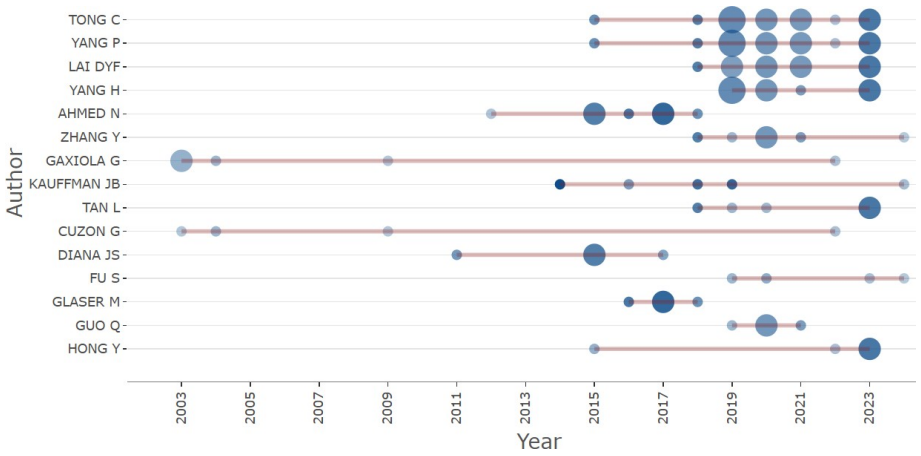

Fig. 8. Author's publication over time.

The most ascendant authors are Tong Chuan and Yang Ping, who each collected a total of 320 citations with 12 documents and had an H9-impact measure as depicted in Figure 9. In summary, Tong Chuan and Yang Ping's significant citation count, consistent document output, and respectable H-index highlight their influential roles in climate change adaptation research. Their work likely addresses vital issues in the field and resonates with a broad audience, making them key figures whose contributions are recognized and utilized by the academic community and beyond. Their success can be attributed to a combination of impactful, relevant research, effective collaboration, and engagement with critical global challenges

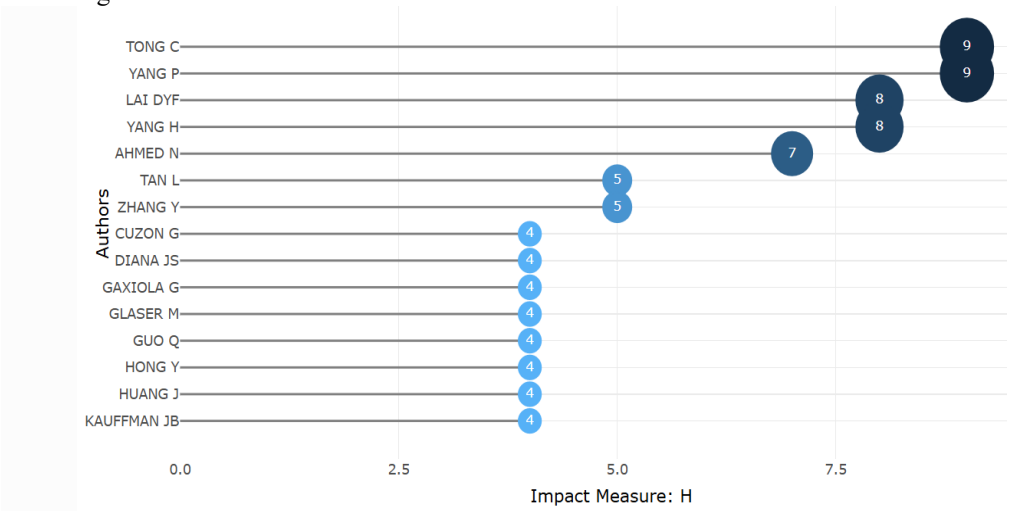

Fig. 9. The top influential authors with authors' local impact (H)

Based on Figure 10 overlay visualization of the most country's from VOSviewer noted that most of the authors are from China, which can offers researchers with very precious information on ways they are massively concerned about climate change adaptation issues by collaborating with leading researchers. In summary, the strong representation of authors from China in climate change adaptation research, as visualized in VOSviewer, reflects not only the country's commitment to addressing climate challenges but also its role as a key player

in global scientific discourse. This collaboration enhances understanding and fosters development of effective strategies for climate adaptation, benefiting both China and the wider international community. Integrating this knowledge into broader climate action initiatives can improve resilience and inform policies in other countries facing similar challenges.

