Mapping Climate Change Research Collaboration in Tanzania from 1964 to 2021: A Bibliometric Analysis

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Abstract

This study explored research collaboration in climate change initiatives in Tanzania. Specifically, it sought to uncover the collaborative networks of researchers based on Tanzania's climate change research outputs from 1964 to 2021. A bibliometric approach was used to analyse co-authorship as an indicator of research collaboration during the investigated period. Data were researched and retrieved from the Dimensions.ai database based on specified keywords. VOSviewer software was employed to analyse the data and obtain co-authorship networks, while MS Excel was used to organise and analyse the frequency data percentages. The results have revealed that researchers from Tanzania have a strong collaborative network with other countries in climate change research. Additionally, researchers from the University of Dar es Salaam seem to have stronger collaborative ties with those from the Sokoine University of Agriculture and the Nelson Mandela African Institute of Science and Technology. International researchers with significant co-authorship alongside Tanzanian researchers come from the United States, the United Kingdom, Germany, Kenya, and South Africa respectively. Furthermore, the results indicate that developed countries such as the US, UK, Germany, and South Africa, despite co-authoring only a few publications, seem to exhibit a high total link strength. Therefore, research collaboration in its various manifestations and levels needs encouragement, as it enhances both the quality and quantity of research output productivity. There is a need to strengthen research collaboration on climate change between researchers from Tanzania and those from African nations to establish local climate change mitigation measures that suit the African environment. Further studies should focus on the motivations for research collaboration and the funding patterns of collaborations within the country.

Keywords: Bibliometrics, climate change, research collaboration, research productivity, Tanzania

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Introduction

The effects of climate change pose a significant threat to the human economy, health, and ecosystems worldwide (Adamo et al., 2021). It hurts the African economy as it affects agriculture, business, health, forestry, minerals, and energy (Baarsch et al., 2020; Islam et al., 2022). The population living in Sub-Saharan Africa is particularly vulnerable to climatic changes due to their heavy dependence on rainfall for farming and other livelihoods (Emediegwu et al., 2022). A large number of people residing in villages in Tanzania rely on rainfall for agricultural activities, and the situation is even more severe for rural livelihoods, especially in semi-arid areas, which are most susceptible to changing weather conditions
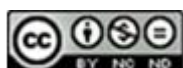
(Tumbo et al., 2020). This puts additional strain on the already deteriorated forest ecosystem in Tanzania (John et al., 2020). Policymakers have implemented all necessary measures to mitigate the effects of climate change on a global scale (Sweileh, 2020).

Stakeholders, including academics, researchers, and development partners, have played a key role in mitigating climate change at various stages. Scientists significantly contribute by researching the effects of climate change on economic and socioeconomic factors (Islam et al., 2022). The findings from these studies are shared through articles, conference papers, and books, ultimately informing decision-makers and the public about the impacts of climate change. According to Sweileh (2020a, p.2), "Assessing research activity on climate change helps identify the national and international contributions to this field, the prevailing themes discussed by researchers, and the existing research gaps." Studies on climate change are increasingly multidisciplinary, requiring strategies for addressing and mitigating the issues to incorporate multiple approaches from various specialties (Amolegbe et al., 2022). Researchers across different disciplines collaborate to investigate climate change using diverse techniques, including collecting and analysing data on Earth's climate patterns and reviewing publications to uncover ongoing research trends and productivity in climate change studies.

The research results on climate change have become a vital resource for providing indicators used to mitigate its effects. In this context, scientists have utilized bibliometrics and scientometric approaches to determine citation trends, collaboration patterns, funding sources, and other areas from various fields of study, including climate science. Bibliometric studies are increasing in prevalence due to their convenient data collection and processing capabilities, supported by advancements in access, capturing, and analysis software (Ülker et al., 2023). These studies have yielded valuable insights as indicators of researchers' Productivity, preferences, and trends assist in decision-making for research management and planning. However, decision-makers working with governments, funding agencies, and organizational management often find bibliometric study results to be very essential (Linnenluecke et al., 2020). As a result, this study uses a bibliometric analysis approach to examine research collaboration in climate change research in Tanzania from 1964 to 2021.

Literature review

Research collaboration
Many scholars have sought to define the meaning of research collaboration from various perspectives. To grasp the term "research collaboration," different literature has been reviewed. According to Green and Johnson (2015, p. 2), "Collaboration is a mutually beneficial and a well-defined relationship established between two or more organizations to achieve common goals" that involves a jointly developed structure, shared responsibility, mutual authority and accountability for success, and the sharing of resources and rewards. The term research collaboration signifies a relationship among multiple researchers who engage in research activities together. It describes the connection between individual researchers and organizations and between individuals and organisations (Bozeman & Boardman, 2014). In other words, it refers to a situation where researchers collaborate to achieve shared objectives in producing scientific knowledge.

Soliday Hong et al. (2019, p. 2) define collaboration as "a result of partnerships between individuals and organizations that emphasize sharing physical resources and governance. Collaborations among stakeholders with shared goals but differing areas of

