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Sains Humanika

Mapping Four Decades of Appropriate Technology Research: A Bibliometric Analysis From 1973 To 2021

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Abstract

Appropriate technology is a highly adaptable, simple, and user-friendly technology that utilises local resources designed for use in a specific community at a particular point in time. The technology is a crucial resource for marginalised groups in solving their everyday problems in the most economical way, which also have positive impact for their social life and environment. However, thus far, there is a lack of research that systematically reviews the patterns of scientific studies inherent in the body of knowledge of appropriate technology. Such review is needed to diagnose the current knowledge about appropriate technology. The purpose of the study is to examine the publication trends, collaborative structures, and central themes in appropriate technology studies. To achieve this objective, this study utilised a bibliometric analysis using the bibliometrix R-package software. The result highlighted three main themes in appropriate technology studies, which are developing countries, technology transfer, and sustainable development. This understanding forms the foundation towards greater understanding and applications of appropriate technologies to empower and improve overall quality of life in the society, especially in developing countries.

Keywords: appropriate technology, bibliometric analysis, bibliometrix, R-package

Abstrak

Teknologi tepat-guna ialah teknologi yang sangat mudah digunakan, ringkas, dan mesra pengguna yang menggunakan sumber tempatan di mana ia direka untuk digunakan dalam komuniti yang spesifik pada masa yang tertentu. Teknologi ini amat penting untuk kelompok terpinggir dalam menyelesaikan masalah harian mereka dengan cara yang paling ekonomik, yang juga memberi kesan positif kepada kehidupan sosial dan persekitaran mereka. Walau bagaimanapun, setakat ini, terdapat kekurangan penyelidikan yang mengkaji secara tinjauan sistematik corak kajian saintifik yang wujud dalam struktur pengetahuan topik teknologi tepat-guna. Tinjauan sedemikian diperlukan untuk mendiagnosis pengetahuan semasa tentang teknologi tepat-guna. Tujuan kajian ini adalah untuk mengkaji trend penerbitan, struktur kolaboratif, dan tema utama dalam kajian teknologi tepat-guna. Untuk mencapai objektif ini, kajian ini menggunakan analisis bibliometrik menggunakan perisian bibliometrix R-package. Hasil kajian ini menekankan tiga tema utama dalam kajian teknologi tepat-guna, iaitu negara membangun, pemindahan teknologi, dan pembangunan mampan. Pemahaman ini membentuk asas ke arah pemahaman yang lebih baik dan aplikasi teknologi tepat-guna untuk memperkasa dan meningkatkan keseluruhan kualiti hidup dalam masyarakat, terutamanya di negara membangun.

Kata kunci: teknologi tepat-guna, analisis bibliomterik, bibliometrix, R-package

1.0 INTRODUCTION

Appropriate technology is characterised as an object, process, concept, or practice that enhances human fulfilment by satisfying the users' needs (Hazeltine and Bull, 2003). Generally, appropriate technology is the technology that is highly adaptable, simple, and friendly to the users, which is developed for use by a specifically targeted community at a particular point in time. Appropriate technology is important, especially for rural communities in developing countries, because it can be utilised as tools or vehicles for empowering the communities to increase their income, hence supporting their survivability in the ever-changing and challenging world (Bhattacharjya et al., 2019; Pattnaik and Dhal, 2015).

According to its history, the concept of appropriate technology had been first popularised by Gandhi in the 1920s. He believed that appropriate technology should be developed to be used in the rural areas where many poor citizens reside in India. Indeed, the technology that is developed and introduced in the rural areas should be suitable for use by the rural people. Hence, it should be cheap and simple to be used (Ahmad, 1989; Bakker, 1990; Teitel, 1978). In the West, a German-British economist, Schumacher, wrote his popular book in 1973, "Small is Beautiful: Economics as if People Mattered", where he illustrates the concept of appropriate technology, which he named as "intermediate technology", that was placed in the middle of a complex high-technology in the market and low-tech and traditional

technologies in a rural area (Basu and Weil, 1998; Lee et al., 2018; Schumacher, 1973). The technology is important to facilitate people in developing countries or other underprivileged territories because of its characteristics – simple, affordable, friendly, manageable, and highly adaptable.

Appropriate technology should be familiar and workable to the users and is administered by the users themselves for long-term usage. Moreover, appropriate technology could resolve the economic and everyday problems of the targeted community due to its reasonable or affordable price and the use of local resources for its production (Baker and Edmonds, 2004; Sugathan et al., 2016). The technology can be any tangible products or new techniques or modifications of existing methods to improve the productivity and quality of life of the users. The success of appropriate technology depends on its impact on the users; therefore, it is important for the technology developers to understand the users' needs before developing any technology (Kummitha, 2020; Sianipar et al., 2013). A technology can be appropriate for a particular community, yet inappropriate for other communities. Appropriate technology does not necessarily be a small-scale or low technology, as long as it can be managed by the targeted individuals and community for a long-term use (Lee et al., 2018; Shin et al., 2019).

Given these characteristics, the use of appropriate technology in rural communities, particularly those in developing countries can be expected to empower them to increase their household income, and hence sustain their livelihood for the long term. Ultimately, this can lead to increased quality of life, and the aggregate economic growth of the countries (Botchie et al., 2018; Pearce, 2012). Moreover, developing appropriate technology for a specific community and its usage will prevent waste of resources, including financial, human, and natural resources. Besides, the ability to operate the technology at the present time enables the community to adopt changes in the technology in the future (Xu et al., 2021; Liu et al., 2021). Therefore, on the whole, appropriate technology will be beneficial to disadvantaged communities for their long-term use.

Appropriate technology has made life easier, and has provided the support for empowering the poor, which implies that appropriate technology has a lot of potentials to overcome some of the issues facing our society, including limited resources and lack of competencies in using advanced technologies (Pearce, 2012; Zelenika and Pearce, 2011). Appropriate technology has shown its significance in the development of several industries globally, especially in the agriculture industry where the technology helps peasant farmers to increase their household income which then indirectly impacts the income for national agriculture industry (Baker and Edmonds, 2004, Bhattacharjya et al., 2019; Patnaik and Bhowmick, 2019). In spite of its significance, however, thus far, there is a lack of research that systematically review the knowledge related to appropriate technologies. On the whole, the concept or the constituents that make up the body of knowledge of appropriate technology is not fully understood. This gap must be addressed in order to enable communities to further benefit from appropriate technology.

Even though the concept of appropriate technology has been further explicated since 1973, there is not much understanding on the literature trends of appropriate technology that has been discussed by scholars. This step is important in order to further develop the body of knowledge of appropriate technology. Moreover, appropriate technology studies are emerging in the literature, yet there are many unexplored topics in appropriate technology that need to be further researched. While Patnaik and Bhowmick (2019) had revisited the definitions of appropriate technology, the authors only focused on the definition of appropriate technology, and hence established the need for a comprehensive analysis of appropriate technology studies.

To fill this gap, the current study aimed to examine the publication trends, collaborative structures, and central themes in appropriate technology studies. To achieve the study's objective, the researchers conducted a literature review on Scopus database using the bibliometrix R-package software and applied the bibliometric analytical technique of Aria and Cuccurullo (2017). The bibliometric analysis was selected as the method to conduct the literature review due to its strengths in providing a comprehensive view of the body of knowledge, which is needed to further understand discussions within appropriate technology studies.

2.0 MATERIALS AND METHODS

The study utilised the bibliometrics analysis in order to review and understand the research topics in appropriate technology studies starting from the 1970s to the present time. Bibliometrics is one of the scientometrics methods, where scientometrics is an area of study concerned with the quantitative attributes and characteristics of research, technology, and innovation (Mingers and Leydesdorff, 2015). Technological advancement in bibliometrics analysis enables users to obtain quantitative information or trends for a specific research area in the form of clusters, networks, maps, and tabulation (Hood and Wilson, 2001; Mingers and Leydesdorff, 2015) in an efficient manner. The detailed analysis informs the patterns of scientific studies inherent in the body of knowledge of a specific topic and identifies avenues for future research.

Specifically for this study, bibliometrics was utilised to analyse data of selected scientific publications, which are journal articles (Bellis, 2009). In this study, the screening methodology was conducted in March 2021, with the aim of retrieving the most precise and complete publications in the field of appropriate technology studies. The search string of "appropriate technolog*" was used in the title (TI) in the advanced search function in the Scopus database. The use of the general keyword of "appropriate technolog*" was to broaden the search to cover all articles with that title. Specifically, the publication title was selected in the search function to get the most related publications and exclude the unrelated or irrelevant ones, as the use of the keywords in the publication title will generally reflect the actual content of the articles. Hence, the use of publication title can be expected to generate only articles that are relevant for the analysis (Annesley, 2010; Jamali and Nikzad, 2011). The general keyword with asterisk symbol (*) allowed articles, which titles contain the terms "appropriate technology", "appropriate technologies", and "appropriate technological" to be included in the search.