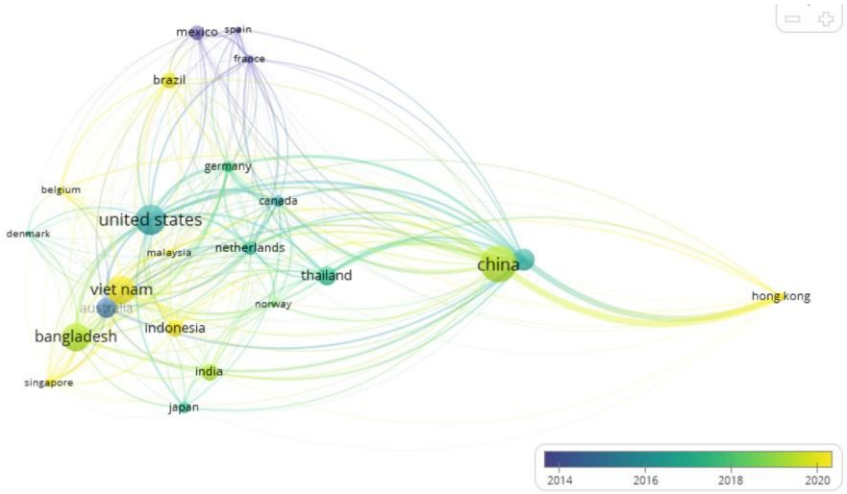

Fig. 10. Overlay visualization of the most country's documents

3.2.4 Countries analysis

This part aims to identify possible collaborators and gain an understanding of countries that are driving the adaptation of shrimp farming to climate change. Figure 11 was created utilizing VOSviewer, with at least 5 documents and 50 citations from every country. Of the total 57 countries involved in the study of shrimp farming adaptation to climate change, only 21 countries meet these criteria. Variations in contributions to climate change adaptation show the presence of diverse aspects studied and differences in locations with different levels of vulnerability. China was recognized as a major contributor to advancing the adaptation of shrimp farming to climate change, with 51 documents and 1,235 citations, as evidenced by the striking yellow knot in Figure 11. After China, the countries with the most research results are the United States (41), Viet Nam (38), Bangladesh (37), the United Kingdom (28), Australia (24), Thailand (22), and Indonesia (20). In Figure 11, there are four groups, where all countries have robust ties with China. The yellow group consists of China, the United Kingdom, and Hong Kong. The green group includes Brazil, Mexico, and France. The blue cluster consists of the Netherlands, Germany, and Canada, while the red cluster includes the United States, Viet Nam, Bangladesh, Australia, Thailand, Indonesia, Japan, and Malaysia. Each cluster is formed from countries that often work together in collaborative efforts.

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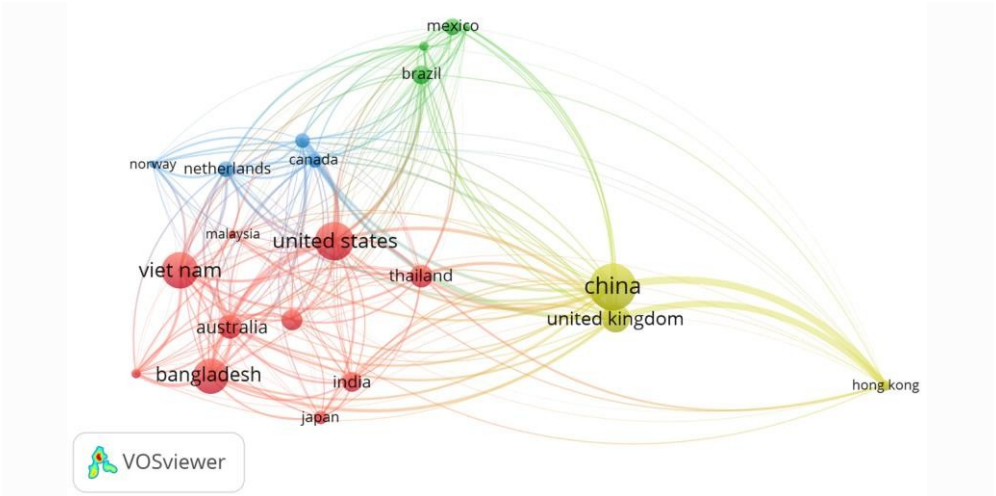