expertise, responsibilities, and roles foster environments that promote innovation and improvement." The authors argue that the outcomes of collaboration are influenced by the actions taken by practitioners at various levels.
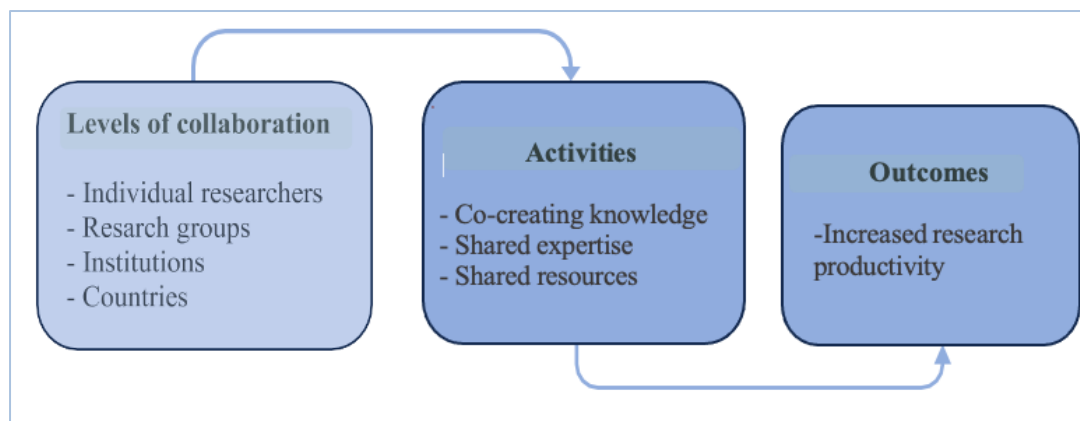

Figure 1: Model of Research Collaboration
Source: Researcher's design, adapted from (Soliday Hong et al., 2019)

The researcher adapts the ideas established by Soliday Hong et al. (2019) and develops a research collaboration model. This model comprises three major components: levels of collaboration, activities, and outcomes. Research collaboration encompasses various levels that may involve individual researchers, research groups, institutions, or countries. Kyvik and Reymert (2017, p. 953) argue that "collaboration can occur between colleagues in a university department, between a staff member and peers in other departments, at other universities and research institutes, in industry, and research organizations in other countries." Collaboration can take place between two individual researchers or among many scientists as members of large teams. The purpose of collaboration is to undertake specific activities, such as co-creating knowledge, sharing expertise, and pooling resources, which enhance research productivity. This conceptual model is relevant to this study as it outlines different levels of collaboration and the activities performed at those levels, ultimately leading to improved research productivity. This model applies to research collaboration in any field of study, including climate change.

Benefits of Research Collaboration

Research collaboration enhances the quality of research output, boosts research productivity, spurs creativity and innovation, attracts funding, encourages resource sharing, and strengthens the network of researchers internationally, nationally, and institutionally (Abramo et al., 2017; Aldieri et al., 2018; Cookson & Stirk, 2022; Estanislao et al., 2022; Rørstad et al., 2021). Researchers who engage in collaboration tend to be more productive than their counterparts. Additionally, there are several advantages of research collaboration beyond those measured by bibliometrics, such as research quality (resulting from expanded networks and knowledge sharing) and improved academic diversity (Rørstad et al., 2021). Collaboration among scientists stimulates their research activities and enriches their knowledge (Kyvik & Reymert, 2017). International collaboration enhances knowledge among researchers by facilitating the
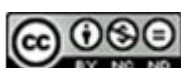
exchange of expertise that may be lacking in the country's knowledge base (Estanislao et al., 2022). Furthermore, collaboration improves both the knowledge and skills of researchers (Cookson & Stirk, 2022). The "diffusion of knowledge is influenced by skills, ideas, division of tasks, and sharing of resources," and this is more effectively realized when researchers collaborate (Estanislao et al., 2022). Additionally, it fosters the development of human capital through knowledge exchange and learning experiences (Ubfa & Maffioli, 2010). Research collaboration significantly impacts the quality of universities, research quality, and quantity, thereby enhancing the overall research productivity of the institution. Collaborating with researchers from developed countries helps build the research capacity of local researchers, increasing their research performance, citation levels, and visibility (Aldieri et al., 2022) 2018). While many acknowledge the benefits of research collaboration, not all scholars agree that collaboration enhances research productivity (Abramo et al., 2017). Nevertheless, a significant number of scholars concur that collaboration is valuable for mapping the scope of research activities conducted, thereby serving as an indicator of the level of research output and partnerships among researchers in a specific area of study research

Research Collaboration Studies on climate change research

The present study builds on existing literature to achieve its objectives. The aim was to map the research collaborations on climate change from Tanzania to analyze the patterns of collaboration as an indicator of research productivity in this field. According to Rørstad et al. (2021, p. 4), there are two indicators of international collaboration: first, measuring international collaboration through co-authorship, and second, the "average proportion of researchers' publications involving international co-authorship." There is disagreement about whether research collaboration leads to co-authorship of publications (Onyancha, 2020). However, co-authorship continues to serve as a proxy for research collaboration in bibliometric studies (Ponomariov & Boardman, 2016a). Therefore, research collaboration is viewed as a means by which researchers enrich their knowledge and skills, thereby increasing research productivity.

Research collaboration has recently increased internationally, as most scholarly publications are co-authored (Rørstad et al., 2021). A study conducted by Sweileh (2020) employed bibliometric analysis to examine literature on food security in relation to climate change from 1980 to 2019, revealing a growth in the number of publications over the past decade, accompanied by significant international collaboration. The reasons for this increase include the directive of the Fourth Intergovernmental Panel on Climate Change (IPCC), which requires all countries to adopt adaptive measures for addressing climate change (Das et al., 2020). This prompted many countries to develop action plans aimed at combatting climate change, which included collaborative research efforts. "The substantial increase in co-authored publications recorded in recent years has been supported by various targeted policies from individual universities as well as national and international research systems (Abramo et al., 2017). Russell et al. (2019) carried out a bibliometric study on collaboration trends over the past 30 years in four major musculoskeletal science journals and discovered a rise in collaborative contributions within the published articles across the journals. Therefore, collaboration in various forms—international, national, or organizational—enhances both the quality and quantity of research by facilitating the sharing of expertise and resources (Aldieri et al., 2018).

