Journal of Sustainability Science and Management
Volume 20 Number 8, August 2025: 1731-1754
eISSN: 2672-7226

THE SUSTAINABILITY OF LANGKAWI ARCHIPELAGO: A BIBLIOMETRIC ANALYSIS FROM 1975 TO 2022

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http://doi.org/10.46754/jssm.2025.08.012
Submitted: 2 July 2024 Revised: 28 January 2025 Accepted: 13 February 2025 Published: 15 August 2025

Abstract: Archipelago tourism, including Malaysia is a growing and important subsector of the tourism industry worldwide. To assess the current status and developments in the area, a bibliometric study was conducted on the Langkawi archipelago using bibliographical data from the Web of Science (WoS) database over a period of 47 years (1975 to 2022). Furthermore, the study utilised VOSviewer to examine co-authorship networks across researchers, publications, nations, institutions, and keywords. In particular, the analysis included 339 articles regarding the Langkawi archipelago, written by 225 authors from 31 countries. As such, "Grismer L. Lee" is a prolific researcher with an interest in the Langkawi archipelago and contributed the highest number of articles with 15 articles and 289 citations. Simultaneously, Malaysia has been the centre of research on the Langkawi archipelago, especially Universiti Kebangsaan Malaysia (UKM) with 93 publications (684 citations), Universiti Malaya (UM) with 22 publications (194 citations), and Universiti Teknologi Malaysia (UTM) with 12 publications (131 citations). These significant discoveries will enhance researchers' comprehension of the present state of research and assist stakeholders in formulating comprehensive policies and plans to promote sustainability in archipelagos. This is especially true in the Langkawi archipelago as a Global Geopark destination.

Keywords: Bibliometric analysis, sustainable, tourism island, VOSviewer, review.

Introduction

The concept of sustainability has become a primary concern globally and is a complex issue due to its significant impact on human livelihoods (Kidd, 1992; Munier, 2005). Notably, sustainability is closely related to sustainable development, which relies on three main pillars: The environment, economic, and social (Munier, 2005). However, rapid development in all economic sectors frequently negatively impacts the system's sustainability (Kates & Parris, 2003).

The modification of systems such as land clearing and energy and material consumption, leads to unprecedented global impacts such as global warming and climate change (Hajra *et al*., 2023). Most studies on sustainability state that the environmental dimension is more crucial than the other pillars (Biermann *et al*., 2022) as the environmental pillar directly correlates to daily human life. Therefore, sustainability is often designed and applied to counter major environmental issues in any region, including islands.

Climate change is the most significant issue affecting island sustainability. According to Thomas *et al*. (2018), islands contribute about 1% of the global greenhouse gas emissions. However, the island communities remain the most affected by climate change. Most studies on sustainability mainly concentrate

on metropolitan areas as major contributors to carbon emissions due to their industrial and commercial activities, with a limited focus on islands. Moreover, inadequate studies have also been discovered that focus on archipelago communities.

Most of the studies could not demonstrate the significant role of islands as living entities in terms of resource generation and consumption. Thus, by considering the vital role of islands as living organisms, the present study concentrated on Langkawi Island's sustainability due to its significant contribution to the economic development of the tourism sector and local community empowerment in Malaysia. Langkawi is identified as one of the best island tourism destinations in Malaysia. Specifically, the archipelago comprises a cluster of 99 islands and is also known as the jewel of Kedah. It is located at 6° 21'N, 99° 48'E and is separated from mainland Malaysia by the Strait of Malacca (Figure 1).

The total area of Langkawi Island is 478.48 km^2 and the total population is 85,588 (Department of Statistics Malaysia, 2010). However, only four out of the 99 islands in Langkawi are lived on. Note that the Langkawi archipelago has the most ancient and comprehensive geological record from the Palaeozoic era (540 million to 250 million years ago) in the surrounding area. Due to its geological significance, Langkawi Island was recognised as a United Nations Educational, Scientific and Cultural Organisation (UNESCO) Global Geopark (UGGp) in 2007, the first Southeast Asian island to receive that recognition.

Langkawi Geopark comprises the Machinchang Cambrian Geoforest Park, Kilim Karst Geoforest Park, Dayang Bunting Marble Geoforest Park, and the Kubang Badak BioGeo Trail (Langkawi Development Authority, 2022). As one of the best tourism destinations in Malaysia, Langkawi Island is solely dependent on the mainland to generate its energy, food, and water resources. For instance, a third high-voltage underwater cable was installed across 26.5 km in 2018, connecting Langkawi Island with the national grid (Zainuddin, 2020). The underwater project connected Kuala Perlis to Teluk Apau in Langkawi. The 132-kilovolt project was installed by Tenaga Nasional Berhad (TNB), the national power company, to strengthen the national electrical infrastructure on the tourism island.

Langkawi offers tourists authentic cultural and natural experiences, contrasted with urbanised and modern life. In 2022, Langkawi was voted the fourth best island to visit in Asia, where three of the resorts were voted as the top 20 resorts in Asia (The Malaysian Reserve, 2023). As tourism has become the major economic activity of the

Figure 1: Location of Langkawi Island

island, Langkawi has undergone significant transformations in terms of government policies and economic, social, and environmental settings (Omar *et al*., 2014). Consequently, Langkawi has experienced significant rapid development, which has attracted more tourists. In 2021, 1,093,937 tourists arrived in Langkawi, dramatically increasing in 2022 to 2,581,605 (Langkawi Development Authority, 2023). Accordingly, hotels, chalets, and tourist attraction sites were built to accommodate the high number of tourists visiting every year. In addition, several attractions were built such as Langkawi Skybridge Cable Car, underwater world aquarium, Maha Tower, Splash water theme park, and many more.

Aligning with the development of Langkawi as a world-class tourism destination, scientific studies on Langkawi and its sustainability have also been increasing in various areas. This includes social science, engineering, environmental science, zoology, business management, tourism management, and science technology. For example, coral health at Pulau Anak Datai (PAD), Langkawi was assessed using the Coral Health Index (CHI) method. The study depicted that PAD could be rated as stressed, unhealthy, and disturbed due to less than 40% of benthic cover and low fish biomass (16.76 g/m^2) (Ismail *et al*., 2022).

Meanwhile, a study on food waste management among hotel operators in Langkawi revealed that several factors (external, internal, and intermediate influences) significantly influenced the food waste generation on the island. It requires a holistic approach with multiple stakeholders to reduce food wastage and move towards sustainable food waste management on the island (Kasavan *et al*., 2019). Nonetheless, it is undeniable that the tourism industry has boosted the environmental, economic, social, and cultural development of the island community. As a positive result, the socioeconomic level of the local community has improved via more employment opportunities and increased income and language skills of the Langkawi community (Ismail *et al*., 2020). Therefore, preserving and improving these spaces is significant to ensure a healthy and sustainable island.

Most previous studies applied bibliometric network analysis to explore the scientific literature on island topics such as geoparks (Herrera-Franco *et al*., 2022), sustainable tourism (Ruhanen *et al*., 2015), and community participation (Iqbal *et al*., 2022). Hence, realising the crucial role of Langkawi Island in national growth and as a global tourism destination, several studies have been conducted focusing on various aspects as efforts to achieve island sustainability. Despite this, the research topic development and performance trends for islands such as Langkawi are still insufficient and unclear and further research is urgent due to the complexity of the topic. To the best of the authors' knowledge, no previous preliminary studies have been conducted to explore the sustainability of these islands in Malaysia using bibliometric analysis. In particular, the goal of the bibliometric is to track the progress of publications relevant to the sustainability of Langkawi Island.