Fig. 11. Network of countries involved in climate change adaptation

Figure 12 shows the geographic distribution of nations involved in study on the application of shrimp farming adjustment to global warming. Table 3 presents the results of research on shrimp farming adaptation in various countries. The number of publications produced in China reflects the country's active efforts to contribute to the mitigation and adaptation of shrimp farming related to climate change. Research [66] states that aquaculture ponds are one of the main sources of greenhouse gas (GHG) emissions and contribute to climate warming in China's subtropical estuaries. In addition, efficiency in the utilization of shrimp feed can effectively reduce CH4 emissions from coastal shrimp ponds [67].

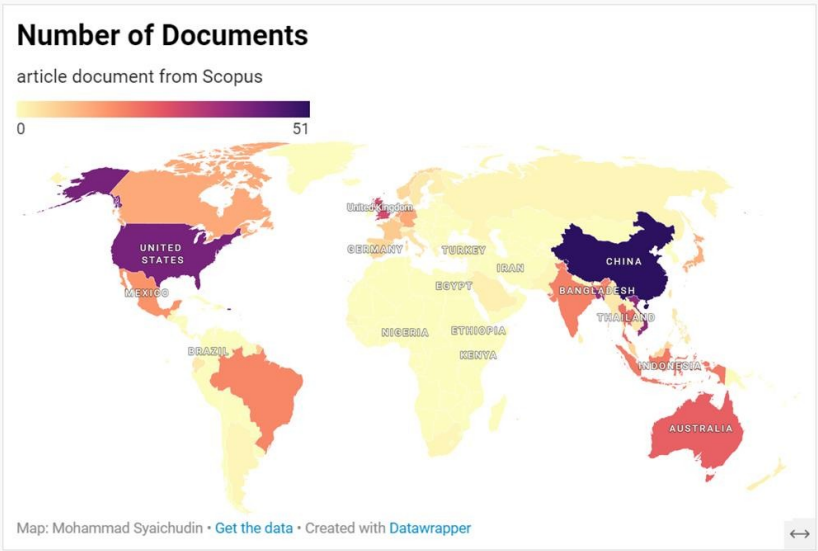

Fig. 12. Geographical distribution of the nations involved in the study of climate change adaptation

Table 3. Most productive countries in climate change adjustment

Country	Documents	Citations	Average Citations	Total link strength
China	51	1235	24	6132
United States	41	1451	35	3980
Vietnam	38	402	11	2349
Bangladesh	37	487	13	2939
United Kingdom	28	749	27	6108
Australia	24	853	36	2202
Thailand	22	333	15	1814
Indonesia	20	203	10	1045
India	19	232	12	834
Brazil	18	252	14	1086
Mexico	16	458	29	717
Netherlands	15	584	39	2113
Canada	13	532	41	2251
Germany	13	574	44	2488
Japan	12	126	11	590

In figure 13 shows the diagram effectively visualizes the pattern of collaboration in document publications in various countries which shows that the number of author documents from each country is categorized based on two types of research collaboration, namely MCP (Multi-Country Partnership) which is pink and SCP (Single-Country Partnership) which is light green. Chinese state dominance appears to have the highest number of documents, with significant advantages in MCP and SCP. Then followed by Bangladesh which also showed a number of important documents in both categories. Other countries such as Thailand, the United States, and India, which have varying amounts of documents, have mostly higher SCP documents compared to MCPs.