This paper explores research collaboration based on Tanzania's climate change research outputs generated from 1964 to 2021. Climate change research serves as a case

study. Therefore, this study seeks to answer the question, What is the trend of climate change research collaboration among researchers from Tanzania?

Methodology

A bibliometric approach was employed to analyse co-authorship based on publications regarding climate change from Tanzania to map research collaboration from 1964 to 2021. Bibliometric analysis effectively evaluates the scientific output of a specific discipline (Yu et al., 2021). Bibliometrics utilizes mathematical and statistical techniques to quantify, classify, and assess publication patterns, co-authorship, and citations. Data were retrieved from the Dimensions database https://app.dimensions.ai/. The Dimensions database was selected as the data source because it offers more comprehensive journal coverage compared to other aggregators like Web of Science and SCOPUS (Singh et al., 2021). Dimensions integrate openly available data sourced from proprietary databases and enhance that data using persistent identifiers and technological methods (Hook et al., 2021). Therefore, the researcher believed this database would provide sufficient information as a basis for analysis. Furthermore, VOSviewer was utilized to create a network map illustrating the relationship between collaboration and funding for publications. This supports the use of Dimensions, as it is compatible with VOSviewer, which offers a bibliographic network of connections among keywords, authors, journal articles, and countries of origin (Einecker & Kirby, 2020). In this study, the extracted data were analysed to quantify collaboration and funding. Data were searched and retrieved within a single day to avoid discrepancies in the volume of online information that is continually updated. The data were extracted in .csv file format and saved on the computer.

Search terms

The main keywords were "climate change" and "Tanzania," which were used to obtain the search results. The name "Tanzania" was officially adopted after the two countries, Tanganyika and Zanzibar, united. These two countries formed the United Republic of Tanzania on April 26, 1964, and the term "Tanzania" became officially recognized by the United Nations (United Nations, 2022). The analysis focused on publications regarding climate change that were produced by researchers in Tanzania or in collaboration with foreign researchers and published from 1964 to 2021. The search terms and keywords were identified, tested, and refined using Boolean logic, phrases, parentheses, and wildcards. Other related terms (synonyms) to "climate change" were considered and combined with the term "Tanzania". Boolean operators "AND" and "OR" were used in two or more terms. These search tools were used to combine climate change as a central term with other terms keywords to attain the desired and accurate results

The search processes

The search process always starts by formulating the keywords that Hook et al. (2021) identify as search strings. "Climate change" and "Tanzania" were the key terms that were tied up together using the Boolean operators "AND" to make a single search string. Climate change has been associated with a lot of related disciplines, although they have dealt with different topics (Haunschild et al., 2016). To accommodate the possible variations of the words "climate" and "change" a wildcard search was used to test the outcome, this is climate* chang* AND Tanzania, which aimed to include words such as climate/climatic,
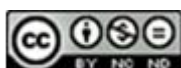
change/changes/changes. Using the wildcard in Dimensions did not yield the intended results as the database ignored it, therefore, the research continued to formulate the search tools without it. The search string was expanded to include publications on climate change in Zanzibar as it was realised that some publications appeared to have Zanzibar without the term Tanzania, but Zanzibar is part of Tanzania United Republic. Therefore, both Tanzania and Zanzibar were combined using Boolean operators "AND" and "OR" and parentheses to combine climate change, Tanzania and Zanzibar that is "climate change" AND (Tanzania OR Zanzibar). Other terms or phrases with similar meanings to "climate change", terms such as "seasonal variability", "environmental change" and "environmental variability" were included using the same search tools to make this search string: *("climate change" OR "seasonal variability" OR "environmental change" OR "environmental variability" OR "global warming") AND (Tanzania OR Zanzibar)* and this string was more inclusive.

The analysis

The data retrieved from Dimensions were exported in .csv file format and imported into VOSviewer to analyse co-authorship networks. The search results were examined using the Dimensions system to identify the funders of the retrieved publications. The retrieved data were exported to MS Excel, where it was sorted and filtered to generate tables and figures that were presented in the results section. In all, 79,495 publications were obtained based on the supplied keywords and filters. The filters were applied to a range of years from 1964 to 2021, and the types of preferred publications used to establish the relationships of collaboration and funding included articles, monographs, pre-prints, and proceedings.

Results

This study aimed to examine the researcher's collaboration based on climate change research outputs from Tanzania generated between 1964 and 2021, along with their sources of funding. The results highlight collaboration among countries, organisations, and individual researchers, which are presented in the figures and tables below.

Research collaboration

The productivity of scholars is gauged by the extent to which researchers engage in co-authoring publications (Programme et al., 2009). This study utilized co-authorship as an indicator of research collaboration (Ponomariov & Boardman, 2016b). It examined collaboration between researchers in Tanzania and their counterparts globally. Data analysis was performed using the VOSviewer software, where the minimum number of co-authorships was set to 25 countries per document while maintaining a minimum of 5 documents for each country. Out of 131 countries, 81 were identified as meeting the threshold. The countries were categorised into 5 clusters, forming 1583 links with a total strength of 10704. According to data in Table 1, Tanzania has many co-authored publications with 80 links and a total link strength (TLS) of 3850. The United States, United Kingdom, Kenya, and Germany follow, respectively.

Table1:   Co-authorship by country

| Countries	Docs	Links	TLS
1. Tanzania	2280	80	3850
2. United States	643	77	1793
3. United Kingdom	578	80	1748
4. Kenya	328	69	1045
5. Germany	316	76	886
6. South Africa	254	77	922
7. Netherlands	201	68	653
8. Sweden	196	63	528
9. China	155	66	623
10. Uganda	144	62	535

Source: Field Data (2022)

As Table 1 illustrates, even though the US, UK, SA, and Germany have contributed fewer co-authored publications, these countries have relatively high total link strengths. In other words, researchers from these countries have a very strong collaborative network with researchers from other countries.