Exploring the earliest to the most recent publications might provide more useful insights into Langkawi. The bibliometric analysis offers objective, detailed, and comprehensive insights on the subject of interest for researchers and organisations (Özdemir & Aydoğdu, 2023). Moreover, bibliometric analysis provides researchers with novel insights into the subject under investigation (Kaba & Aydoğdu, 2023). Bibliometric studies can also reveal the countries, journals, institutions, and authors that are most active in a subject, which allows researchers to understand recent progress in the study area (Özkadi *et al*., 2022). Considering the advantages, a bibliometric analysis was conducted to explore research trends regarding the sustainability of the Langkawi archipelago from 1975 to 2022. In line with this, the current study and future research can also be used to provide additional information for developing sustainable solutions and improving the social well-being of the archipelago community.

Materials and Methods

Data Source and Search Strategy

Bibliometrics is a quantitative analytic technique that uses mathematical and statistical techniques to assess the connections and influences of publications within a certain academic field (Fu *et al*., 2023). This approach offers a comprehensive analysis of extensive volumes of scholarly literature. It can also be applied to evaluate research productivity based on bibliographical data such as year, subject area, author, organisation, countries, language, source type, and document type. The Web of Science (WoS) database was developed by Thomson Reuters and covers scientific research engines and the most relevant databases to retrieve bibliometric data (Zhang *et al*., 2019).

Unlike other databases such as Google Scholar, Dimension, Scopus, and PubMed, WoS is considered a global quality database that contains standardised records for retrieving scientific literature. Therefore, the WoS database was used as the primary scientific data source for executing this bibliometric analysis. This study employed all types of indexes, including the Expanded Science Citation Index (SCI-EXPANDED), Social Science Citation Index (SSCI), Book Citation Index-Science (BKCI), Emerging Sources Citation Index (ESCI), Conference Proceedings Citation Index-Science (CPCI-S), Book Citation Index-Social Sciences and Humanities (BKCI-SSH), and the Arts and Humanities Citation Index (A&HCI), as also used by Kasavan *et al*. (2021) and Ali *et al*. (2022).

To retrieve publications related to Langkawi, this study utilised the advanced search in the WoS core collection database. The search was made to ensure that only publications related to Langkawi would be selected. The search terms included the title, abstract, and keywords as follows: TS = (("Langkawi" OR "Pulau Langkawi" OR "Langkawi Island")). At the same time, Boolean operators were used to avoid missing publications. The study's time frame was determined from the earliest publication to 2022. Therefore, the time frame was set from 1975 to 2022. The search for relevant scientific publications was conducted on 15 January 2023 on a single day to avoid bias, as the WoS database is updated daily. Furthermore, this study considered only publications that were written in English and Malay. A total of 406 publications were identified. After removing duplicates and excluding articles from 2023 and with unknown years, a total of 339 articles were retained for the final analysis, as displayed in Figure 2.

Statistical Analysis

Statistical analysis was conducted to identify the research growth and performance on Langkawi sustainability. The assessment focused on the number of published articles, the performance of the author(s), the authors' country, and the authors' institutions and research hotspots, as determined through keyword co-occurrence analysis. The publication output was analysed using Microsoft Excel 2019 based on publication output and citations. Meanwhile, the social network was analysed using VOSviewer software due to its unique advantages and complex network analysis with knowledge domain mapping.

The analysis of Langkawi generated a network map based on the size of the node and the thickness of the linkage lines. In addition, the analysis will also provide additional information such as co-occurrences, links, and total link strength. The co-occurrences analysis was conducted to identify the research hotspots of Langkawi in the time frame. The analysis assists readers in understanding the research focus in a particular year. As such, the analysis was conducted via two approaches: Using authors and keywords and refined keywords. This ensures that Langkawi is emphasised as the case study. Note that combining these two approaches will provide a clearer picture of the scientific study, particularly of tourism in Langkawi in Malaysia.

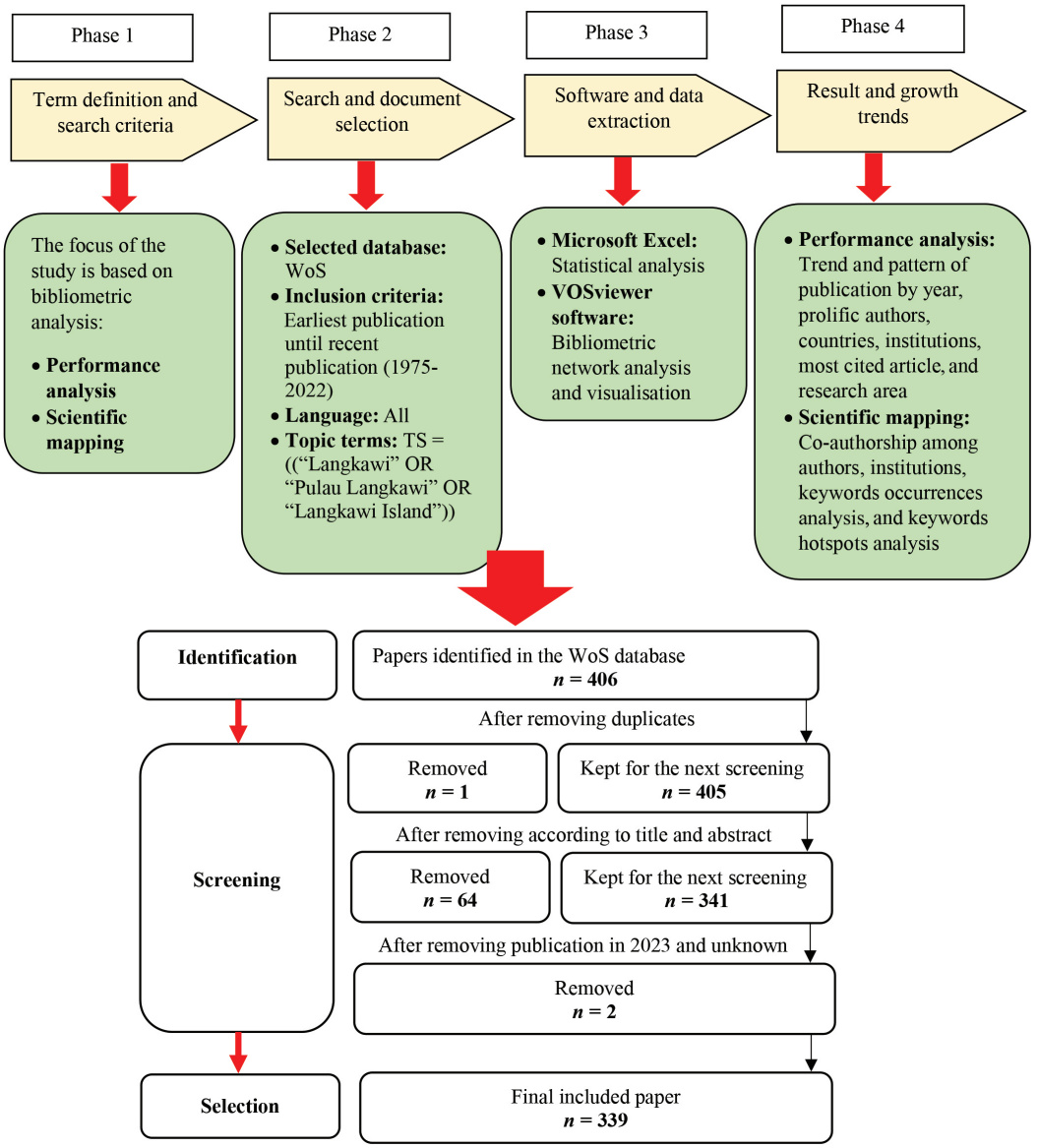


Figure 2: Research flow and procedure

Results and Discussion

Number of Published Articles

Research Publication

Figure 3 depicts the total publication output and citations related to the Langkawi archipelago. The total number of publications and citations with regard to Langkawi indicates fluctuations from 1975 to 2022. Simultaneously, the search of the WoS database reveals that a total of 339 publications related to Langkawi were identified from 1975 to 2022. Furthermore, the trend

suggests that the limited output of Langkawi research was published prior to Langkawi Island receiving its recognition as a UNESCO Global Geopark (UGGp) in 2007. Within the 1975-2007 timeframe, the total number of works published increased slowly, reaching 31 publications, with a total of 597 citations. The trend also fluctuates in terms of publications and citations, with the highest number of publications per year at four in 1997 and 2001. Within this timeframe, 271 citations were recorded in 1995. During the same period, most publications were from anthropology and geoscience studies while a significant portion of the WoS subject index was from SCI-Expanded.