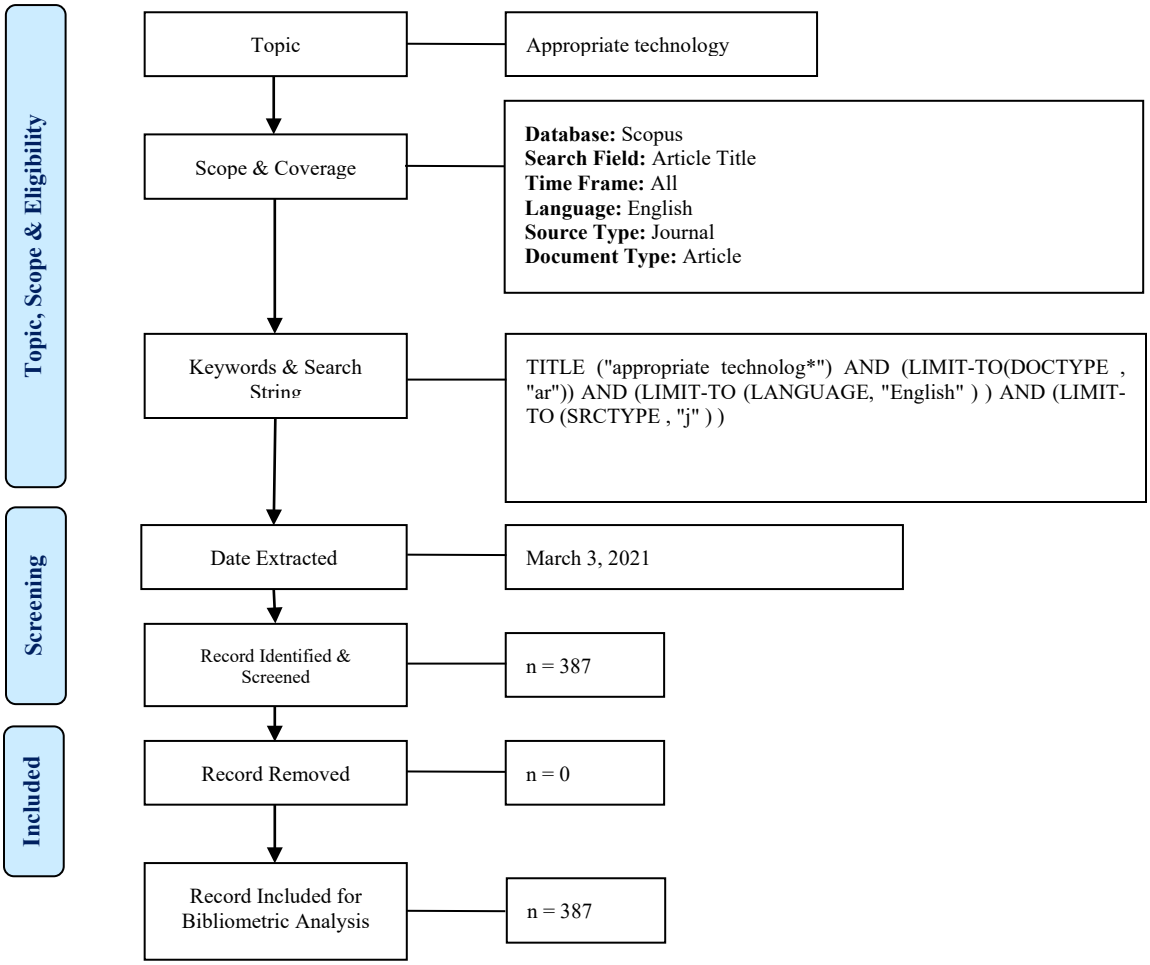
The study used Scopus as the main database because it is able to extract a comprehensive bibliometric data, which provides detailed demographic data of author and organisation, and profiles of the publications, ensuring efficient and high accuracy of analysis, which makes it one of the most powerful databases for bibliometric analysis studies (Baas et al., 2020; Okoli, 2015; Xu et al., 2021). Moreover,

Scopus is a stable database that enables accurate searching strategies and has consistency in its search results. Furthermore, Scopus database consists of high-quality publications, hence, serves as a reliable source for understanding the research trends in the current literature (Boyack et al., 2018; Oakleaf, 2009). The search in the Scopus database includes all fields of disciplines but include only "journal" in the source type, "article" in the document type, and "English" in the language type of the documents.

Table 1 summarises the steps in inclusion criteria of article searching for the current study, while Figure 1 shows the flow of the search strategy adopted from Zakaria et al. (2021). The flow diagram is based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) diagram. PRISMA consists of a four-phase flow diagram that explains a systematic review in detail (Moher et al., 2009). The phases include the identification, screening, eligibility, and finally the included phases where the final number of selected articles from the collections for analysis are disclosed at the end of the flow. PRISMA aims to improve the reporting of systematic reviews in more presentable ways. After screening all the documents found in the database, the final total number of documents examined was 387 articles.

Table 1. The summary of inclusion criteria in selecting the total documents examined

Source	Scopus	No. of items or no. of articles
Time period	All years	
Keyword	"appropriate technolog*"	
Document type	Total contributions	783
Articles		476
Book chapters		33
Conference paper		208
Other items		67
Language	English	719
Source type	Journal	387
Total Documents Examined (TDE)		**387**



Adapted from Zakaria et al. (2021)

Figure 1. Flow diagram of the search strategy

In conducting the bibliometric analysis, the study mainly utilised the bibliometrix R-package software to analyse the bibliometric data derived from the Scopus database. The bibliometrix R-package is a software tools for science mapping that provides a comprehensive quantitative analysis in bibliometrics and scientometrics. The software supports a complete science mapping workflow starting from data collection to data analysis and finally, to data visualisation. Moreover, it is flexible with the ability to be easily modified and combined with other statistical R packages (Aria and Cuccurullo, 2017).
First, the bibliometric data analysis began by generating the bibliometric data of the 387 articles and then second, the data was run in the R-software for analysis. The analyses conducted were the descriptive, collaboration, and thematic analysis. Third, the software generated the visualisation of the bibliometric data analysis (Aria and Cuccurullo, 2017). For certain analysis, Microsoft Excel was used to draw a graphical visualisation of the frequency and percentage of the published materials that were used to present the findings of the analysis.

■3.0 FINDINGS

Figure 2 shows the map of findings of the bibliometrics analysis that are divided into three main categories, which are: a) publication trends, b) collaborative structures, and c) central themes.

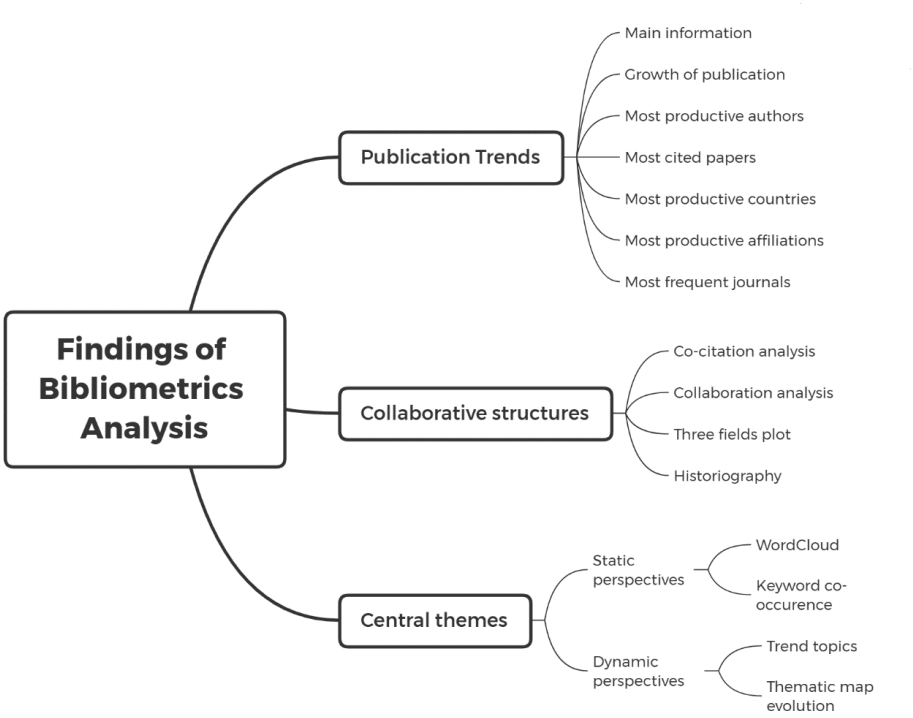


Figure 2. Map of findings of bibliometrics analysis

3.1 Publication Trends

In this study, publication trends contain the statistics of the domains used in the analysed Scopus database. The domains used for the analysis are the information of the authors, articles, and journals in the collection (Aria and Cuccurullo, 2017). Most trends were identified using their frequency of occurrence in the analysis.

3.1.1 Main information

The general information of the total documents examined is provided in Table 2, which were generated using the bibliometrix tool. The timespan or period of analysis is from 1973 to 2021. The 387 articles are from 294 sources. There are 217 single-authored articles, which is 56% of the total articles, while the remaining 44 percent of articles involved team research or other sorts of research collaboration with the collaboration index of 3.22.

Table 2. Main information regarding selected articles

Description	Results
Timespan	1973:2021
Sources	294
Documents	387
Average years from publication	25.5
Average citations per documents	10.11
Keywords plus	1967
Author's keywords	518
Authors	731
Author appearances	800
Authors of single-authored documents	183
Authors of multi-authored documents	548
Single-authored documents	217
Documents per author	0.529
Authors per document	1.89
Co-Authors per document	2.07
Collaboration index	3.22

3.1.2 Growth Of Publications

The growth of publications can be determined by the number of articles that are published in a particular year, and the total number of citations of those articles in that year. As shown in Figure 3, for the period of 1973 until 2021, the first appropriate technology article was written in 1973 by Menck K. W. which was published in *Intereconomics* journal (Menck, 1973) the same year when Schumacher wrote his book (Schumacher, 1973). From that time until March 2021, the number of articles grew to 387 in more than four decades. It can be noted that from 1973 to 1980, there was a growing number of publications. The number then decreased in 1981, before increasing in 1984. Starting from 1989, the number of articles dropped significantly. In the 2000s, scholars have written an average of seven appropriate technology articles a year from 2000 to 2021. As for the total citation per year, it can be observed that the number of citations rose dramatically in 1985 (907 citations), whereas the number of citations is gradual at other times. The number of citations also rose in 1991 (210 citations) and 1998 (280 citations). These happened because of highly cited papers that had been published in those particular years.

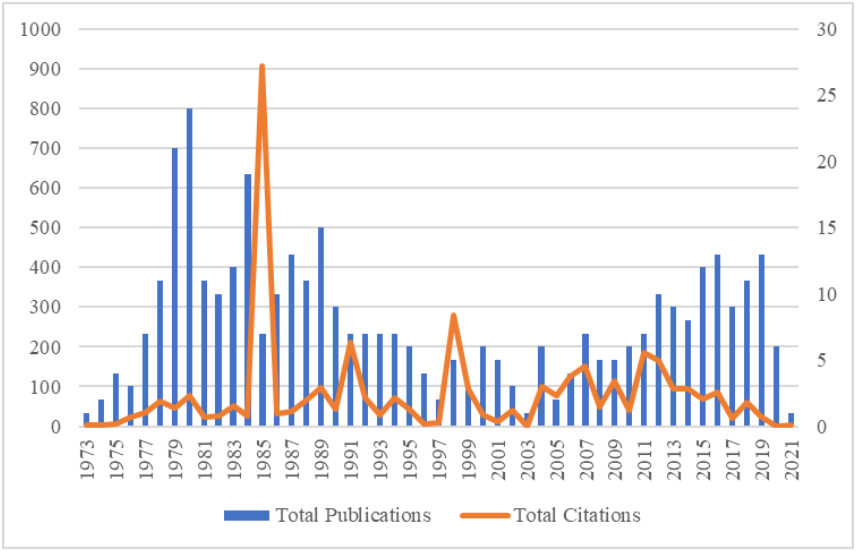


Figure 3. Growth of publications

3.1.3 Most Productive Authors

Table 3 identifies the most productive authors for appropriate technology studies. The table was built by listing the authors who produced the largest number of publications, with a minimum of three articles. Table 3 shows a list of the authors, the number of articles that they had contributed, SCOPUS h-index, g-index, m-index, and the first publication year for the listed authors. There are three indices that had been included for each individual author in the list. The h-index is an appraisal of both quantity (number of papers) and quality (number of citations) of an author's publications. The value of h defines the number of papers an author published together with his/her lowest number of citation (Hirsch, 2005). Meanwhile, the g-index is determined based on the distribution of citations of the author's publications where it puts more weight to highly cited papers of the author (Egghe, 2006). Finally, the m-index considers the years after the first publication and is more applicable to early career researchers than the h-index.