Co-authorship map of countries
In this study, the level of collaboration was examined using data extracted from Dimensions.ai and analysed and visualised using VOSviewer to depict the network map of the country's co-authorship. A network map was created with indicators for visualizing the network, including the size of nodes, the distance between each node, and the thickness of the lines. The colours and sizes of the nodes indicate the type of relationship between items, such as organizations (Tanudjaja & Kow, 2018). In this analysis, the strength of collaboration between two units of analysis on the map is represented by the thickness of the lines between the nodes. Nodes represent the number of publications co-authored by researchers. This corresponds to a score known as link strength; the higher this score, the thicker the lines, and the thicker the lines between nodes, the stronger the collaboration relationship.

In this study, criteria were established in VOSviewer Wizard to assess international collaboration for publications on climate change from 1964 to 2021. A maximum of 25 countries per document was set, and a minimum of 5 documents per country was desired. Out of 131 countries, 81 met the threshold. The results in Figure 2 display lines and nodes in varying sizes and colours. The countries are grouped into 5 clusters based on their connections. The largest set of connected countries comprises 20 countries represented by red nodes (including China, Australia, Spain, Saudi Arabia, etc.), followed by a cluster that includes 19 countries represented by red nodes, including Tanzania, Kenya, Nigeria, Uganda, Rwanda, South Africa, and Ethiopia. The other three clusters have a connection of 14 countries each (see Figure 2).
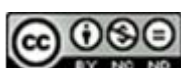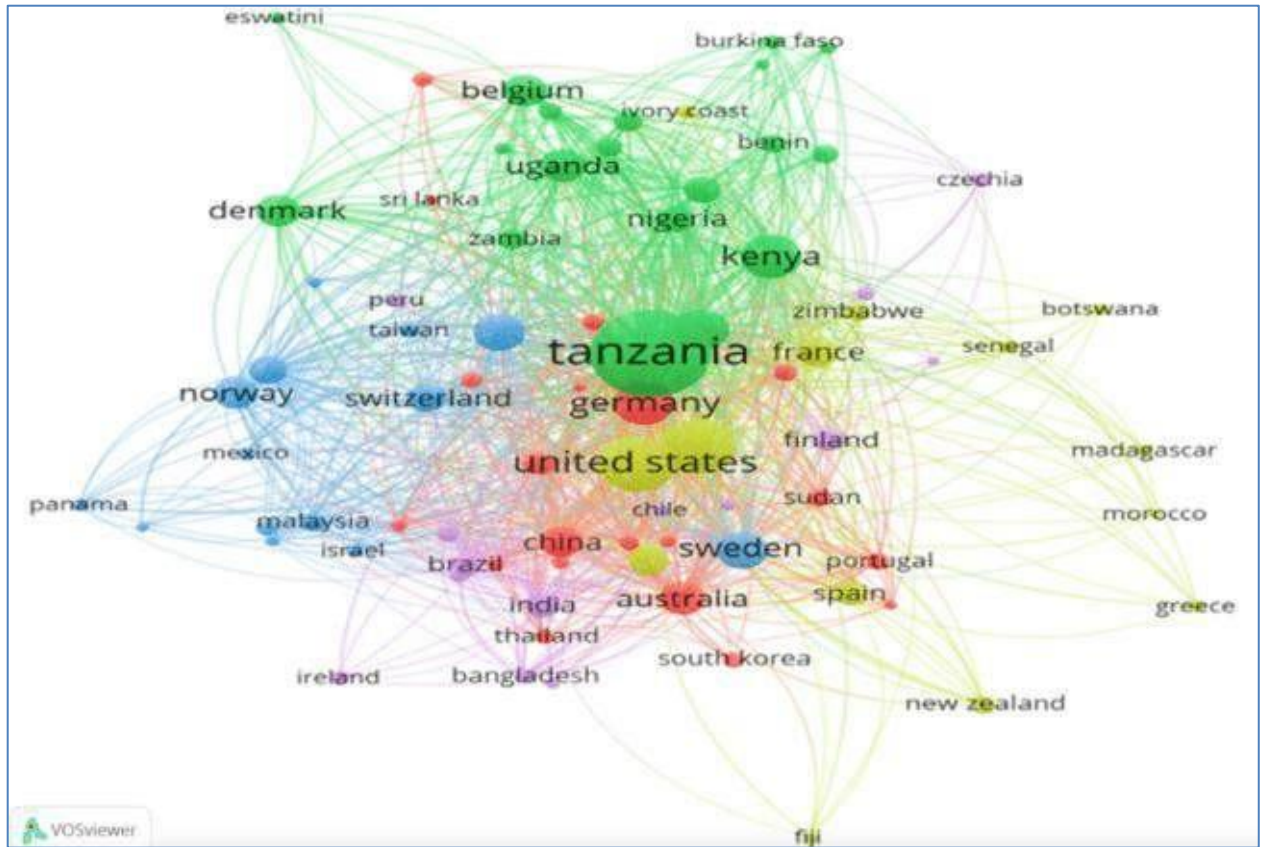
Figure 2: Collaboration among countries
Source: Field Data (2022)

As indicated in Figure 2, Tanzania has very strong collaboration links with many countries worldwide. The five prolific international countries that have collaborated the most with Tanzania are the United States, the United Kingdom, Germany, Kenya, and South Africa.