Meanwhile, after Langkawi received the UGGp recognition, the total number of publications on Langkawi dramatically increased from only 31 publications in 1975 to 2007 to 308 in 2008 to 2022. The increase in publications among researchers was now focused on the conservation of the Langkawi archipelago, which plays a vital role in Malaysian cultural heritage, especially in civilisation, socioeconomics, environment, and history. Total citations also suggested a similar trend, from only 597 in 1975 to 2007 to 2,093 citations in 2008 to 2022. Within this period (2008 to 2022), the highest publication and citation numbers were recorded in 2016, with 38 publications and 302 citations. In contrast, the lowest publication and citation numbers were recorded in 2008, with seven publications and eight citations in 2022.

The trend also indicated changes in terms of niche areas where the majority of the studies were in the Social Sciences field (104 publications), followed by Energy and Engineering (30 publications). In contrast, researchers emphasise areas such as Agriculture, Forestry, and Urban Studies less. The present study also indicated that the SCI-EXPANDED and the ESCI were the highest indexes used, with total publications of 125 and 71, respectively. In terms of publication type, most of the output was journal articles, with published works totalling 229 publications, followed by proceedings papers (103 publications), and other publication types. Notably, the majority of the publications were written in English and Malay.

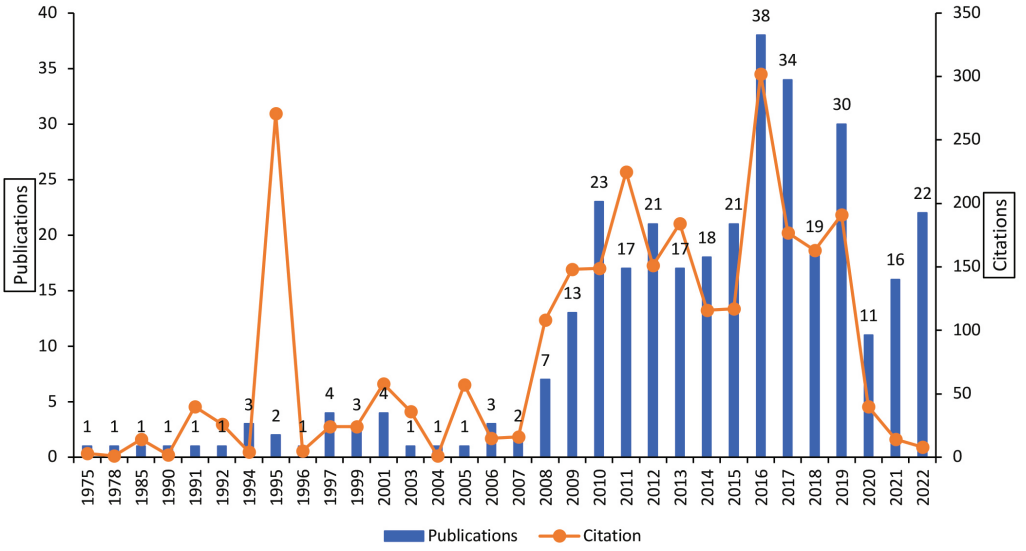


Figure 3: Total annual publications and citations

Most Cited Research Articles

This study used total citations as a metric to evaluate the influence and quality of publications. Table 1 provides a concise overview of the 10 papers that have received the greatest number of citations in Langkawi from 1975 to 2022. The results depict that 247 of the 339 publications were cited 2,690 times, with an average of 10.89 citations per article. Interestingly, 92 (27.1%) of the total number of publications have not been cited yet. Moreover, most of the zero citation outputs were published within the timeframe of 2008 to 2022. Additionally, 10 publications were cited 706 times, representing 26.2% of the total citations and becoming the key players in research related to the Langkawi archipelago.

The study by Carsten (1995) entitled "The substance of kinship and the heat of the hearth-feeding, personhood, and relatedness among Malays in Pulau-Langkawi" appeared as the top-cited article, with 196 citations (6.76 average citations per item). This article explained how Malays in Pulau Langkawi become complete persons, meaning being kin, via living, and consuming together in their houses. Conversely, the study entitled "Memorable customer experience: Examining the effects of customers experience on memories and loyalty in Malaysian resort hotels" by Ali *et al*. (2014) ranked the second most cited paper with 78 citations (7.8 average citation per item). This proceeding focused on four elements that influenced customer experience regarding their memories and loyalty.

The article "The politics of forgetting-migration, kinship and memory on the periphery of the southeast-Asian state" by Carsten (1995) appeared as the third-most cited article with 73 citations (2.52 average citation per item). This is followed by Marzuki *et al*. (2012), with a total of 59 citations and the highest average citation per article of 16.37. Interestingly, two articles were published in 2007 (before Langkawi received its Global Geopark status) while eight articles were published in 2008. Most of these articles were published in reputable journals such as the Journal of Cleaner Production, Energies, and the Journal of Sustainable Tourism. Accordingly, these findings suggest that Langkawi is becoming a significant destination for tourism and scientific research, especially for naturalists, ecologists, and environmentalists concentrating on island sustainability.

Researchers in Malaysia are concerned about environmental protection in Langkawi to achieve sustainable development. In addition, research on the Langkawi archipelago has also attracted the interest of researchers from the United States (US) and the United Kingdom (UK) exploring a sustainable Langkawi archipelago. This ensures a better environment that should be shared equitably with developing countries such as Malaysia.

Table 2 illustrates the top ten research areas related to Langkawi from 1975 until 2022. The results indicate that most of the scientific outputs were concentrated in areas such as Social Sciences Other Topics, with 61 publications (18%), Science Technology Other Topics, with 43 publications (12.7%), Engineering, with 33 publications (9.7%), Environmental Science and Ecology, with 23 publications (6.8%), and Zoology, with 19 publications (5.6%). The citations from these subject areas were also the highest, with the total citations exceeding 100, compared to other areas.

These findings were likely influenced by the total publications from 2008 to 2022 after Langkawi was recognised as Global Geopark in 2007. Meanwhile, subject areas such as Computer Science and Geology, with 10 publications (2.9%), Physics and Business Economics, with nine publications (2.6%), and Area Studies, with eight publications (2.3%) were recorded as having the least number of publications from 1975 to 2022. However, Computer Science was cited only two times in the period 1975 to 2022. This implies that scholars from different disciplines are aware of the significance of maintaining the UGGp recognition in order to maintain sustainable development in Langkawi in the future.