Referring to Table 3, the author who contributed the most in the collection is Tharakan, J. with four articles. Tharakan is affiliated with Howard University in the USA. The other five authors published three articles each. They are Forsyth, D. J. C. (University

of Strathclyde, UK), Hwang, J. (Seoul National University, Korea), Hyman, E. L. (Appropriate Technology International, USA), Sakai, A. (University of Marketing Distribution Sciences, Japan), and Yapa, L. S. (Pennsylvania State University, USA). Most authors are from the US where one of them is from an appropriate technology research institution. The author with the most recent publication is Hwang, J., which is in the year 2018. The average number of citations per year for the author is 12.67, which is quite high and shows the author's impact on the collection.

Table 3: The highest contributors in appropriate technology studies (minimum of three articles)

Author	Affiliation	Country	NP	h	g	m	TC	PY_1
Tharakan, J.	Howard University	USA	4	2	3	0.286	12	2015
Forsyth, D. J. C.	University of Strathclyde	UK	3	2	3	0.044	21	1977
Hwang, J.	Seoul National University	Korea	3	3	3	0.75	38	2018
Hyman, E.L.	Appropriate Technology International	USA	3	2	2	0.057	8	1987
Sakai, A.	University of Marketing Distribution Sciences	Japan	3	2	3	0.125	44	2006
Yapa, L. S.	Pennsylvania State University	USA	3	2	3	0.05	48	1982

Notes: NP = number of publications; h=h-index; g=g-index; m=m-index; TC = total citations; PY_1 = the year of authors' first publication

3.1.4 Most Cited Papers

Table 4 lists the ten most cited articles in the Scopus database for the appropriate technology topic. The table consists of the main author with the year of publication. The table also includes the article title, the journal title, the total number of global and local citations, and annual citations for each document. From the table, it can be observed that articles with the most citations were published in economics journals. Appropriate technology topic was also an important discussion in societal development and policies journals, such as *Environment, Development and Sustainability*, *Research Policy*, and *Journal of Development Economics*. There are also articles that discuss the ap-propriate technology topic from technical perspectives, where most of the articles elaborate on a specific technology for the targeted community, for example, in the medical and environmental science context.

Table 4: Highly cited articles, in descending order by number of citations

Author-Date	Article Title	Journal Title	GC	GCpY	LC	LCpY
WHO (1985)	Appropriate technology for birth	Lancet	871	23.54	3	0.08
Basu, S. & Weil, D. N. (1998)	Appropriate technology and growth	Quarterly Journal of Economics	240	10	9	0.38
Diwan, I. & Rodrik, D. (1991)	Patents, appropriate technology, and North-South trade	Journal of International Economics	156	5.2	0	0
Kaplinsky, R. (2011)	Schumacher meets Schumpeter: Appropriate technology below the radar	Research Policy	122	11.09	6	0.55
Mafongoya, P. L. (2006)	Appropriate technologies to replenish soil fertility in Southern Africa	Nutrient Cycling in Agroecosystems	91	5.68	0	0
Rowland, M. et al. (1999)	Permethrin-treated chaddars and top-Sheets: Appropriate technology for protection against Malaria in Afghanistan and other complex emergencies	Transactions of the Royal Society of Tropical Medicine and Hygiene	79	3.43	0	0
Jerzmanowski, M. (2007)	Total factor productivity differences: Appropriate technology vs efficiency	European Economic Review	70	4.66	2	0.13
Murphy H.M., McBean E.A., & Farahbakhsh K. (2009)	Appropriate technology - A comprehensive approach for water and sanitation in the developing world	Technology in Society	67	5.15	3	0.23
Pearce, J. M. (2012)	The case for open-source appropriate technology	Environment, Development and Sustainability	64	6.4	5	0.5
Los B. & Timmer M.P. (2005)	The 'appropriate technology' explanation of productivity growth differentials: An empirical approach	Journal of Development Economics	63	3.70	2	0.12

*GC = Global citations; GCpY = Global citations per year; LC = Local citations; LCpY = Local citations per year

An article written by World Health Organisation (WHO), with a total of 871 citations and an average of 23.54 citations per year since 1985, is the most cited paper in the global citations. Global citations determine the impact of a document or article in the whole bibliographic database. This WHO article might be cited by other disciplines and topics, especially in medical and health-related articles. The article was written in April 1985, when WHO had organised a conference on appropriate technology for birth. The organisation then wrote an article for a general guide in assessing appropriate technology for birth during that time (WHO, 1985). The article was published by the prominent medical journal, *Lancet*, and was mostly cited by sources in the medical fields.

This is followed by Basu and Weil (1998) with 240 citations and an average of ten citations in a year. The article has the highest number of local citations (nine citations), which means it is highly cited and most impactful, specifically for the appropriate technology topic starting from 1973 to 2021. Local citations depict the number of citations an article received within the collection (Aria and Cuccurullo, 2017). Local citations can also be defined as a subset of global citations.

More recent articles dated after 2010, such as Pearce (2012) and Kaplinsky (2011), which have a high number of citations, shows that appropriate technology is an emerging topic that has caught the attention of researchers. It also shows that these articles were only published in the last nine to ten years but managed to get six to eleven citations per year, on average. Moreover, the diverging field of journals that publish appropriate technology articles shows that the topic has been a point of interest for cross-field authors, not only economics and development journals.

3.1.5 Most Productive Countries

Figure 4 illustrates the number of articles production for appropriate technology in the top 20 countries. Based on the table, the USA is the highest contributor with 74 articles, which is almost 20 percent of all articles in the appropriate technology studies in the collection. There are other developed countries that produced most of the articles, for example, UK (51), Canada (17), South Korea (13), Australia (8), and Netherlands (7). Researchers in developing countries have also published articles on appropriate technology, including India (25), Indonesia (10), Nigeria (10), Thailand (7), and South Africa (6).

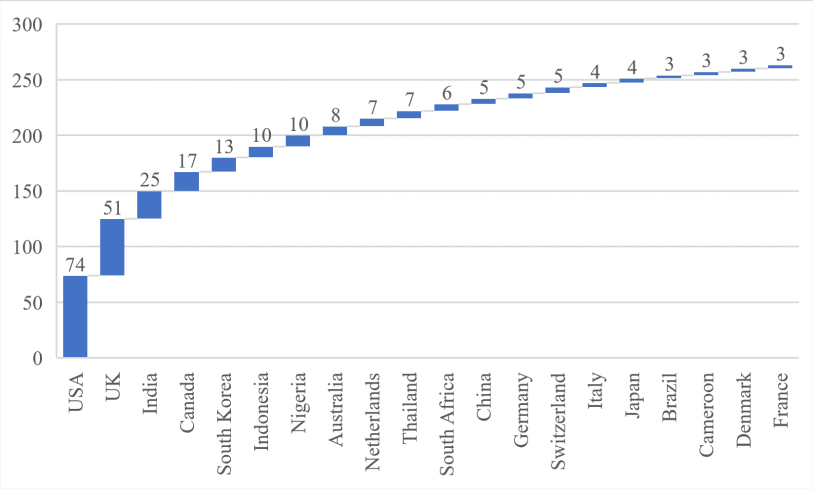


Figure 4: Country of articles production in appropriate technology

3.1.6 Most Productive Affiliations

Figure 5 shows a list of affiliations of authors in appropriate technology publications, with a minimum number of three articles published. The most productive institution is the University of Strathclyde, Glasgow, UK, which had contributed six articles. Other productive institutions include Seoul National University, South Korea and the University of California, Davis, USA, which published five articles each. Next is Howard University in Washington, USA and Organisation Mondiale de la Santé (the French name for the World Health Organisation – WHO), Switzerland, which published four articles. The other institutions published three articles, including Pennsylvania State University (USA), University of Leeds (UK), University of Guelph (Canada), University of Sussex (UK), University of Oxford (UK), and University of Marketing and Distribution Sciences (Japan). Besides universities, appropriate technology centres also contribute articles to appropriate technology body of knowledge, for example, Appropriate Technology International in the US, which contributed three articles. All twelve top affiliations in the collection are from developed countries, which shows that developed countries pay attention to the appropriate technology topic, which might provide benefits to the developing countries, indicating the importance of such technology in support of their needs.

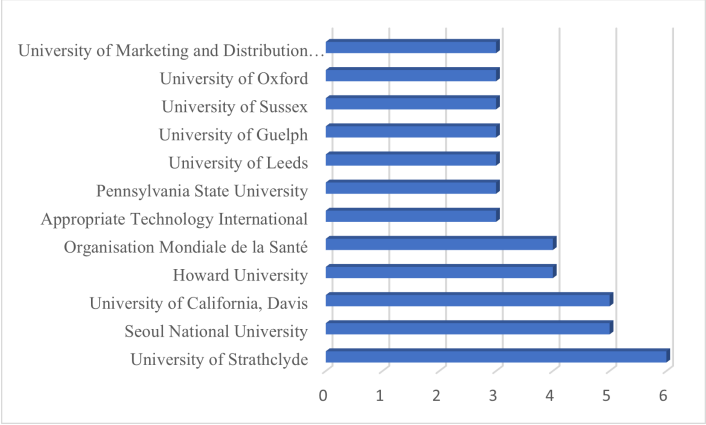


Figure 5: Most productive affiliations with the greatest number of articles published

3.1.7 Most Frequent Journals

Table 5 shows the most relevant sources in appropriate technology studies starting from 1973 to 2021, with a minimum publication of three articles. The most relevant sources are defined as the leading and frequent journals in appropriate technology publications. The table shows a list of indexed journals in the Scopus database, its number of publications, h-index, m-index, and the first appropriate technology-related publication published in the journal. The journal with the most articles is *Technology in Society* with eight articles, followed by three other leading journals, *African Journal of Science Technology Innovation and Development*, *Sustainability (Switzerland)*, and *World Development,* with seven articles each. *Tropical Doctor* journal published six articles, while *Journal of Asian and African Studies*, *Technological Forecasting and Social Change*, *The Developing Economies*, and *Transactions of the Royal Society of Tropical Medicine and Hygiene* published five articles each. Most journals are grouped in the social science cluster, including technology management, economics, and planning and development studies. There are also natural science journals and medical journals that are relevant for appropriate technology studies.