Institutional collaboration

The analysis included a minimum number of 5 documents for each organization. Of 1873 organizations, 407 meet the thresholds. Table 2 shows organizations with strong links of researchers the University of Dar es Salaam has 683 documents with 1302 Total Link Strength, Sokoine University of Agriculture has 576 documents with 1197 Total Link Strength, Nelson Mandela African Institute of Science and Technology has 233 documents with 442 Total Link Strength, the University of Copenhagen Denmark has 94 documents with 378 Total Link Strength, Tanzania Fisheries Research Institute has 117 documents with 339 Total Link Strength. The twenty organizations whose researchers have collaborated with researchers from international organizations are indicated in Table 3. Of the top twenty organizations presented in Table 3, Fifty percent (50%) of them are from Tanzania and three are from the United Kingdom while Kenya, South Africa, and Uganda have two researchers each, also, Denmark and the Netherlands have one organisation each.

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Table 2: Research Organisations' Collaborative Links

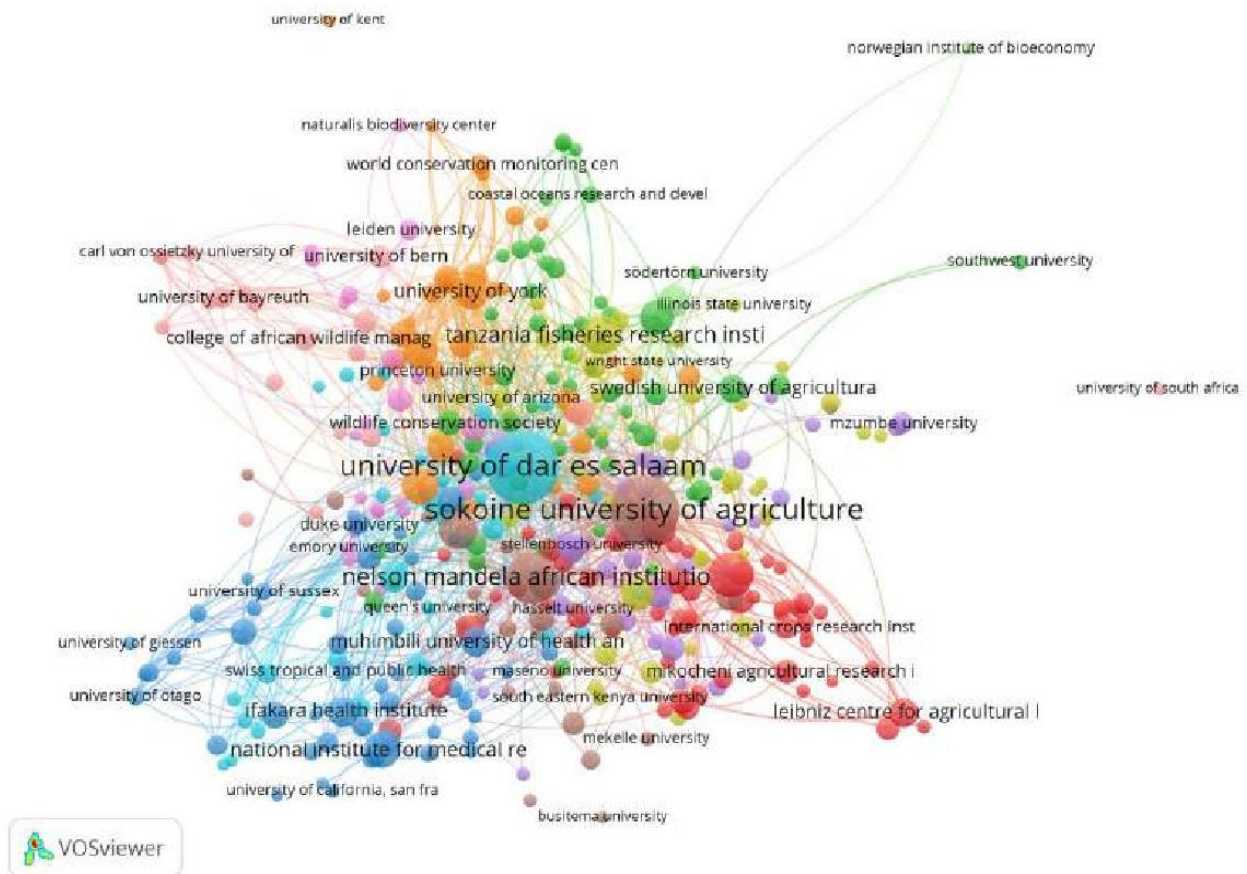|	Organisation	Country	Docs	TLS
1	University of Dar es Salaam	Tanzania	683	1302
2	Sokoine University of Agriculture	Tanzania	576	1197
3	Nelson Mandela African Institute of Science and Technology	Tanzania	233	442
4	Univ. of Copenhagen	Denmark	94	378
5	Tanzania Fisheries Research Institute	Tanzania	117	339
6	University of York	United Kingdom	69	338
7	International Institute of Tropical Agriculture	Tanzania	163	336
8	Tanzania Fisheries Research Institute	Tanzania	82	300
9	University of Cambridge	United Kingdom	43	280
10	Wageningen Univ.& Res	Netherlands	88	271
11	Makerere University	Uganda	69	251
12	University of Oxford	United Kingdom	44	238
13	University College of London	United Kingdom	43	223
14	University of the Witwatersrand	South Africa	47	219
15	University of Nairobi	Kenya	47	211
16	Wildlife Conservation Society	Tanzania	32	201
17	University of Dodoma	Tanzania	103	192
18	Worldwide Fund for Nature	Tanzania	36	190
19	National Institute for Medical Research	Tanzania	84	186
20	University of Cape Town	South Africa	47	184

Source: Research data (2022)
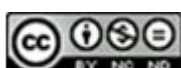
Figure 3: Network of Collaboration by Organisations Worldwide

Source: Field Data (2022)

Data in Figure 3 shows that the University of Dar es Salaam and Sokoine University of Agriculture are strongly connected with many research organisations worldwide, followed by the Nelson Mandela African Institute of Science and Technology, as they all seem to have several co-authored publications, as indicated in Figure 3. The Figure shows these organizations have large nodes and are close to each other as an indication of strong link strength.