Table 1: Top 10 most cited research

No.	Title	Year	First Author	First Affiliation	Country	Journal	Total Cited	Average Citations per Item	Reference
1.	The substance of kinship and the heat of the hearth - feeding, personhood, and relatedness among Malays in Pulau Langkawi	1995	Carsten, J	University of Edinburgh	UK	American Ethnologist	196	6.76	(Carsten, 1995)
2.	Memorable customer experience: Examining the effects of customers experience on memories and loyalty in Malaysian resort hotels	2014	Ali, Faizan	Universiti Teknologi Malaysia	Malaysia	Procedia-Social and Behavioral Sciences	78	7.8	(Ali *et al*., 2014)
3.	The politics of forgetting - migration, kinship and memory on the periphery of the southeast-asian state	1995	Carsten, J	University of Edinburgh	UK	Journal of The Royal Anthropological Institute	73	2.52	(Carsten, 1995)
4.	Public participation shortcomings in tourism planning: The case of the Langkawi Islands, Malaysia	2012	Marzuki, A	Universiti Sains Malaysia	Malaysia	Journal of Sustainable Tourism	59	16.37	(Marzuki *et al*., 2012)
5.	Technical feasibility studies for Langkawi WCO (waste cooking oil) derived-biodiesel	2011	Kumaran, P	Universiti Tenaga Nasional	Malaysia	Energy	58	4.46	(Kumaran *et al*., 2011)
6.	A review of Lower and Middle Palaeozoic biostratigraphy in west Peninsular Malaysia and southern Thailand in its context within the Sibumasu Terrane	2005	Cocks, LRM	National History Museum	UK	Journal of Asian Earth Sciences	57	3	(Cocks *et al*., 2005)

7.	Investigation of potential hybrid renewable energy at various rural areas in Malaysia	2016	Izadyar, Nima	Universiti Malaya	Malaysia	Journal of Cleaner Production	54	6.75	(Izadyar *et al.*, 2016)
8.	Wind energy potential and power law indexes assessment for selected near-coastal sites in Malaysia	2017	Albani, Aliashim	Universiti Malaysia Terengganu	Malaysia	Energies	44	6.29	(Albani & Ibrahim, 2017)
9.	Public education in heritage conservation for geopark community	2010	Azman, N	Universiti Kebangsaan Malaysia	Malaysia	Procedia-Social and Behavioral Sciences	44	3.21	(Izadyar *et al.*, 2016)
10.	A new insular species of Cyrtodactylus (Squamata: Gekkonidae) from the Langkawi Archipelago, Kedah, Peninsular Malaysia	2008	Grismer, LL	La Sierra University	US	Zootaxa	43	2.75	(Grismer & Ahmad, 2008)

Performance of the Authors

Number of Articles by Authors

The findings indicated that 225 authors participated in publication from 1975 until 2022. Interestingly, six authors from among them have published more than 10 articles in the timeframe. Table 3 presents the top 10 most prolific authors. Grismer Lee (h-index: 8) and Komoo Ibrahim (h-index: 6) were the most prolific authors, each of whom published 15 articles. This is followed closely by Norhayati Ahmad (14 articles, h-index of 4) and Halim Sharina Abdul (13 articles, h-index of 6), respectively. Of the remaining authors, Jaafar Mastura (h-index: 4), and Marzuki Azizan (h-index: 5) published 11 articles while Leman Mohd Shafeea (h-index: 4), Ali Che Aziz (h-index: 4), Ahmad Anuar (h-index: 2), and Azman Norzaidi (h-index: 2) published less than 10 articles each. Surprisingly, Grismer Lee from La Sierra University, US is the only non-Asian listed as the most prolific author, with a total of 289 citations and an average of 18.06 citations per year while the remaining authors are from Malaysia. Nevertheless, there are insufficient studies focusing on Langkawi's development, additional interdisciplinary and transdisciplinary studies are needed.

Collaboration between Writers

The examination of co-authorship was limited to research publications with a maximum of 25 authors per document, resulting in a total of 956 authors. The total number of writers was then decreased to 68, considering only those authors with at least three publications. Figure 4 presents the network map of co-authorship among authors with significant linked items involving 24 authors in Langkawi research. Accordingly, the co-authorship analysis depicted five clusters, each established around four to five core authors. In particular, Cluster 1 is centred on "Komoo Ibrahim", "Halim Sharina Abdul", "Azman Norzaini", and "Kasavan Saraswathy", and is closely connected with Cluster 2, Cluster 3, and Cluster 4. Meanwhile, Cluster 5, centred on "Md-Zain Badrul Munir", "Mohd-Yusof

Table 2: Top 10 research area

No.	Area	Total	Total Cited
1.	Social Sciences Other Topics	61 (18%)	425
2.	Science Technology Other Topics	43 (12.7%)	351
3.	Engineering	33 (9.7%)	529
4.	Environmental Sciences and Ecology	23 (6.8%)	199
5.	Zoology	19 (5.6%)	262
6.	Computer Science	10 (2.9%)	2
7.	Geology	10 (2.9%)	77
8.	Physics	9 (2.6%)	14
9.	Business Economics	9 (2.6%)	55
10.	Area Studies	8 (2.3%)	25

Table 3: Top 10 prolific authors

No.	Scholar	Affiliation	Region	Number of Articles	Total Citation (TC)	Average Citation per Year	h-index
1.	Grismer, L. Lee	La Sierra University	US	15	289	18.06	8
2.	Komoo, Ibrahim	Universiti Kebangsaan Malaysia	Malaysia	15	155	8.16	6
3.	Ahmad, Norhayati	Universiti Kebangsaan Malaysia	Malaysia	14	194	12.93	4
4.	Halim, Sharina Abdul	Universiti Kebangsaan Malaysia	Malaysia	13	146	12.17	6
5.	Jaafar, Mastura	Universiti Sains Malaysia	Malaysia	11	85	10.63	4
6.	Marzuki, Azizan	Universiti Sains Malaysia	Malaysia	11	131	9.36	5
7.	Leman, Mohd Shafeea	Universiti Kebangsaan Malaysia	Malaysia	9	32	1.39	4
8.	Ali, Che Aziz	Universiti Kebangsaan Malaysia	Malaysia	9	27	3.38	4
9.	Ahmad, Anuar	Universiti Teknologi Malaysia	Malaysia	8	15	3	2
10.	Azman, Norzaidi	Universiti Kebangsaan Malaysia	Malaysia	8	72	6.55	2

Nur Syafika", "Senawi Juliana", and "Yaakop Salmah" is closely connected to Cluster 2. Co-authorship among authors measures the networking among the authors, where inter-individual, inter-institutional, and fields of expertise connect, particularly regarding the sustainability of an island or an archipelago.

Writers Origin

Article Counts by Country

In the present study, 31 countries are represented in the 339 publications on Langkawi sustainability research from 1975 until 2022. Figure 5 depicts that Malaysia, the US, Japan, Australia, the UK, Indonesia, Singapore, Nigeria,