Table 5: Most relevant sources for appropriate technology publications

Source	NP	h	g	m	PY_1
Technology in Society	8	5	8	0.125	1982
African Journal of Science, Technology, Innovation and Development	7	2	3	0.222222222	2013
Sustainability (Switzerland)	7	4	7	0.444444444	2013
World Development	7	4	5	0.088888889	1977
Tropical Doctor	6	3	3	0.069767442	1979
Journal of Asian and African Studies	5	2	3	0.05	1982
Technological Forecasting and Social Change	5	3	5	0.068181818	1978
The Developing Economies	5	2	3	0.042553191	1975
Transactions of the Royal Society of Tropical Medicine and Hygiene	5	4	5	0.129032258	1991
Proceedings of the Royal Society of London -Biological Sciences	4	2	2	0.044444444	1977
International Journal on Advanced Science, Engineering and Information Technology	3	1	2	0.25	2018
Journal of Environmental Science and Health - Part A	3	2	3	0.090909091	2000
Science and Public Policy	3	1	1	0.022727273	1978
Water Science and Technology	3	2	3	0.060606061	1989

Notes: NP = number of publications; h = h-index; g = g-index; m = m-index; PY_1 = the year of first publication related to the topic

Figure 6 shows the distribution frequency of articles, which reveals the number of appropriate technology articles published in the selected journals. Between 2006 and 2021, there is a significant growth in the number of articles published related to appropriate technology studies, except for *Tropical Doctor* and *World Development* journals. The graph also shows the outcome of the regression of the quantity and the publication year of the journals in the collection. The calculations then show the growth of selected journals in publishing appropriate technology studies over time (Jacoby, 2000).

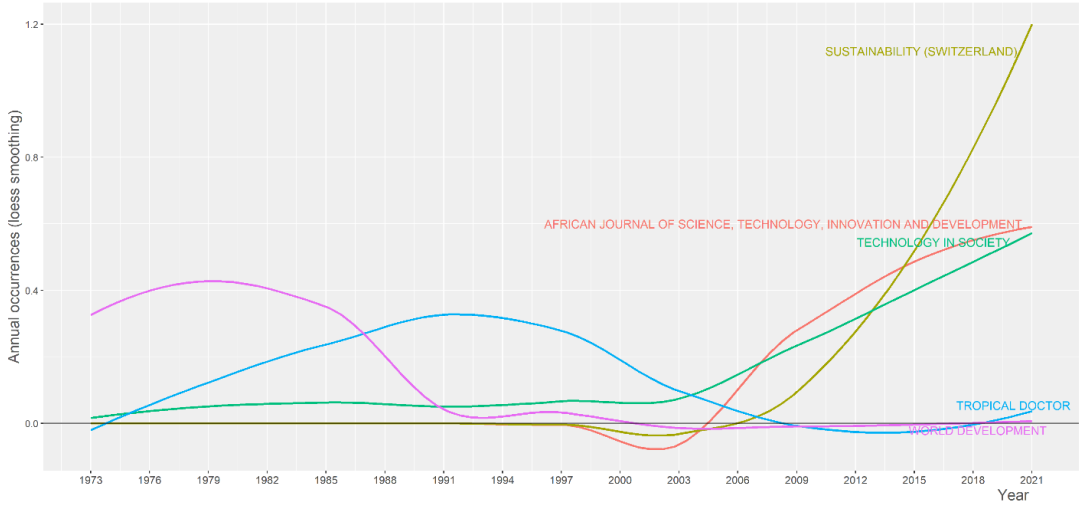


Figure 6: The growth of selected journals in appropriate technology publications

3.2 Collaborative structures

This section deliberates on the relationship variations between the domains in appropriate technology studies. The collaborative structures include intellectual and social structures of bibliometrix. This analysis further explains the science mapping in the body of knowledge of the topic being studied (i.e., appropriate technology) from the statistical point of view (Aria and Cuccurullo, 2017).

3.2.1 Co-Citation Analysis

Citation analysis, particularly co-citation between authors or documents, is one of the analyses enabled by the bibliometrics software. The co-citation analysis of the authors offers some valuable insights into the relations between the authors or documents. When studied over

time, co-citation analysis is able to identify the patterns of citations and discussions in the publications (Small, 1973). Figure 7 shows the co-citation analysis for appropriate technology studies, specifically focusing on the intellectual structure. The diagram consists of rectangles, whose size reflects the frequency of the authors' co-citation, the bigger the size, the higher the frequency. Another dimension of the diagram is the thickness of the lines, which represents the intensity of these co-citation relations. These forms of the relations reflect the degree of closeness or relatedness of the discussions between the authors.

In Figure 7, seven types of clusters can be identified, referring to their cluster colour. Sub-clusters are defined in seven thematics, which are recognisable by the colours of purple, green, red, blue, pink, brown, and orange. The centre of gravity, which is purple, is identifiable as the principle and social structure. It is where the prominent authors are located, which means the authors who were most cited by other authors. In the analysis, the most co-cited reference is Schumacher (1973), which made this book as the landmark study in appropriate technology. The importance of this document is also shown by its box size, which is the largest in the network diagram. The other purple documents are highly related to the most prominent document, which was also being cited in most appropriate technology studies – the documents include Stewart (1977), Lovins (1977), and Akubue (2000), which are the essays on appropriate technology concepts. The pink and green sub-clusters surround the purple sub-cluster correspond to the roots of the appropriate technology studies. The green boxes are larger than that of the pink boxes, which shows that the green sub-cluster is more important in appropriate technology discussions. The green sub-cluster includes the article written by Basu and Weil (1998) and Willoughby (1990). The pink sub-cluster lists two recent appropriate technology articles that have high impact, which are Kaplinsky (2011) and Pearce (2012). The red, orange, blue, and brown sub-clusters are isolated from others. They are also called outliers.

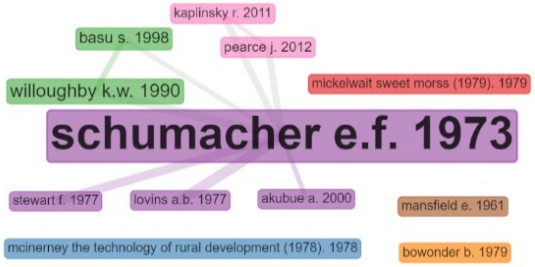
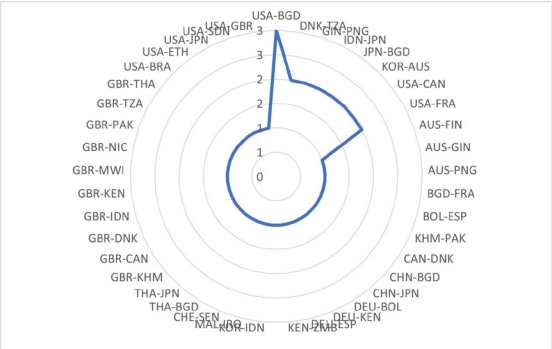


Figure 7: Co-citation analysis on appropriate technology studies

3.2.2 Collaboration Analysis

Figure 8 shows the country collaboration analysis in appropriate technology studies. Based on the analysis, there were active research collaborations of authors in discussing appropriate technology topic. Interestingly, most collaborative works were between developed and developing countries. For example, authors in the UK and the USA did most collaborative works with many developing countries, including UK-Indonesia, UK-Kenya, UK-Pakistan, USA-Bangladesh, and USA-Ethiopia. This might be because the articles are related to technology that originated from the developed countries and then transferred to developing countries. In these instances, the principal investigators were from the developed countries. On the other hand, there were a few collaboratives works of developed-developed countries, such as Australia-Finland, UK-Canada, USA-France, and USA-Japan. Besides that, there were also several collaborations between developing countries with other developing countries, for example, Cambodia-Pakistan, Kenya-Zambia, and Malaysia-Iraq. Figure 9 displays the country collaboration map for appropriate technology studies. It shows that most of the collaboration works were between developed countries, such as the USA, with developing countries, like Bangladesh and India.



Notes: USA = United States of America, BGD = Bangladesh, DNK =Denmark, TZA = Tanzania, GIN = Guinea, PNG = Papua New Guinea, IDN = Indonesia, JPN = Japan, Kor = Korea, Aus = Australia, CAN = Canada, FRA = France, FIN = Finland, BOL = Bolivia, ESP = Spain, KHM = Cambodia, PAK = Pakistan, CHN = China, DEU = Germany, KEN = Kenya, ZMB = Zambia, MAL= Malaysia, IRQ = Iraq, CHE = Switzerland, SEN = Senegal, THA = Thailand, GBR = United Kingdom, MWI = Malawi, NIC= Nicaragua, BRA = Brazil, ETH = Ethiopia, SDN = Sudan