Co-authorship by researchers from organizations in Tanzania

VOSviewer analysis wizard was used to filter organizations that have collaborated on publications in which only organizations from Tanzania were selected. The maximum number was 25 organizations per document, while a minimum of 20 documents per organization was established. Out of 1,873 organisations, 91 met the thresholds. As indicated in Figure 4, the network map illustrates ten clustered groups of interlinked organizations. The map highlights three organizations from Tanzania with robust collaborative networks: the University of Dar es Salaam, whose researchers co-authored 683 documents with a total link strength of 668, and Sokoine University of Agriculture, whose researchers had co-authored 576 documents

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with a total link strength of 733, and Nelson Mandela African Institute of African Science whose researchers had co-authored 233 documents with a total link strength of 275 and Technology seem to have strongly connected with researchers from other organisations.
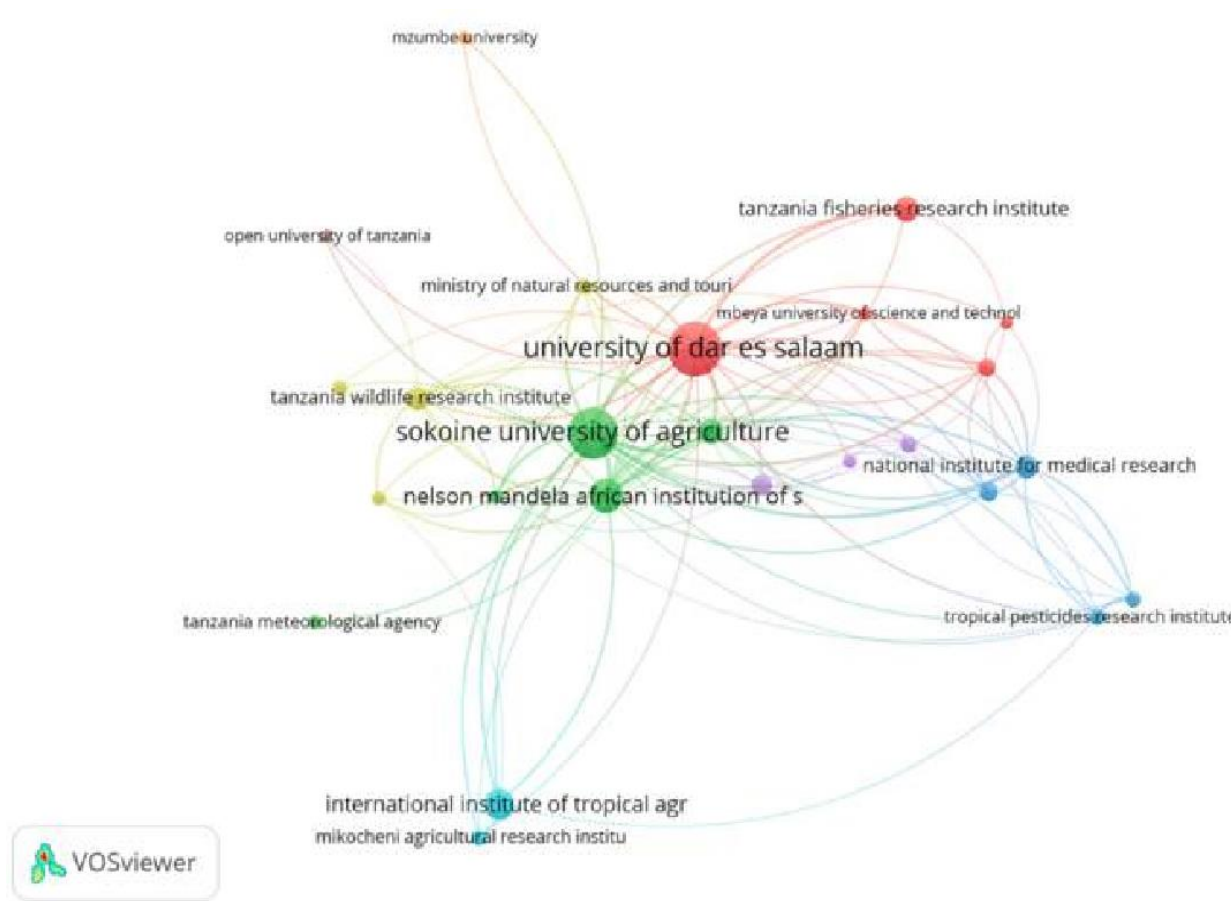

**Figure 4: Network of Collaboration by Organisations in Tanzania**
Source: Field Data (2022)

Researchers' co-authorship

The researchers' level of collaboration was analysed by limiting the number of publications to a maximum of 25 authors per document and a minimum of at least 10 documents per author. Table 3 shows the number of documents and the Total Link Strength of each author:

Table 3 Researchers' co-authorship

Author	Organization	TLS	Docs
1. Zahabu Eliakimu	Sokoine University of Agriculture	26	23
2. Gobakken, Terje	Norwegian University of Life Sciences	25	14
3. Naeset, Erik	Norwegian University of Life Sciences	23	11
4. Munishi, Linus	Nelson Mandela African Institution of Science and Technology	20	28
5. Sindato, Calvin	National Institute of Medical Research	19	11
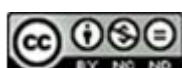
6.	Misinzo, Gerald	Sokoine University of Agriculture	18	13
7.	Mkocha, Harran	Kongwa Trachoma Project	18	19
8.	Baquedano, Enrique	Instituto de Evolución en África, Museo de los Orígenes, Madrid.	17	12
9.	Dominguez-Rodrigo, Manuel	University of Alcalá de Henares	17	13
10.	Gullstrom, Martin	Environmental Science, Södertörn	17	11
11.	Mtei, Kelvin	Nelson Mandela African Institution of Science and Technology	17	15
12.	Munoz, Beatriz	University of Copenhagen	17	11
13.	West, Sheila. K.	Johns Hopkins Bloomberg School of Public Health	17	12
14.	Burgess, Neil D.	University College London	16	23
15.	Mabulla, Audax	University of Dar es Salaam	16	10
16.	Ndakidemi, Patrick	Nelson Mandela African Institution of Science and Technology	16	10
17.	Marchant, Rob	University of York	15	19
18.	Bjork, Mats	Stockholm University	14	14
19.	Graef, Frieder	Institute of Land Use Systems, Leibniz Centre for Agricultural Landscape Research	14	18
20.	Kock, Richard	agricultural-environment nexus	12	11

Source: Field Data (2022)

The twenty most connected researchers were selected whereby the top authors were Zahabu, and Eliakimu from SUA who had a very strong network with a Total Link Strength (TLS) of 26 followed by Gobakken, Terje, Naeset, Erik both from the Norwegian University of Life Sciences who have TLS of 25 and 23, respectively. Other researchers are Munishi, Linus from Nelson Mandela African Institution of Science and Technology with a TLS of 20, and Sindato, Calvin from the National Institute of Medical Research who has 19 TLS more details have been indicated in Table 4. In the list of the top twenty most connected authors, Eight (8) researchers are from Tanzania organisations.
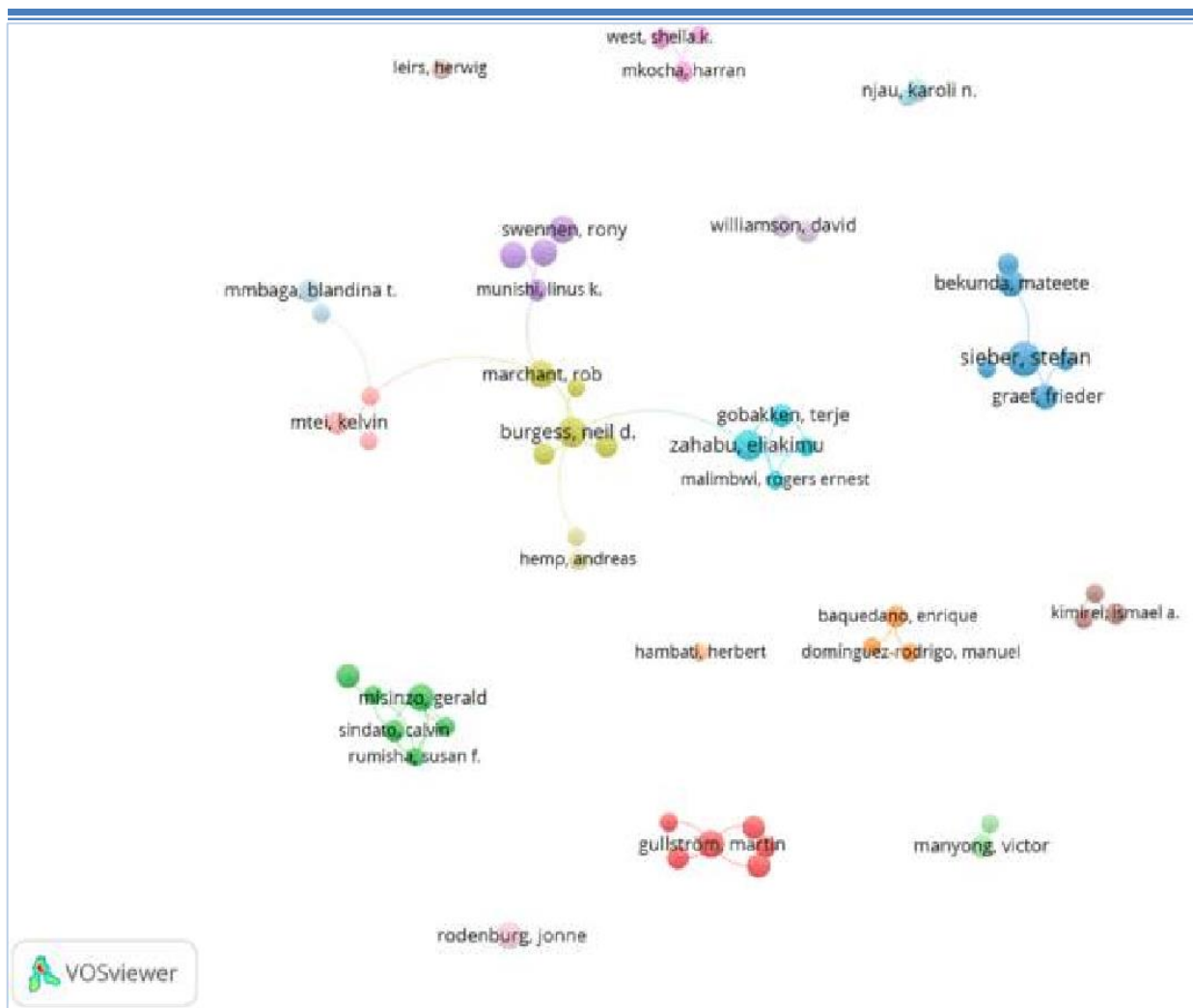
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Figure 5: Collaboration among Authors
Source: Field Data (2022)

The selection criteria were set in VOSviewer Wizard to obtain researchers who have co-authored at least 10 publications from 1964 to 2021. based on this decision, 56 authors met the threshold out of 11,862, resulting in 18 research groups or clusters with 61 links and a Total Link Strength (TLS) of 281 obtained.