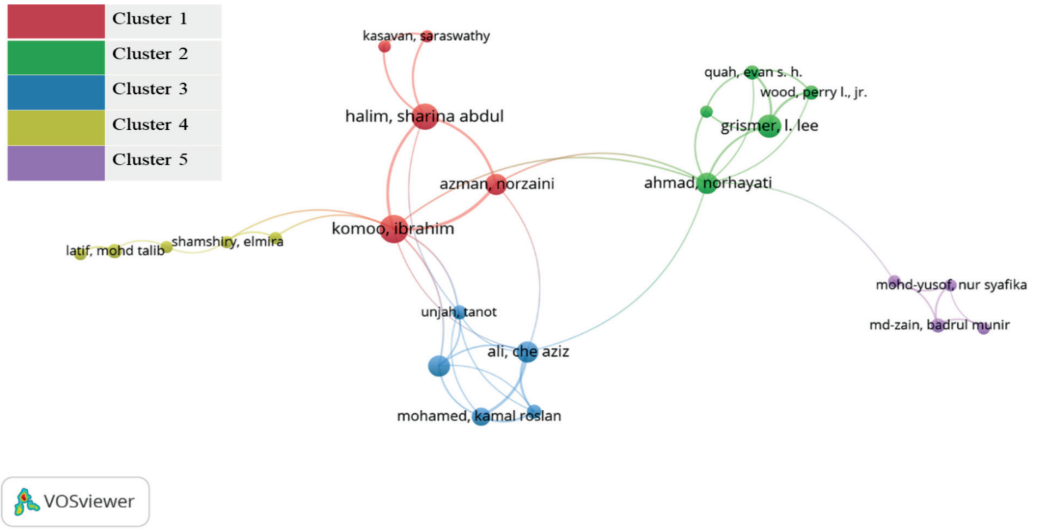
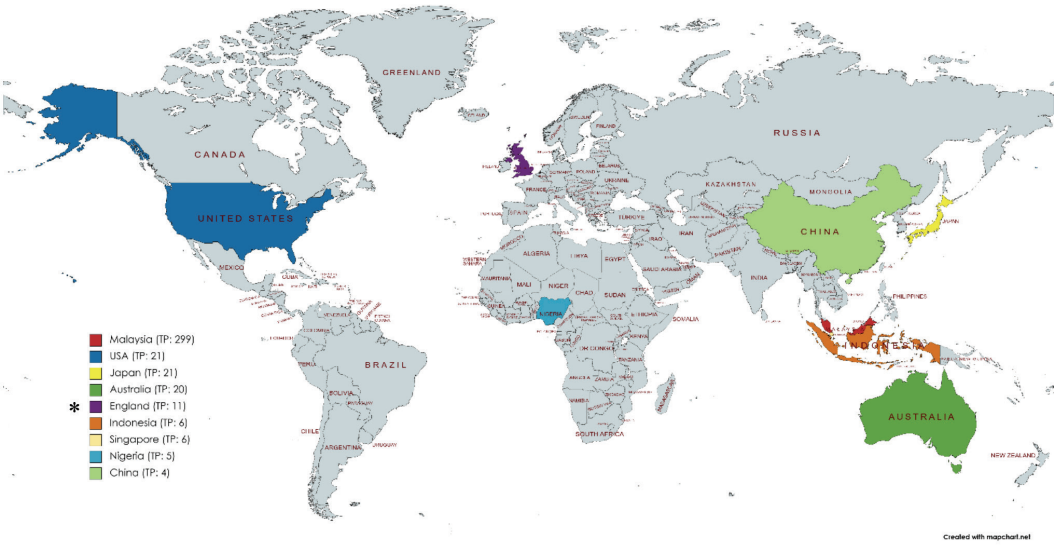


Figure 4: Co-authorship authors



*England, also known as the UK

Figure 5: Number of publications and country of origin. The map was generated using the web link: https://mapchart.net/world.html

and China are the leading nations in terms of publishing the largest amount of research output regarding Langkawi from 1975 until 2022. Specifically, the highest number of publications were published in Malaysia, with a total number of publications of 299 or 88.2%. Notably, most of the publications issued in Malaysia were produced after Langkawi received recognition from UNESCO in 2007. Meanwhile, the US and Japan recorded the second-highest publication numbers regarding Langkawi, with total publications in the two countries of 21. Note that Australia was the only country from Oceania producing 20 publications on Langkawi while the UK published 11. These are followed by other countries such as Indonesia, which has six publications; Singapore, which has six; Nigeria, which has five; and China, which has four. Interestingly, the Asian countries emerged as the dominant region that published the highest works on Langkawi compared to other regions.

International Collaborations

The international collaboration has revealed that 31 countries are connected with the threshold of having at least one publication regarding Langkawi. Figure 6 is a collaboration map demonstrating the level of cooperation among writers from different nations. According to Kasavan *et al*. (2021), the strength of the collaborations is highly determined by the size of the nodes. In Langkawi's research, countries with larger nodes indicate greater cooperation and collaboration among researchers from various countries. In this research topic, Malaysia has been identified as having a significant role and closely collaborating with various countries due to its densest links and largest locations in the co-authorship map (26 links, 98 total link strength).

The co-authorship results also indicated that the US had a higher link strength than the other countries, with Japan coming in second with five links and a total link strength of 22 and Australia in third with five links and a total link strength of 20. Yemen, Trinidad Tobago, Taiwan, Sri Lanka, Oman, and Lithuania have relatively small nodes (1 link) due to the limited number of publications and collaboration from these countries. Countries like Malaysia, which are productive in research on the Langkawi archipelago suggest that the island of Langkawi

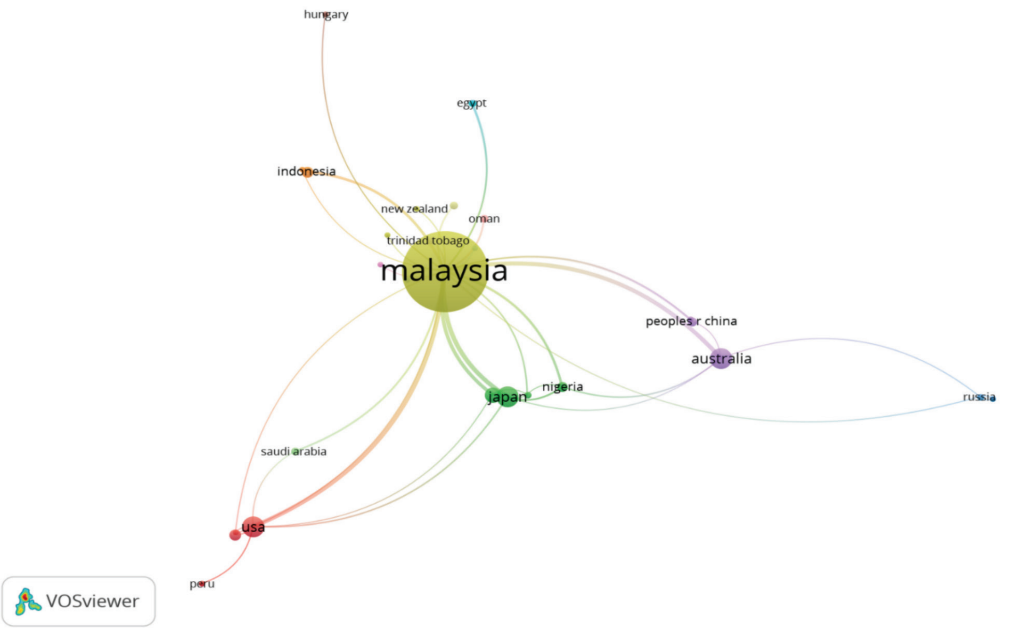


Figure 6: Co-authorship countries

can generate income for both local people and the nation through eco-tourism.

According to Chi and Liu (2023), the archipelago is highly sensitive to external disturbances from tourism activities and human development will cause loss of and damage to the natural environment. Thus, this study set out to demonstrate the significance of sustainability in the archipelago. This includes the importance of researchers worldwide and Malaysia building a cooperative network to protect and conserve the environment in Langkawi.

Author Institutions Analysis

Institutional Publication

A total of 212 academic institutions from several nations contributed to the publications about Langkawi Island. Table 4 presents a ranking of the number of publications based on the institution, nation, total publications, total citations, and h-index over the period of 1975 to 2022. Among the top 10 institutions, nine are in Malaysia and one institution is from the US. The study depicted that Universiti Kebangsaan Malaysia (UKM) is the most dominant institution in terms of Langkawi publications, with 93 publications, 684 citations, and an h-index of 17. Interestingly, 27.4% of the total publications were from UKM.

Meanwhile, Universiti Sains Malaysia (USM) ranked second with 42 total publications, 242 citations, and a h-index of 12. Subsequently, Universiti Malaya (UM) was the third-most active institution with 22 publications and 194 citations, followed by Universiti Teknologi MARA (UiTM) with 29 publications (94 citations), Universiti Teknologi Malaysia (UTM) with 12 publications (131 citations), Universiti Putra Malaysia (UPM) with 11 publications (100 citations), Universiti Utara Malaysia (UUM) with 16 publications (42 citations), Universiti Malaysia Terengganu (UMT) with nine publication (89 citations), and International Islamic University Malaysia (IIUM) with eight publication (24 citations).

La Sierra University, from the US was the only institution outside Malaysia and ranked as the tenth highest contributor to research relating to Langkawi, with seven publications, 177 citations, and an h-index of 7. The study also found that most Langkawi publications originated from institutions in the Klang Valley, including UKM, UPM, UM, UiTM, and IIUM. In contrast, only 58 publications originated from institutions close to Langkawi Island. Note that UTM and UMT were the only institutions from the south and east coast of Peninsular Malaysia that contributed to the Langkawi research.