Figure 8: Country collaboration analysis

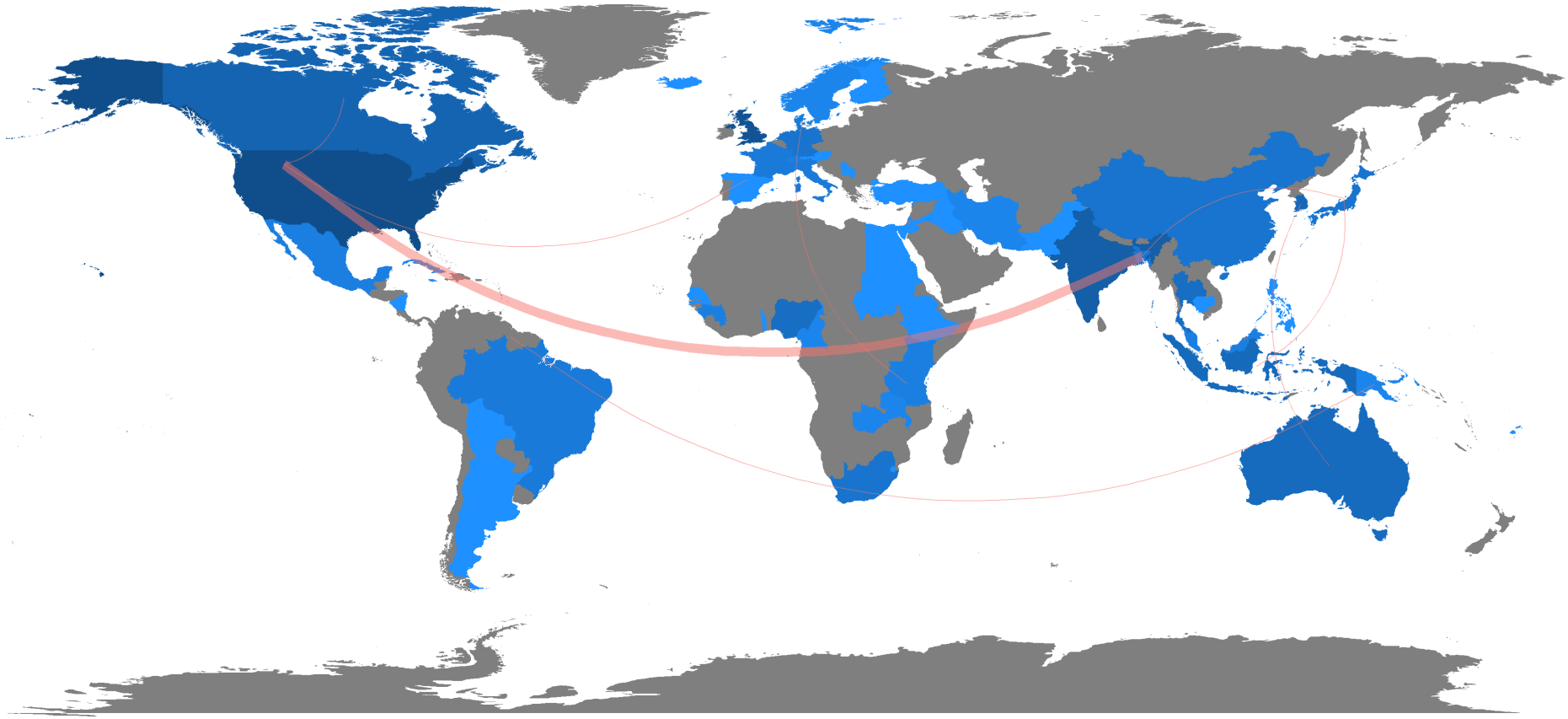


Figure 9: Country collaboration map

3.2.3 Three Fields Plot

Figure 10 is a three-fields plot which shows the connections between three variables of the collection, namely the sources (name of journal), countries (authors' affiliated countries), and author's keywords. The plot visualises the relationships between the variables using the thickness of the connecting lines. The size of each item in the variable shows the frequency of its occurrence in appropriate technology studies. In the figure, the appropriate technology keyword was used for most of the documents. The sustainable development keyword is significant to countries such as the USA and India, with a number of articles published in the *African Journal of Science, Technology, Innovation, and Development* and *Technology in Society* journal. The keyword technology transfer has gained attention from authors in developed countries, such as the USA and UK, and also developing countries, such as India and Mexico; these authors are also related to publications in *Technology in Society* and *Technological Forecasting and Social Change* journals

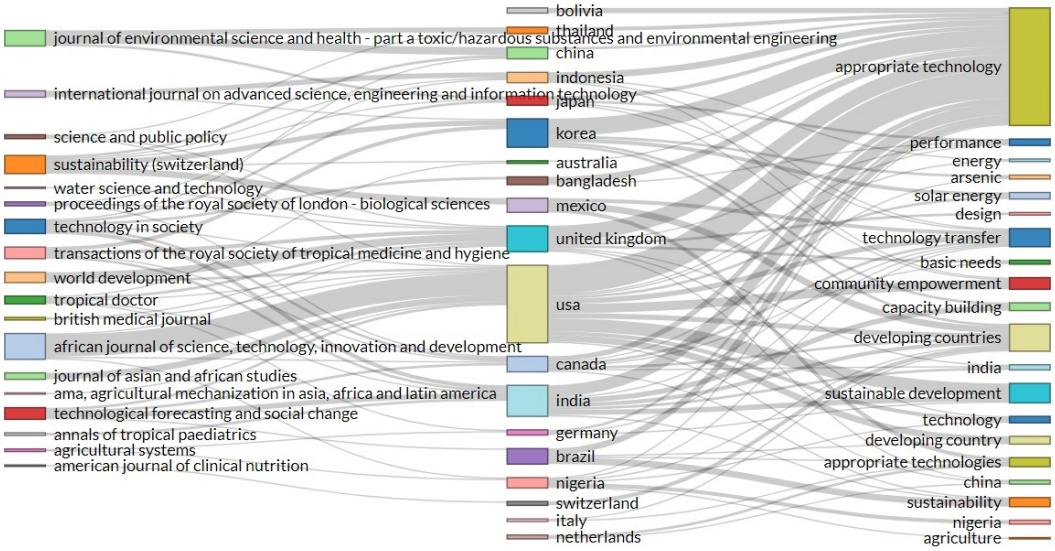


Figure 10: Three field plots of sources-countries-keywords

3.2.4 Historiography

Figure 11 shows the historical direct citation network to identify the most important scientific articles along the timeline, which is from 1973 to 2021. The historiograph presents a chronological map of the relevant citations of the articles that are being analysed (Aria and Cuccurullo, 2017; Garfield, 2004). In this study, the historiograph enabled the authors to trace historical development of the relevant citations as well as citation network of appropriate technology studies by identifying its strands of connection.

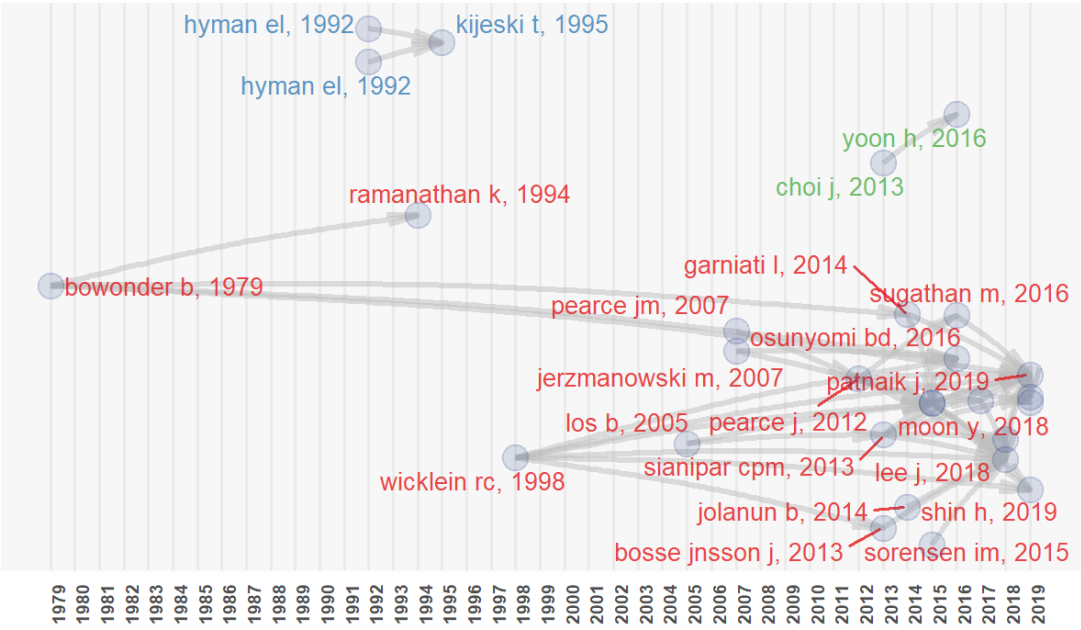


Figure 11: Historiograph for appropriate technology studies

In the study, three cluster connections emerged, which consist of 24 articles that are related to each other. The biggest cluster is denoted by red font, which includes the following authors: Bowonder (1979), Ramanathan (1994), Wicklein (1998), Los (2005), Jerzmanowski (2007), Pearce (2007), Pearce (2012), Sianipar (2013), Jonsson (2013), Garniati (2014), Jolanun (2014), Sorensen (2015), Osunyomi (2016), Sugathan (2016), Lee (2018), Moon (2018), Shin (2019), Patnaik (2019), and Lopez-Sosa (2019). The second cluster is denoted by the blue font consisting of two articles written by Hyman (1992) and Kijeski (1995). The third cluster is denoted by the green line, which starts with Choi (2013) and is connected to Yoon (2016).

In Figure 11, in the first cluster, the first important article was Bowonder (1979). The article lists the barriers in appropriate technology selection in developing countries, where the major limitation is "information". He then proposed effective forecasting and planning strategies for those countries, with consideration of their own capacity and capability. Fifteen years later, Ramanathan (1994) wrote an article on appropriate technology selection among firms in developing countries. He illustrated the scenario by presenting the case of wood waterpower plant technology that is only suitable for countries with an abundance of wood waste. Later, Wicklein (1998) listed out several criteria to evaluate the appropriateness of any particular technology for developing countries, including systems independence, types of technology (collective technology or independent), cost of technology, and purpose of technology.

In the early 2000s, Los and Timmer (2005) studied labour productivity growth performance among several selected countries in relation to appropriate technology, while Jerzmanowski (2007) analysed the total factor productivity cross-country differences using the appropriate technology view and inefficiency view. In his earlier article, Pearce (2007) used appropriate technology projects in teaching physics to the students. The philanthropic value of appropriate technology made the students better understand the subject by developing their own low-tech, yet high impact innovations. Later, Pearce (2012) continued his attempt to share appropriate technologies in open sources, which then created Open-Source Appropriate Technology (OSAT). OSAT is a sharing platform for appropriate technology developers and users all over the world. The concept of OSAT is that the technologies shared there is open and free for any takers. As the development of appropriate technology is to benefit targeted communities, Sianipar et al. (2013) introduced the Engineering Problem Solving in appropriate technology development. These authors suggested that the technology developers or the engineers should consider both top-down and bottom-up information before developing an appropriate technology in order to prevent waste of resources, including financial, time, and human resources.