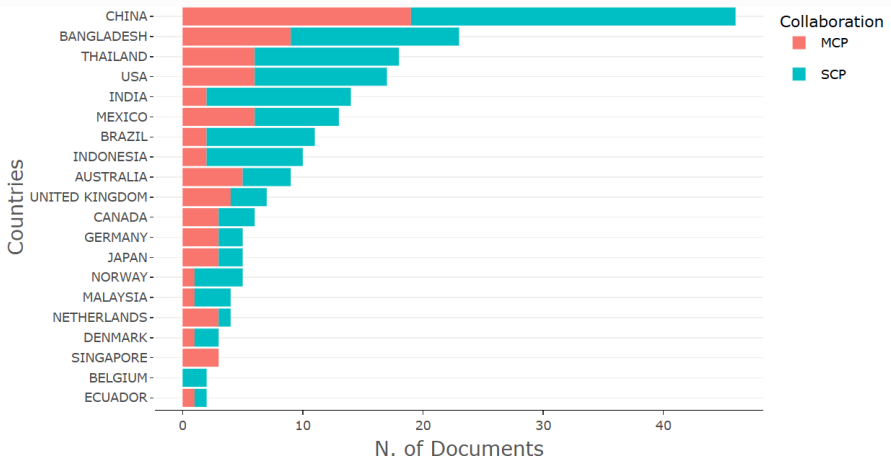

Fig. 13. Corresponding author's country

3.2.5 Research trends and tematic map

This part showss an analysis of the trends of study and topics related to shrimp farming adaptation to climate change. Based on Figure 14 the trend topics produced by Biblioshiny are taken from the Scopus meta data. It can be seen that a time series plot diagram depicting the frequency of various terms over the years from 2003 to 2023 shows that terms such as "eutrophication" [68–70] and "shrimp farming" [16,58], appear to have more consistent mentions, while others may indicate a spike in specific years. On the Y axis, various terms related to environmental and biological topics appear to be listed, where the data points of each term are represented by a series of points along the timeline, which indicate the number of occurrences or mentions of the term in each year, while the size of the dots that vary enough has the potential to indicate the frequency or significance of the term in that year. The plots show a general upward trend in the frequency of many terms over the years, indicating an increase in interest or this area of research. Specific terms such as "decapoda", "climate change", and "bacteria" are likely to be of particular interest, as they can indicate significant trends or patterns in their use over time, where horizontal lines extending from the dots indicate the range of mentions for each term in a given year, providing a visual representation of variability.

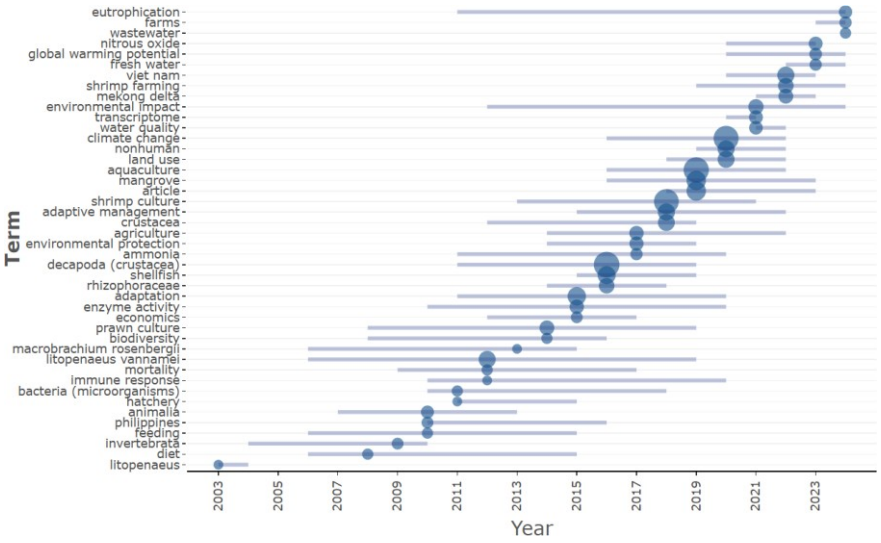

Fig. 14. Trending topics in adaptation of shrimp farming and climate chnage over time.

Based on Figure 15. the thematic map diagram shows the categorization of scattered plots of various themes based on the axes of relevance level (centrality) and development level (density). The upper right quadrant area marked in red includes themes related to "decapoda (crustaceans)", "shrimp farming" [40], and "climate change"[71], which shows that this research topic is very relevant and quite well developed, including the themes of mangroves, adaptive management and coastal zones. Meanwhile, the lower left quadrant area shows that the research themes "animals" and "adaptation" [40,72]may be included in the research categories that are less central and less developed compared to the highlighted themes.