Table 4: The most active institution produced articles and high total citations on the Langkawi archipelago from 1975 to 2022

Institute	Country	Total Publication	Total Citations	h-index
Universiti Kebangsaan Malaysia (UKM)	Malaysia	93	684	17
Universiti Sains Malaysia (USM)	Malaysia	42	242	12
Universiti Malaya (UM)	Malaysia	22	194	15
Universiti Teknologi MARA (UiTM)	Malaysia	29	94	6
Universiti Teknologi Malaysia (UTM)	Malaysia	12	131	10
Universiti Putra Malaysia (UPM)	Malaysia	11	100	6
Universiti Utara Malaysia (UUM)	Malaysia	16	42	4
Universiti Malaysia Terengganu (UMT)	Malaysia	9	89	7
International Islamic University Malaysia (IIUM)	Malaysia	8	24	4
La Sierra University	US	7	177	7

Co-authorship Institution

Using VOSviewer, co-authorship institution analysis was performed. Figure 7 displays the network relationships among author institutions with a minimum of one publication from 1975 to 2018. The strength of the links, publications, and articles cited depends on the size of the nodes. For instance, institutions with bigger nodes cooperated more with other institutions to research sustainability in the Langkawi archipelago. The findings depicted that 212 organisations contributed to publications regarding Langkawi, with the major contributors being Malaysian institutions such as UKM, USM, UM, and UTM. These institutions tended to collaborate more with other institutions.

In addition, the Research University (RU) in Malaysia, which includes USM, UM, UKM, UPM, and UTM is funded by the government to assist in the knowledge economy and the improvement of the quality of research outputs towards sustainable development in Malaysia (Amran *et al*., 2014). Most academicians from UKM are enthusiastic about research on sustainable development in the Langkawi archipelago. Concurrently, researchers from UKM are concentrating their research on Langkawi Island since UKM serves as the research hub for the Langkawi Geopark in Malaysia. The Langkawi Research Centre (PPL) is located at Tunku Abdul Halim Mu'adzam Shah Campurs, Langkawi UNESCO Globalpark, under UKM's Institute of Environment and Development (LESTARI). It focuses on research and academic services, especially heritage conservation and geopark development.

Based on the analysis, the collaborations were partly joined by other institutions such as Kyoto University, Hiroshima University, and Soka University in Japan while other institutions were from Germany and Australia, as illustrated in Figure 6. The interconnections between local universities from Malaysia and universities from Japan, Germany, Australia, and other countries worldwide allow researchers to collaborate and exchange ideas. According to Promoz Medved and Matjaz Ursic (2021), the institution of co-authorship can also recognise the expertise of people outside academia to collaborate on

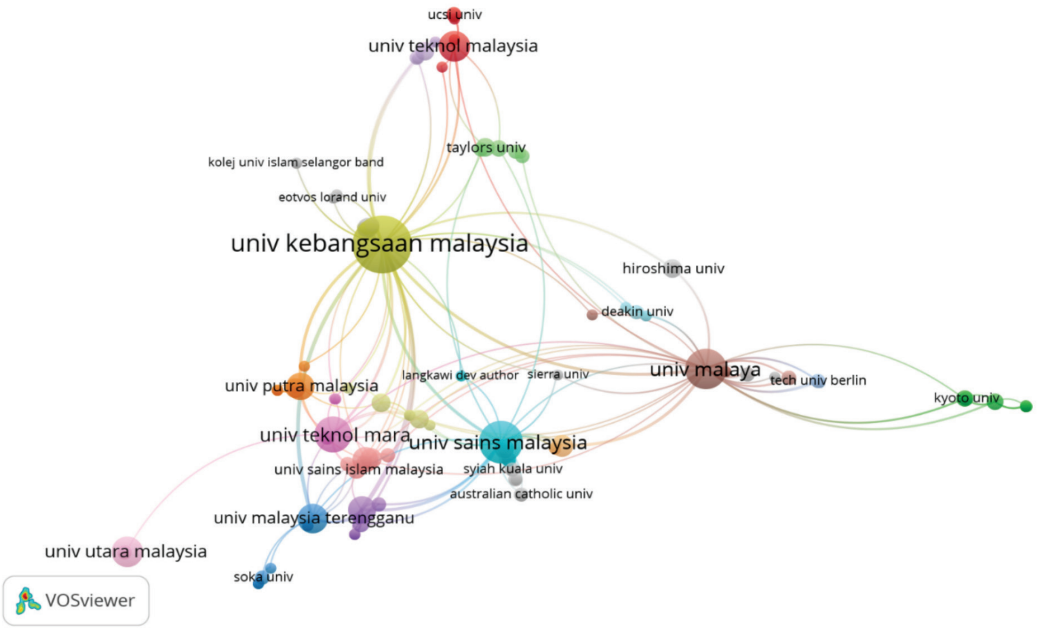


Figure 7: Authors' collaboration network mapping for articles on sustainability published in the Langkawi archipelago from 1975-2022

ideas, technologies, strategies, and policies for sustainable development in the Langkawi archipelago.

Research Hotspot Based on Keyword Co-occurrence Analysis from 1975 to 2022

Co-occurrence analysis of keywords examines pairing two or more terms within a given data collection. Furthermore, academics in the discipline will find it more convenient to choose a prestigious journal for conducting their publishing searches. Notably, the scholarly community gains valuable insights from the compilation and bibliometric assessment of pertinent publications. This aids in comprehending the academic landscape, including authorship collaborations, group dynamics, and international partnerships (Mohamad *et al*., 2023). The research hotspot of Langkawi sustainability was determined based on keyword co-occurrence analysis. According to Einecker and Kirby (2020) and Kasavan *et al*. (2021), in scientific journals, keywords are used to understand research patterns, focus direction, and identify research gaps.

Therefore, a high frequency of keywords in scientific journals indicates a research hotspot. In this section, the co-occurrence analysis was applied in order to identify the links within different topics with two separate approaches. Author keywords were included in the first approach without eliminating the keywords identified. At the same time, keywords such as "Malaysia," "Peninsular Malaysia", "Langkawi", "Langkawi Island", and "Pulau Langkawi" were included in order to identify the specific area of the study, i.e., that it had been conducted in Langkawi Island.

Based on this analysis, the connection line will demonstrate a close relationship while larger sizes of nodes will display high occurrences of the items. Therefore, the result of the co-occurrence analysis will assist readers in understanding the strength of the linkages and evolution of the research of Langkawi from 1975 until 2022, which can be referred to in Figure 8.