Meanwhile, Jønsson et al. (2013) did their case study research on artisanal and small-scale gold mining in Tanzania. The case study described that the existing gold mining technology released a lot of mercury into the environment. The case study illustrated that the technology generator introduced the use of retort in gold mining to the gold miners to reduce the amount of mercury released in the environment. However, the gold miners were reluctant to use the technology because of lack of awareness, perhaps due to their low education level. Garniati et al. (2014), Sorensen and McBean (2015), and Osunyomi et al. (2016) emphasised the importance of supporting the ecosystem for a successful appropriate technology development and utilisation. These authors suggested that policymakers should work hand-in-hand with implementers to ensure that the appropriate technology that is being developed is able to be utilised by the target community. Furthermore, the key success factor in promoting a local-based appropriate technology is community co-operation and participation (Jolanun et al., 2014). On the other hand, appropriate technology has been shown to benefit the targeted specific community. For example, Sugathan et al. (2016) studied a special machine that is beneficial to Indian rural women. They found that the machine was not only able to produce high-quality hand-knitted yarn, but the ease of handling the machine also allowed the women to do other daily chores and have free time to attend classes to increase their knowledge.

The authors suggested that the initial idea of developing an appropriate technology should not come only from the technology generator, instead the technology generator also has to acquire inputs from the grassroots or the potential users, which is also called local demand (López-Sosa et al., 2019; Sianipar et al., 2013). Besides increasing the acceptance level of technology, the integration of grassroots innovation concept in appropriate technology development will reduce the risk of wasting available resources (Lee et al., 2018; Shin et al., 2019). Appropriate technology should be fitted to the local economies, social, culture, and also has environmental-friendly features (Patnaik and Bhowmick, 2019). Moreover, Moon and Hwang (2018) suggested the crowdfunding channel to support the financial resources for appropriate technology development. The donators of crowdfunding have altruistic values in offering the funds as they do not look at the financial return, yet they realise that the appropriate technologies will be beneficial for the whole community in the long term.
As for the second cluster, Hyman (1992) and Kijeski (1995) discussed three case studies on appropriate technologies in Africa which covered Cameroon, Kenya, Malawi, and Botswana. They argued that government intervention is one of the most important factors in the development of appropriate technologies. Meanwhile, in the third cluster, two Korean-affiliated articles present water treatment technologies that are cost-efficient and energy-saving for developing countries. Choi et al. (2013) and Yoon et al. (2016) introduced the appropriate technology and its efficiency in small-scale lab experiments.

3.3 Central Themes

This section discusses the central themes in appropriate technology studies based on the analysis of the keywords. Analysing and interpreting data from the structures enable the researchers to understand the evolution of theories, techniques, and also identify the themes of discussion about appropriate technology across time and disciplines, which finally enhances the understanding of the knowledge structure in appropriate technology body of literature within the Scopus database. The analysis also allows the identification of the potential research avenue for future studies.

3.3.1 Static Perspectives Of Central Themes

Static perspective is defined as an analysis on the pattern of the themes for a particular time span, in which the analysis is standing or fixed at one place, or also called a 'screenshot' of present time (Shi et al., 2020). There are two types of keyword analysis that use the static perspective, which are: a) WordCloud and b) keyword co-occurrence.

In order to identify the central themes using the most frequent keywords, the researchers utilised the word cloud analysis. A word cloud is a visual representation of text data to depict keywords frequency occurrences in metadata, as for the study, the appropriate technology articles listed in the Scopus database. The words that appear could be single or up to a maximum of three words (the study set a maximum of 50 characters), and the importance of each keyword is shown by its font size. The importance of the keywords is to determine by their number of occurrences in the collection. The word cloud is useful in quickly perceiving the most prominent terms in the body of knowledge.

The word cloud depicts the most frequent emerging keywords, such as sustainable development, technology transfer, and appropriate technologies. Other emerging keywords in appropriate technology studies include sustainability, solar energy, community empowerment, indigenous knowledge systems, and developing country. It is worth noting that all of the words produced in Figure 12 are currently trending words in appropriate technology studies. All keywords, regardless of their size, are also important in explaining the appropriate technology topic. The larger word size determines its frequency being used by the authors and does not directly show its significance to the topic.

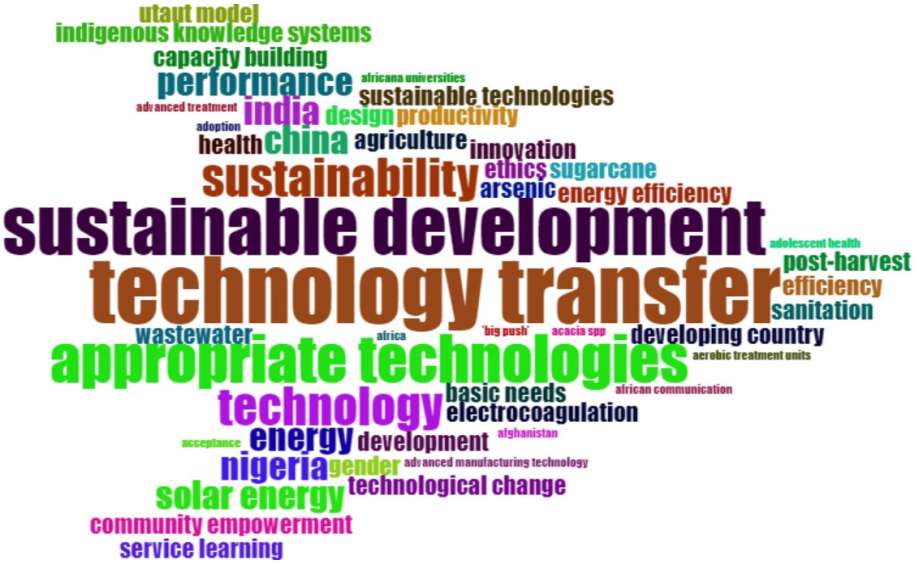


Figure 12: Word cloud of author keywords

Figure 13 shows the co-occurrence network of Keyword Plus for appropriate technology studies. There are four clusters of keywords, which are differentiated by their colours. The frequency of the occurrences of the keywords are indicated by their box size, and their centrality location shows their importance in the specific cluster. There are four clusters in appropriate technology studies, which are: a) appropriate technology and developing countries cluster (green), b) technology and developing country cluster (blue), c) human and article cluster (red), and d) primary health care cluster (purple). For example, in the purple cluster, the main keyword, which is *primary health care*, is surrounded by health-related keywords including *pregnancy*, *maternal-child health services*, *delivery of health care*, and *prenatal care*.

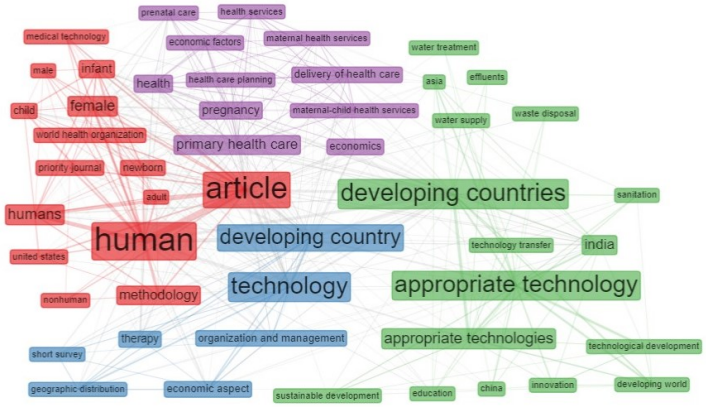


Figure 13: Co-occurrence network of Keyword Plus

3.3.2 Dynamic Perspectives Of Central Themes

Dynamic perspectives are thematic analysis of the bibliometric data over time. From the pattern of the central theme, the researchers are able understand the evolving themes in the topic being studied. In contrast to screenshot analysis, which shows the themes at one point in time, the dynamic perspective enables the identification of the patterns of themes over the course of time (Shi et al., 2020). There are two types of keyword analysis that use dynamic perspectives, which are: a) topic trends and b) thematic map evolution.

Trend topics are the analysis conducted to understand the relationship between the author's keywords or topics that are discussed in the appropriate technology literature over time. Besides, these analyses also enable researchers to identify emerging topics for research in the future. In displaying the trend of topics that have been discussed in the appropriate technology context starting from the year 1973 to 2021, Figure 14 represents the plot graph. There are variations in the keywords over the years, starting from the 1970s to the 1980s, when the term appropriate technology was being popularised in the literature. The trending topics human, technology, developing country, methodology, education, health, economic aspect, child, geographic distribution, organisation and management, and therapy were discussed within the timeframe. The topics also include the countries that become the context of the study, which are India and Asia. In the 90s, the keywords that emerged were developing countries, primary health care, pregnancy, infant, newborn, economics, and United States. From the 2000s onwards, the trending keywords are appropriate technology, appropriate technologies, humans, water supply, and female. There are also technology-related terminologies that were used or studied at that time, which are technology transfer and technological development.