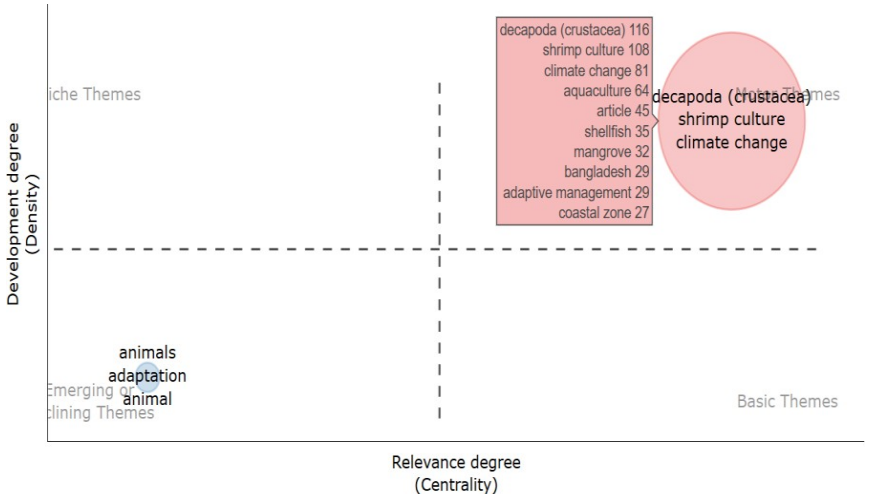

Fig. 15. Tematic map shows the categorization of scattered plots of various themes

From the tematic map “decapoda” is a very relevant and quite well developed research topic. Decapoda is an order of crustaceans that includes familiar species such as shrimp, crabs, lobsters, and crayfish. Members of this order are characterized by having ten limbs (from which the name Decapoda is derived: "deca" meaning ten and "poda" meaning feet). They play critical roles in aquatic ecosystems as both predators and prey, and are important to human economies, particularly in fisheries and aquaculture. Shrimp farming also become very relevant topic, where shrimp farming, or aquaculture, involves the cultivation of shrimp in controlled environments, typically in coastal areas. It has become a significant industry due to high consumer demand for shrimp, which is favored for its taste, nutrition, and versatility. However, shrimp farming practices can lead to various environmental concerns, including habitat destruction (especially mangrove forests), water pollution from excess feed and waste, and the spread of diseases. Beside that climate change impacts also get intention for relevant topic.

Climate change, primarily caused by human activities like fossil fuel use and deforestation, results in increasing sea temperatures, ocean acidification, and changes in precipitation patterns. These alterations can significantly impact marine ecosystems and aquaculture, including: (1). Impact on ocean environments (warmer water temperatures can affect the distribution and reproductive cycles of decapod species, including shrimp. For instance, some shrimp species may migrate to cooler waters, potentially disrupting local fisheries), (2). Altered farming conditions (shrimp farming is susceptible to climate-induced changes such as increased water temperatures and salinity fluctuations, where these changes can exacerbate disease outbreaks among farmed shrimp, making it challenging for farmers to maintain healthy stocks), (3). Coastal ecosystem degradation (As rising of sea levels and severe weather events are occurring with greater frequency, coastal regions are at risk, where this impacts mangrove forests and wetlands, which serve as critical habitats for juvenile shrimp and other marine life), and (4). Food security and economic impact (climate change can jeopardize both wild shrimp populations and shrimp farming, affecting food security in regions where shrimp is a staple protein, where economically, disruptions can lead to job losses in fishing communitiesand aquaculture sectors).

In summary, the themes of decapoda, shrimp farming, and climate change are intricately linked, with each influencing the others in terms of ecological balance, sustainable

practices, and economic viability. Addressing these interconnected issues requires a holistic approach that considers both environmental and human factors.

4 Conclusions

Using bibliometric analysis, this paper delineates research trends and future directions from 2009 to 2024. VOSviewer and Biblioshiny software are utilized to visualize the datasets extracted from the Scopus meta data. The bibliometric analysis includes elements such as descriptions, source groups, analysis of keyword co-occurrence, analysis of author, country analysis, thematic mapping, and trending topics, which can be used to draw conclusions. The results indicate that China is at the forefront of climate change adaptation analysis then following by United States, Vietnam, Bangladesh, UK, Australia, Thailand and Indonesia. Thematic map shows that very relevant and quite well developed topic are "decapoda (crustaceans)", "shrimp farming", and "climate change", including the themes of mangroves, adaptive management and coastal zones. Meanwhile, the research themes, such as: "animals", "adaptation", and "animals" may be included in the research categories that are less central and less developed compared to the highlighted themes. Bibliometric analysis of research trends indicates that future studies should focus on : "eutrophication" and "shrimp farming", appear to have more consistent mentions, while others may indicate a spike in specific years. Specific terms such as "decapoda", "climate change", and "bacteria" are likely to be of particular interest, as they can indicate significant trends or patterns in their use over time.

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