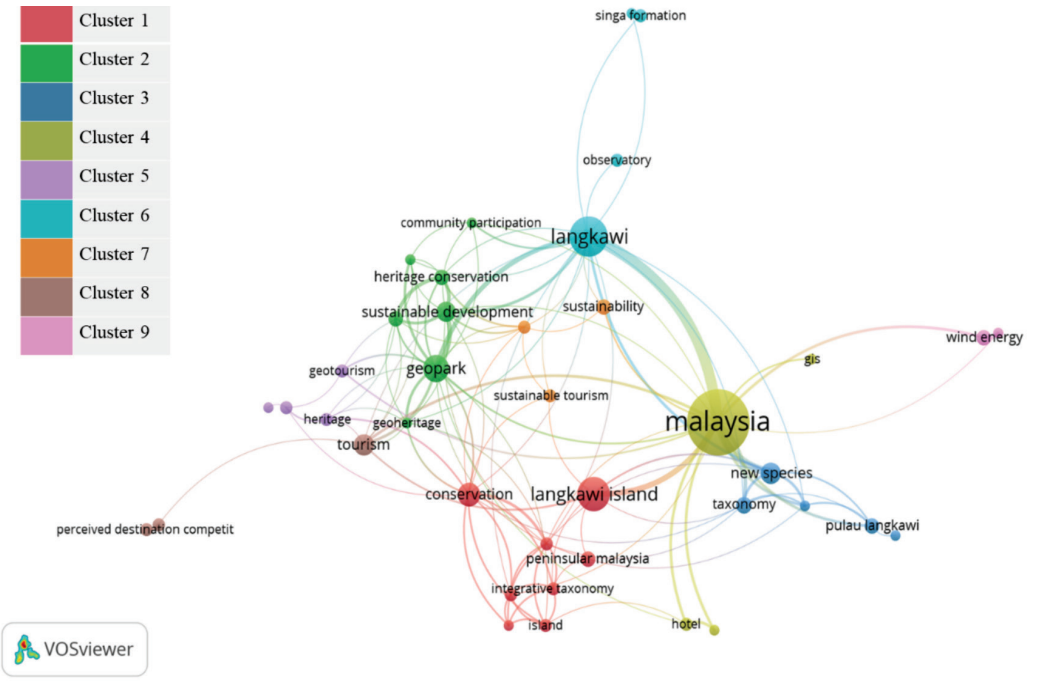


Figure 8: Network mapping of co-occurrence of the author's keyword of the published articles related to the Langkawi archipelago from 1975 to 2022

The researcher then determined to include author keywords with at least three occurrences in the VOSviewer. The co-occurrences analysis displayed nine clusters related to keywords from 1975 to 2022 (Table 5). In **Cluster 1** (red colour), eight keywords were identified: "Conservation", "Integrative Taxonomy", "Island", "Karst", "Langkawi Island", "Molecular Systematics", "Peninsular Malaysia", and "Phylogeny". Cluster 1 also revealed that "Conservation"

Table 5: Author keywords based on cluster

Cluster	Co-occurrences	Link	Total Link Strength	Author Keyword
Cluster 1	10	14	23	Conservation
(Red colour)	4	7	12	Integrative Taxonomy
	4	7	12	Island
	4	13	19	Karst
	19	7	14	Langkawi Island
	3	5	10	Molecular Systematics
	5	2	2	Peninsular Malaysia
	4	7	12	Phylogeny
Cluster 2	3	7	9	Community Development
(Green colour)	3	5	6	Community Participation
	3	8	11	Geoheritage
	13	16	35	Geopark
	5	6	14	Heritage Conservation
	5	8	14	Public Education
	8	12	24	Sustainable Development
Cluster 3	3	6	12	Cnemaspis
(Blue colour)	3	1	1	Heavy Metal
	9	7	23	New Species
	5	5	9	Pulau Langkawi
	6	8	14	Taxonomy
Cluster 4	3	1	2	GIS
(Olive green	4	4	8	Hotel
colour)	3	2	6	Human Resource Management
	55	19	62	Malaysia
Cluster 5	3	1	1	Geodiversity
(Purple colour)	4	4	6	Geotourism
	4	6	8	Heritage
	4	4	5	Langkawi Geopark
Cluster 6	3	2	3	Facies Analysis
(Light blue)	24	20	40	Langkawi
	4	1	1	Observatory
	4	2	3	Singa Formation
Cluster 7	4	8	10	Governance
(Orange colour)	5	3	4	Sustainability
	4	4	4	Sustainable Tourism
Cluster 8	4	1	3	Perceived Destination Competition
(Brown colour)	9	9	14	Tourism
	4	2	4	Tourist Satisfaction
Cluster 9	5	2	6	Wind Energy
(Pink colour)	3	2	4	Windpro

was the most significant keyword with 10 co-occurrences, 10 links, and 23 total link strengths. This is followed by "Karst", with four co-occurrences, 13 links, and 19 total link strengths. Furthermore, the keyword "Peninsular Malaysia" was the most insignificant keyword with five co-occurrences, two links, and two total link strengths. In Cluster 1, most studies discussed public education rules on island conservation.

The study by Azman *et al*. (2011) explored the view and appreciation of the local community living in the Langkawi Global Geopark. The study suggested that public education programmes to enhance local community awareness can be promoted to encourage the community's involvement in the Langkawi conservation programme. The results of the hot keyword in Cluster 1 will help researchers address the conservation issue on the Langkawi archipelago and work towards Sustainable Development Goals by 2030. Notably, the Langkawi archipelago is well-known for its rich geological and natural history. Thus, resource sustainability must be ensured in accordance with Geopark's stated idea of sustainable development.

Meanwhile, seven keywords were identified in **Cluster 2** (green colour): "Community Development", "Community Participation", "Geoheritage", "Geopark", "Heritage Conservation", "Public Education", and "Sustainable Development". In Cluster 2, "Geopark" was identified as the most significant keyword with 13 co-occurrences, 16 links, and 35 total link strengths, followed by "Sustainable Development", with eight co-occurrences, 12 links, and 24 total link strengths. In comparison, "Community Participation" was identified as the most insignificant keyword with three co-occurrences, five links, and six total link strengths.

Analysis of the WoS database identified that 20 studies have focused on the keyword "Geopark". The study by Yusof and Abdul Aziz (2010) stressed that local community understanding and awareness regarding the Geopark need to be strengthened for a better future for Langkawi. Notably, sustainable eco-tourism in Langkawi has spurred positive socioeconomic changes, especially for the community in the Langkawi archipelago, which has job opportunities in the tourism sector. Furthermore, Mohd Yusof *et al*. (2019) discussed that although the stakeholders were supportive and accepted Langkawi as a Global Geopark, the geopark concept is still unclear. This indicates that efforts should be made to create awareness among Langkawi's local community and business operators.

The analysis revealed that five keywords were identified in **Cluster 3** (blue colour). The keyword "New Species" emerged as the most significant keyword with nine co-occurrences, seven links, and 23 total link strengths, followed by "Taxonomy" with six co-occurrences, eight links, and 14 total link strengths. Conversely, "Heavy Metal" was identified as the most insignificant keyword in Cluster 3, with three co-occurrences, one link, and one total link strength. Additionally, studies have discovered that a new species of gekkonid lizard has been discovered in the Langkawi archipelago with strong tuberculation, scale, and colour patterns (Grismer & Ahmad, 2008). This is in addition to water bugs (Zettel & Tran, 2009), freshwater crabs (Ng, 2017), and black flies (Takaoka *et al*., 2014). In contrast, **Cluster 4** revealed four main keywords: "GIS," "Hotel," "Human Resource Management," and "Malaysia."

In this cluster, "Malaysia" was identified as the most significant keyword and had the highest occurrence with 55, 19 links, and 62 total link strengths. At the same time, "GIS" was the most insignificant keyword with three co-occurrences, one link, and two total link strengths. The definition keyword of "GIS" refers to Geographic Information Systems (GIS), which are effectively used in the tourism sector, especially in mapping, planning, recreation and park management, facility monitoring, management, and monitoring tourism activities in the Langkawi archipelago. According to Samat and Harun (2013), GIS technology is a powerful tool for tourism activities. It is usually

used for camping, cycling routes, determining distances between tourists or hotels with transport networks, and monitoring land use on Langkawi Island. In addition, the GIS application on Langkawi Island is vital as a decision-making tool for stakeholders to promote tourism development in Langkawi. In other words, GIS is an effective tool for preserving Langkawi Island as a geopark under UNESCO.

In **Cluster 5** (purple colour) and **Cluster 6** (light blue), four significant keywords can be identified. The keyword "Geodiversity" had a total link strength of one. "Geotourism" was next with a total link strength of six, followed by "Heritage" with a total link strength of eight and a co-occurrence of four. "Langkawi Geopark" had a total link strength of five and a co-occurrence of four. Meanwhile, in Cluster 6, "Facies Analysis" had a total link strength of three (three co-occurrences) while "Langkawi" had the highest total link strength of 40 and 24 co-occurrences. "Observatory" had a total link strength of one, and "Singa Formation" had three and six co-occurrences.