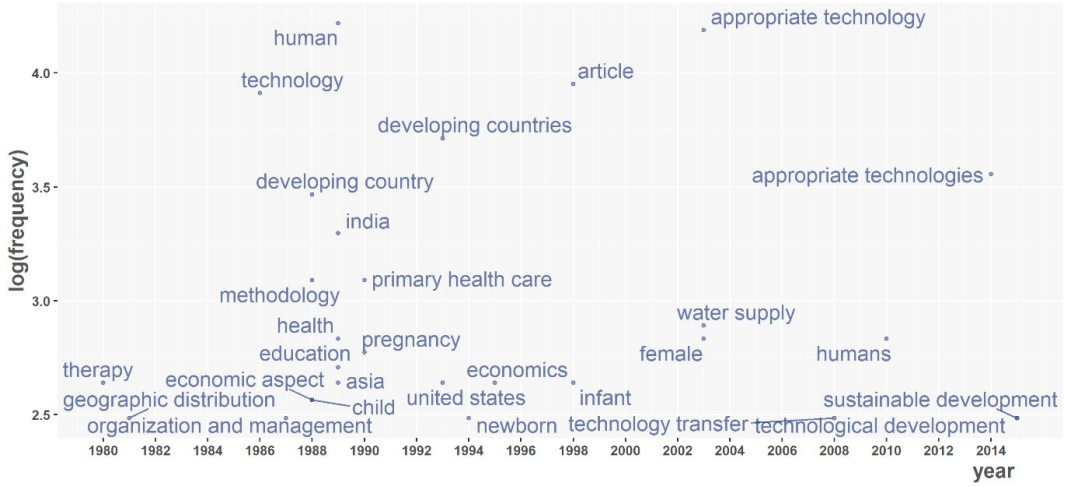


Figure 14. The trend topics in appropriate technology based on author keywords

Towards the end of the 2000s, the emerging trend topic is sustainable development, which is believed to be an effort to embrace Sustainable Development Goals that had been introduced by the United Nations in 2015. In discussing appropriate technology, researchers also discuss human and technology issues. The developing countries were also the focus of most appropriate technology articles because these technologies benefited those countries (i.e., Asia and India), for example, in promoting sustainability in terms of economic returns or quality of life (Hu et al., 2018; Uddin et al., 2014). As for the topics, which include primary healthcare, health, therapy, female, child, pregnancy, infant, and newborn, they show that appropriate technology has been discussed from the medical perspective, whereas the articles usually discuss case studies on medical events where the technologies benefit the users in the developing countries (de Silva, 2018; King and Beck, 1990). In develop-ing countries, appropriate technology is found to benefit mostly women, for instance, in facilitating their daily works and enabling them to have more time for their own education as well as for their children (Anderson, 2005; Sugathan et al., 2016).

In order to further explain the themes in appropriate technology studies, Figure 15 shows the thematic evolution of the keywords in appropriate technology studies. Thematic evolution is the dynamic perspective of the thematic map for the collection. In the present study, the research period or timespan of the collection is from 1973 to 2021, which was split into four time slices or sub-periods. Bibliometrix automatically sliced the time periods according to the Keyword Plus of the articles in the collection. The first time slice is 1973 to 1981, the second slice is 1982 to 1987, the third slice is 1988 to 1998, and the final slice is 1999 to 2021. In the thematic map, there are four quadrant of themes: a) Highly developed or isolated themes – high density and low centrality, which shows that the themes have solid internal relations, yet less important in appropriate technology studies, b) motor themes – high density and high centrality, which means the themes are important and established in shaping appropriate technology studies, c) emerging or declining themes – low density and low centrality, which depicts that the themes are less important and not well established in appropriate technology studies, and d) basic and transversal themes – high centrality and low density, the themes which are important in shaping appropriate technology studies, yet not adequately established. Centrality is defined as the relevance of the subject in the entire body of knowledge. Next, density is a measure of the growth of the topic along the timeline (Aria and Cuccurullo, 2017).

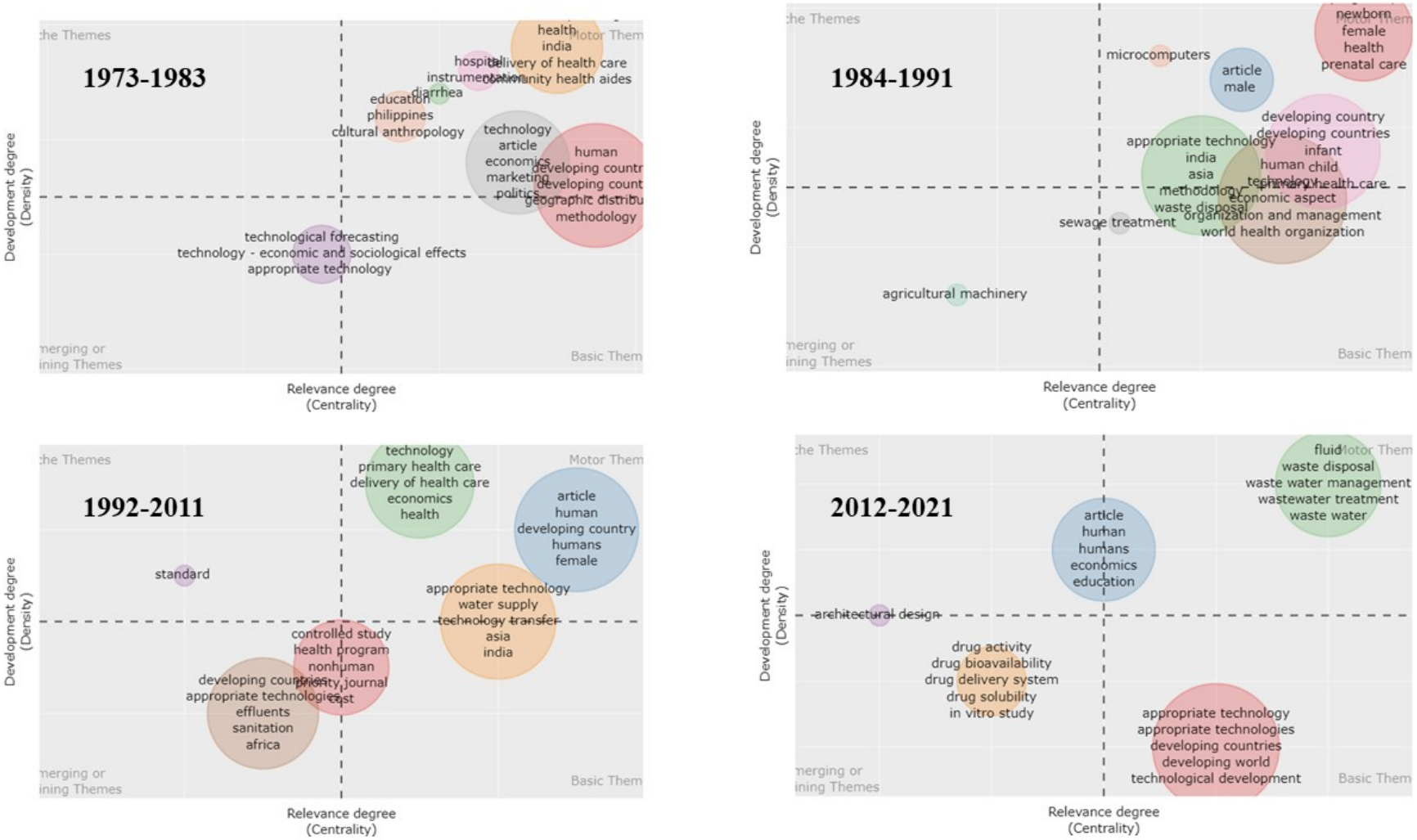


Figure 15: Thematic map evolution diagrams of appropriate technology studies (1973-2021), based on Keyword Plus

There are a number of bubbles on the map. Each bubble symbolises a network cluster, and its name (the keyword) belongs to the cluster with the higher occurrence value. The size of each bubble is relative to the cluster word occurrences, and the location in the map is based on Callon centrality and density (Callon et al., 1991). For example, in the second time slice of the year 1984 to 1991, the theme *water disposal* is first located at the fourth quadrant, which means it is relevant to appropriate technology studies, yet not well developed. At that time, the size of the bubble was small. Later, in the fourth time slice (2012 to 2021), the *water disposal* theme is diversified to other water topics, which include fluid, wastewater management, wastewater treatment, and wastewater. The size of the bubble is getting larger, and it is located in the second quadrant, which means the topic is relevant to appropriate technology studies and is well-developed in the body of knowledge.

Figure 15 visualises that the themes in appropriate technology studies have evolved from the first time slice (1973 to 1981) to the fourth time slice (1999-2021). The number of themes has increased, as shown by the number of bubbles produced, overlapping bubbles, and colourful themes, which show that the themes in appropriate technology studies are getting more complex and diversified. On the whole, the trending keywords in the thematic evolution map that are based on Keyword Plus are consistent with the trend topics based on author keywords, even though author keywords have richer variations in nature. The most recurring themes over time are *appropriate technology, developing country*, *technology*, *human*, and *health*, which means these themes are important and relevant for appropriate technology studies.

■4.0 CONCLUSION

In conclusion, the bibliometric analysis found the trends of appropriate technology studies and indicated the potential avenues for future research. The study shows that the most relevant themes in appropriate technology studies include *developing countries*, *technology transfer*, and *sustainable development*. Indeed, appropriate technology can be one of the solutions for rural communities to have a sustainable quality of life, and for their social and environmental impacts. Based on author keywords, there have been increasing trends in the discussion of technology transfer and sustainable development starting from the 2000s. Based on Keyword Plus, there is an evolution for certain themes, including agriculture-related topics, water-related topics, and health-related topics. These results further extend the understanding about the body of knowledge of appropriate technologies. The avenues for future research identified through the insights gained from the bibliometric analysis include more possibility for linking the discussion of the appropriate technology innovation process to the bigger agenda of sustainable development goals.

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References

Ahmi, A. (2022). *Bibliometric Analysis Using R for Non-Coders: A Practical Handbook in Conducting Bibliometric Analysis Studies using Biblioshiny for Bibliometrix R Package*. Retrieved from https://www.aidi-ahmi.com/download/TOC_bibliometric_analysis_using_R.pdf. Access date: 10 December 2022.

Akubue, A. (2000). Appropriate Technology for Socioeconomic Development in Third World Countries. *JOTS-Appropriate Technology Socioeconomics Development in Third World Countries*, *26*(1).

Anderson, G. T. 2005. Innovations in Early Childhood Teacher Education: Reflections on Practice: Theorists in a Teacher Education Classroom. *Journal of Early Childhood Teacher Education*, *26*(1), 91-95.

Annesley, T. M. (2010). The Title Says It All. *Clinical Chemistry*, *56*(3), 357-360.

Aria, M., & Cuccurullo, C. (2017). Bibliometrix: An R-tool for Comprehensive Science Mapping Analysis. *Journal of Informetrics*, *11* (4), 959-975.

Baas, J., Schotten, M., Plume, A., Côté, G., & Karimi, R. (2020). Scopus as a Curated, High-Quality Bibliometric Data Source for Academic Research in Quantitative Science Studies. *Quantitative Science Studies: An Open Access Journal*, *1*(1), 377-386.

Baker, K. M. & Edmonds, R. L. (2004). Transfer of Taiwanese Ideas and Technology to The Gambia, West Africa: A Viable Approach to Rural Development. *Geographical Journal*, *170*(3), 189-211.

Basu, S. & Weil, D. N. (1998). Appropriate Technology and Growth. *The Quarterly Journal of Economics*, *113*(4), 1025-1054.