Researchers who have collaborated with many authors are indicated by the size of nodes, as shown in Figure 5. As can be observed in Figure 4; two issues are observable in collaboration, first, a relationship of links among individual researchers, and also, there are networks of links between groups. The most connected research group is cluster 4 (yellow nodes), which is linked to clusters 5(orange), 10(purple), 13(light-yellow), and 18(blue), respectively the researchers in this strongly linked research group are Burgess, Neil from the University of London, Marchant, Rob from the University of York, Other researchers are Kashagili, Japhet and Mbilinyi, Boniface, all from Sokoine University of Agriculture, and Rovero, Francesco from University of Florence. The research group that follows is cluster 5(red) which is linked with two research groups that are cluster 4(yellow) and 12(light blue). One observable collaboration pattern here is that researchers from Sokoine University of Agriculture (cluster 2) have mostly co-authorship many papers among themselves, as
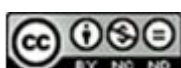
evidenced in Figure 5., though Nelson Mandela African Institute of Science and Technology have co-authored among themselves as well as having links with a strongly connected research group in cluster 4 (yellow). This kind of collaboration shows why researchers from that institution seem to have produced more publications with a strong network of collaboration as presented in Table 3.

Discussion

This study analysed climate change publications in Tanzania from 1964 to 2021 to reveal the collaboration network of researchers from various countries, institutions, and individuals as an indicator of research productivity. Efficient research collaboration has been linked to increased research productivity, as noted by Abramo et al. (2017), confirming a positive relationship between research productivity and research collaboration. According to Kyvik and Reymert (2017), most research is conducted collaboratively in groups since two or more researchers produce higher-quality research output than when working alone. Working in multidisciplinary teams is significantly more efficient and impactful than working individually (Stubbs et al., 2018). This acknowledges that one of the key indicators of research collaboration is the co-authorship of scientific research across different subject areas.

The results of this study indicate that research on climate change in Tanzania is being conducted collaboratively by researchers within various institutions, as well as through partnerships between different research groups and research networks both within and outside the country. This aligns with Kyvik and Reymert (2017), who noted that "collaboration can be undertaken between colleagues in a university department, between a staff member and peers in other departments, in other universities and research institutes, in industry, and research establishments in other countries." Based on the findings of this study, it is established that Tanzanian researchers are making a significant contribution to climate change research through research collaboration.

The results of this study further indicate a network of collaboration among researchers both within and outside the country. Findings reveal that Tanzania possesses a strong collaborative network with other countries. This might be because most research on climate change in Tanzania has been conducted by researchers from both within and outside the nation. The five most prolific countries in this collaborative network include the United States, United Kingdom, Germany, Kenya, and South Africa, as shown in Figure 2. Moreover, researchers from Sokoine University of Agriculture exhibit strong collaboration among themselves, while researchers from the Nelson Mandela African Institute of Science and Technology demonstrate robust local collaboration and maintain strong links with international research organizations, as illustrated in Figure 3.

Furthermore, local collaboration in Tanzania demonstrates that researchers from the University of Dar es Salaam, along with those from the Sokoine University of Agriculture and the Nelson Mandela African Institute of Science and Technology, are closely connected with researchers from other organizations across the country, as shown in Figure 4. These findings are not surprising since these three public institutions engage in extensive research on topics related to life sciences, the environment, agriculture, and similar fields. It has been observed that, although the US, UK, South Africa, and Germany have co-authored a limited number of publications, these countries possess a high total link strength, as indicated in Table 1. International researchers with strong co-authorship ties to researchers in Tanzania

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come from the United States, the United Kingdom, Germany, Kenya, and South Africa, as illustrated in Figure 5.

Overall, co-authorship is one measure of research collaboration that provides insight into the extent of researchers' interactions in scientific inquiries. This study utilized data from Dimensions, which was analysed using VOSviewer to create collaboration network maps. According to Romero & Portillo-Salido (2019), these collaborative maps offer valuable insights that assist researchers in identifying potential collaborators. In other words, research collaboration is essential in developing countries like Tanzania to enhance the skills and knowledge of local researchers across various fields, ultimately boosting research productivity.

The findings of this study indicate that researchers from Tanzania have strong collaborative relationships with researchers from developed countries in climate change research, but weaker collaborations with developing countries, particularly in Africa. The results suggest that the collaboration is skewed toward the Global North. However, if strong collaboration among African researchers is fostered, it could enhance the understanding of the climate change challenges facing Africa and help identify mitigation strategies that suit the local environment.

Conclusion

This study analyses the collaboration networks of climate change publications regarding Tanzania from 1964 to 2021. The collaboration networks at the country, institutional, and research levels have been revealed and discussed. The most prolific countries are presented first, followed by institutions and individual researchers. The findings of the study provide evidence of ongoing collaboration among researchers in Tanzania, indicating a network connected with international research partners in climate change research. It is also clear that large public universities in the country have made significant collaborative efforts in climate change research. Therefore, research collaboration should be encouraged, as it enhances both the quality and quantity of research output. Further studies should focus on the motives for research collaboration and the funding patterns of collaboration countries.

Limitations of the study
The findings of this study indicate the research collaboration on climate change in Tanzania, which was extracted from dimensions.ai. Therefore, the results may not represent a broad range of data sources that might be available in other renowned commercial context databases

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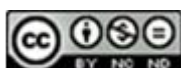
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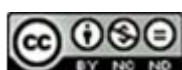
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