Clusters 5 and **6** had hot keywords related to tourism such as heritage, geotourism, geodiversity, Langkawi Geopark, Langkawi, and the Singa formation. Tourism is a fundamental industry that contributes to Malaysia's income. Moreover, stakeholders are undertaking initiatives to promote and encourage tourists to visit Langkawi using cultural and historical attractions (Mahsuri Tomb), ecological attractions (Pulau Payar Marine Park), mangroves and the Dayang Bunting Marble Geoforest Park, and the natural geological landscape (the Singa formation and Kilim Karst Geoforest Park). According to Shafeea Leman *et al*. (2007), Langkawi Geopark had 90 geoheritage sites, three geoforest parks, three geological monuments, and several protected geosites. Sustainable development in Langkawi Island is essential in ensuring the island's ecology, culture, and pristine conditions are protected.

Furthermore, **Cluster 7** (orange colour) and **Cluster 8** (brown colour) indicated three crucial keywords. The keywords "Governance", "Sustainability", and "Sustainable Tourism" can be observed in Cluster 7 while "Perceived Destination Competition", "Tourism", and "Tourist Satisfaction" can be noted in Cluster 8. Moreover, the keywords "Governance" and "Tourism" were identified as the most notable keywords in Cluster 7 and Cluster 8 with four co-occurrences, eight links, a total strength of 10 and nine co-occurrences, and nine links and a total strength of 14, respectively. In essence, the keywords from Clusters 7 and 8 suggest that the sustainability of Langkawi as a global tourism destination relies on its natural characteristics. In line with this, the involvement of various stakeholders such as the island community and government is vital to ensure the success of the tourism industry in Malaysia and to place Langkawi on the world map as the best tourism destination.

However, an increase in the number of tourists will encourage tourism development. According to Mohd *et al*. (2014), rapid tourism development with poor management will deteriorate the Langkawi environment, causing problems such as pollution, noise, loss of habitat, erosion, and sedimentation. However, in Clusters 7 and 8, the emphasis on the keywords "Governance", "Tourism", and "Sustainable Tourism" implies that the government plays an essential role in the policies and implementation of sustainable tourism development for equitable economic and social development in Langkawi.

In **Cluster 9,** only two keywords were noted: "Wind Energy" with a total link strength of six (five co-occurrences) and "Windpro" with a total link strength of four (three co-occurrences). The term refers to wind energy in Langkawi, one of the fastest-developing renewable technologies. In addition, Windpro is software used to determine annual energy production via simulation. Nowadays, Malaysia recognises it cannot rely on non-renewable resources such as diesel and coal to generate electricity for its communities. Renewable Energy (RE) such as wind and solar energy should be alternative sources of electricity generation.

The benefits of using wind energy include avoiding environmental pollutants and reducing greenhouse gas emissions, moving towards sustainability in Langkawi (Mokhtar *et al*., 2021). Other than that, Hussin *et al*. (2019) asserted that the state government had also planned to turn Langkawi Island into the nation's first carbon-neutral island by 2030. However, supplying electricity to the island is challenging, sustainable wind energy has yet to be fully utilised in Langkawi. The findings of this cluster highlight that Langkawi Island needs a holistic carbon emission reduction policy and strategy to achieve sustainable energy consumption in Langkawi and to become the first carbon-neutral island by 2030.

Future Research Direction

The scope of the study was limited based on the methods used. In particular, the study's database is limited to the WoS while other databases such as Scopus and Google Scholar were excluded. Articles published in English and Malay were selected for the study. The study revealed that most studies were conducted by Malaysian universities compared to other universities. Furthermore, the study also indicated a lack of studies exploring the impact of climate change on the island community's livelihoods, material use, and potential RE generation in Langkawi Island (Table 5). For small islands such as Langkawi, economic development is highly dependent on tourism. Thus, relying on a single economic activity makes the island vulnerable and fragile to climate-related changes (Wolf *et al*., 2021; Carrillo *et al*., 2022). Therefore, the readiness of the island and its community would minimise the impact of climate change.

To the best of the authors' knowledge, no studies are focusing on island metabolism, particularly on materials used such as the energy-food-water nexus, on tourism islands in Malaysia. However, the islands now use resources and generate output in quantities disproportionate to their population. As the island is highly dependent on the mainland for its resources, quantifying and benchmarking the environmental, economic, and social impact of tourism is vital for sustainable island metabolism. Furthermore, minimal studies have been conducted to understand energy consumption on the island. Most studies were reported to have focused on urban regions or megacities.

A study on island metabolism was conducted by Ginard-Bosch and Ramos-Martín (2016) on the Balearic Islands, which applied a Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM) to evaluate the complex system of the islands. Meanwhile, Harrison and Popke (2018) investigated the geography of RE transition in the Caribbean, focusing on island energy metabolism to conceptualise the relationship between biophysical and fossil fuel-based metabolism on the island. On the other hand, Chen *et al*. (2020) assessed the food-energy-water nexus of urban metabolism on Kinmen Island, Taiwan. It was emphasised that evaluating prospective resource management solutions within a resource nexus is necessary to prevent the transfer of problems.

This is attributable to the fact that the urban metabolism of food, energy, and water is influenced by lifestyle, industrial structure, and infrastructure. Therefore, evaluating the metabolism of islands in terms of material use and energy consumption may provide additional information on the resources used in tourism islands. This would ultimately benefit the development of Langkawi Island as a low-carbon tourism island destination in the global tourism sector.

Conclusions

The study presented a comprehensive bibliometric analysis of Langkawi archipelago sustainability, covering publications from 1975 until 2022 via the WoS database. The study covered 339 research articles by 956 authors affiliated with 212 organisations in 35 countries, which were cited 2,093 times. The results depicted that the trend of publications in relation to Langkawi has increased significantly in the past 47 years, especially after Langkawi

received its Global Geopark recognition from UNESCO in 2007.

Most of the studies of Langkawi were concentrated in areas such as Social Sciences Other Topics (18%) and Science Technology Other Topics (12.7%), with most of the publications written by prolific authors such as Grismer (h-index: 8) and Komoo (h-index: 6). Both authors contributed 15 articles with total citations of 444. Furthermore, most authors originated from Malaysia and were affiliated with UKM, USM, UM, and UiTM. In particular, UKM recorded the highest citations (684 citations, 93 publications) among the universities in Malaysia, followed by USM and UM.

The research hotspots based on keyword analysis were noted via two approaches (authors' and refined keywords). The authors' keywords in the first approach suggested that "Malaysia" and "Langkawi" emerged as the most significant keywords, with total link strengths of 62 and 40, respectively. In contrast, keywords such as "Heavy Metal", "Geodiversity", and "Observatory" were the least significant keywords for Langkawi, with total strengths for these keywords of one. Accordingly, the author also refined the keywords by excluding keywords such as "Malaysia", "Peninsular Malaysia", "Langkawi", "Langkawi Island", and "Pulau Langkawi" in the second approach. Moreover, the analysis indicates that keywords such as "Conservation", "Geopark", "Tourism," "Sustainable Development", and "New Species" were the most significant to Langkawi.

Keywords such as "Geopark", "Sustainable Development", "Conservation", and "New Species" were recorded as having higher significance, with total strengths of 35, 24, and 23, respectively. The uniqueness of Langkawi as a Global Geopark, along with its geological, cultural, and natural settings, makes it a major attraction for tourists. Therefore, every agency and local community should play their part to ensure that Langkawi remains the best tourism destination, thanks to its geological uniqueness, cultural diversity, and breathtaking natural setting.

Acknowledgements

This research was supported by the Ministry of Higher Education (MoHE) of Malaysia through the Fundamental Research Grant Scheme (FRGS/1/2022/SS07/UUM/02/6).

Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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