Bellis, N. D. (2009). *Bibliometrics and Citation Analysis: From the Science Citation Index to Cybermetrics.* Scarecrow Press Inc.

Bhattacharjya, B. R., Kakoty, S. K., & Singha, S. (2019). A Feedback Mechanism for Appropriate Technology Development and Dissemination: Case Study Approach. *Technology in Society an International Journal*, *57*, 104-114.

Bowonder, B. (1979). Appropriate Technology for Developing Countries: Some Issues. *Technological Forecasting and Social Change an International Journal*, *15*(1), 55-67.

Boyack, K. W., van Eck, N. J., Colavizza, G., &Waltman, L. (2018). Characterising in-Text Citations in Scientific Articles: A Large-Scale Analysis. *Journal of Informetrics*, *12*(1), 59-73.

Callon, M., Courtial, J. P., & Laville, F. (1991). Co-Word Analysis as a Tool for Describing the Network of Interactions between Basic and Technological Research: The Case of Polymer Chemistry. *AK Journal*, *22*(1), 155-205.

Choi, J., Park, C. G., & Yoon, J. (2013). Application of an Electrochemical Chlorine-Generation System Combined with Solar Energy as Appropriate Technology for Water Disinfection. *Transactions of The Royal Society of Tropical Medicine and Hygiene Journal*, *107*(2), 124-128.

De Silva, P. N. (2018). Use of Appropriate Technology to Improve Mental Health Service Delivery. *British Journal of Hospital Medicine*, *79*(12), 682-685.

Egghe, L. (2006). Theory and Practice of the g-Index. *Chinese Science Bulletin*, *69*(1), 131-152.

Garniati, L., Owen, A., Kruijsen, J., Ishadamy, Y., & Wibisono, I. (2014). Interface between Appropriate Technology and Sustainable Energy Policy in Vulnerable Societies. *Int. J. Services Technology and Management*, *24*(12), 9-15.

Hazeltine, B., & Bull, C. (2003). *Field Guide to Appropriate Technology*. Academic Press, Cambridge.

Hirsch, J. E. (2005). An Index to Quantify an Individual's Scientific Research Output. *Proceedings of the National Academy of Sciences, 102*(46), 16569-16572.

Hood, W. W. & Wilson, C. S. (2001). The Literature of Bibliometrics, Scientometrics, and Informetrics. *Scientometrics*, *52*(2), 291-314.

Hu, K., Zhao, Q. L., Chen, W., Wang, W., Han, F., & Shen, X. H. (2018). Appropriate Technologies for Upgrading Wastewater Treatment Plants: Methods Review and Case Studies in China. *Journal of Environmental Science and Health, 53*(14), 1207-1220.

Hyman, E. L. (1992). The Design of Micro-Projects and Macro-Policies: Examples from Three Appropriate Technology Projects in Africa. *Journal of Asian African Studies*, *27*(1), 134-152.

Jacoby, W. G. (2000). Loess: A Nonparametric, Graphical Tool for Pepicting Relationships between Variables. *Electoral Studies*, *19*(4), 577-613.
Jamali, H. R. and Nikzad, M. (2011). Article Title Type and its Relation with the Number of Downloads and Citations. *Scientometrics*, *88*(2), 653-661.
Jerzmanowski, M. (2007). Total Factor Productivity Differences: Appropriate Technology vs. Efficiency. *European Economics Review*, *51*(8), 2080-2110.
Jolanun, B., Kaewkam, C., Bauoon, O., & Chiemchaisri, C. (2014). Turned Windrow Composting of Cow Manure as Appropriate Technology for Zero Discharge of Mulberry Pulp Wastewater. *Environmental Technology*, *35*(16), 2104-2114.
Jønsson, B. J., Charles, E., & Kalvig, P. (2013). Toxic Mercury Versus Appropriate Technology: Artisanal Gold Miners' Retort Aversion. *Research Policy*, *38*(1), 60-67.
Kaplinsky, R. (2011). Schumacher Meets Schumpeter: Appropriate Technology below the Radar. *Research Policy*, *40*(2), 193-203.
Kijeski, T. (1995). "Appropriate" Technology and the Botswana Television Experience: On the Efficacy of Waiting. *Howard Journal of Communications*, *6*(4), 292-305.
King, K. & Beck, H. (1990). Medical AI Systems as Appropriate Technology for Developing Ccountries. *The Knowledge of Engineering Review*, *5*(4), 251-263.
Lee, J., Kim, K., Shin, H., & Hwang, J. (2018). Acceptance Factors of Appropriate Technology: Case of Water Purification Systems in Binh Dinh, Vietnam. *Sustainability*, *10*(7), 2255-2275.
López-Sosa, L. B., Núñez-González, J., Beltrán, A., Morales-Máximo, M., Morales-Sánchez, M., Serrano-Medrano, M., & García, C. A. (2019). A New Methodology for the Development of Appropriate Technology: A Case Study for the Development of a Wood Solar Dryer. *Sustainability*, *11*(20), 5620-5640.
Los, B. & Timmer, M. P. (2005). The 'Appropriate Technology' Explanation of Productivity Growth Differentials: An Empirical Approach. *Journal of Development Economics*, *77*(2), 517-531.
Lovins, A. B. (1977). Lovins on" Lovins' Fever". *Science*, *197*(4309), 1133-1133.
Menck, K. W. (1973). The Concept of Appropriate Technology. *Intereconomics*, *8*(1), 8-10.
Metin, I., and Tepe, G. (2021). Gravity Model: A Bibliometric Analysis and Detailed Overview. *International Journal of Business and Society*, *22*(1), 365-381.
Mingers, J. & Leydesdorff, L. (2015). A review of Theory and Practice in Scientometrics. *European Journal of Operational Research*, *246*(1), 1-19.
Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & PRISMA Group. (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *PLoS Med.*, *6*(7), 1-9.
Moon, Y. and Hwang, J. (2018). Crowdfunding as an Alternative Means for Funding Sustainable Appropriate Technology: Acceptance Determinants of Backers. *Sustainability*, *10*(5), 1456-1476.
Oakleaf, M. (2009). Writing Information Literacy Assessment Plans: A Guide to Best Practice. *Communications in Information Literacy*, *3*(2), 80-89.
Okoli, C. (2015). A guide to Conducting a Standalone Systematic Literature Review. *Communications of the Association for Information Systems*, *37*(1), 43.
Osunyomi, B. D., Redlich, T., & Wulfsberg, J. P. (2016). Could Open-Source Ecology and Open-Source Appropriate Technology be Used as a Roadmap from Technology Colony? *International Journal of Technological Learning and Innovation Development*, *8*(3), 265-282.
Patnaik, J. and Bhowmick, B. (2019). Revisiting Appropriate Technology with Changing Socio-Technical Landscape in Emerging Countries. *Technology in Society*, *57*, 8-19.
Pattnaik, B. K. & Dhal, D. (2015). Mobilising from Appropriate Technologies to Sustainable Technologies based on Grassroots Innovations. *Technology in Society*, *40*, 93-110.
Pearce, J. M. (2007). Teaching Physics using Appropriate Technology Projects. *The Physics Teachers*, *45*(3), 164-167.
Pearce, J. M. (2012). The Case for Open-Source Appropriate Technology. *Environmental and Development Sustainability*, *14*(3), 425-431.
Ramanathan, K. (1994). An Integrated Approach for the Choice of Appropriate Technology. *Science and Public Policy, 21*(4), 221-233.
Schumacher, E. F. (1973). *Small is Beautiful: Economics as if People Mattered*. Harper Perennial, New York.
Shi, J., Duan, K., Wu, G., Zhang, R., & Feng, X. (2020). Comprehensive Metrological and Content Analysis of the Public–Private Partnerships (PPPs) Research Field: A New Bibliometric Journey. *Scientometrics*, *124*(3), 2145-2184.
Shin, H., Hwang, J., and Kim, H. 2019. Appropriate technology for grassroots innovation in developing countries for sustainable development: The case of Laos. *Journal of Cleaner Production*, *232*, 1167-1175.
Sianipar, C. P., Yudoko, G., Dowaki, K., & Adhiutama, A., (2013). Design Methodology for Appropriate Technology: Engineering as if People Mattered. *Sustainability*, *5*(8), 3382-3425.
Small, H., (1973). Co-citation in the Scientific Literature: A New Measure of the Relationship between Two Documents. *Journal of the American Society for information Science*, *24*(4), 265-269.
Sorensen, I. M. & McBean, E. A., (2015). Beyond Appropriate Technology: Social Considerations for the Sustainable Use of Arsenic–Iron Removal Plants in Rural Bangladesh. *Technology in Society*, *41*, 1-9.
Stewart, F. (1977). *The Choice of Technology in Developing Countries - Some Cautionary Tales*. Harvard University, Cambridge.
Sugathan, M., Cassidy, T., & Carnie, B. (2016). The Development and Evaluation of a Specialty Hand-Knitting Yarn using Appropriate Technology for the Empowerment of Women in Rural India. *Research Journal of Textile Apparel*. *20*(3), 1-12.
Uddin, S. M. N., Muhandiki, V. S., Sakai, A., Al Mamun, A., & Hridi, S. M. (2014). Socio-Cultural Acceptance of Appropriate Technology: Identifying and Prioritising Barriers for Widespread Use of the Urine Diversion Toilets in Rural Muslim Communities of Bangladesh. *Technology in Society*, *38*, 32-39.
Wicklein, R. C. (1998). Designing for Appropriate Technology in Developing Countries. *Technology in Society*, *20*(3), 371-375.
Willoughby, K. W. (1990). *Technology Choice: A Critique of the Appropriate Technology Movement*. Westview Press, Boulder.
World Health Organization. (1985). Appropriate Technology for Birth. *Lancet*, *2*, 436-437.
Yoon, H., Kim, J., & Yoon, J. (2016). Forward Osmosis as Appropriate Technology with Starch-Based Draw Agent. *Desalination of Water Treatment*, *57*(22), 10129-10135.
Zakaria, R., Ahmi, A., Ahmad, A. H., & Othman, Z., (2021). Worldwide Melatonin Research: A Bibliometric Analysis of the Published Literature between 2015 and 2019. *Chronobiology International*, *38*(1), 27-37.
Zelenika, I. & Pearce, J. (2011). Barriers to Appropriate Technology Growth in Sustainable Development. *European Journal of Sustainable Development*, *4*(6), 12-22.